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Energy Transitions in Latin America

The Tough Route to Sustainable Development

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Esteban Serrani
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Editors
Lira Luz Benites Lazaro
Department of Environmental Health
School of Public Health
University of São Paulo
São Paulo, Brazil

Durham Energy Institute and
Department of Anthropology
Durham University
Durham, UK

Esteban Serrani
National Scientific and Technical
Research Council (CONICET)
National University of San Martín
(UNSAM)
San Martín, Argentina

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Preface

Energy: Transition, Crisis, and Sustainability

The timing of this book on the energy transition in Latin America is particularly noteworthy, given the ongoing energy crisis that has swept across the globe in the wake of the COVID-19 pandemic and Russia's invasion of Ukraine. This crisis has underscored the fragility of European countries when it comes to energy security and has raised questions about the feasibility of their energy transition plans in the short term, particularly in light of the European "green deal" and the 2015 Paris Agreement on climate change. In this context, it is paradoxical to consider the energy transition in Latin America, a region whose energy landscape is characterized by the dominance of hydrocarbons in some countries, and whose efforts to transition to more sustainable energy sources face several political, economic, and social challenges. Despite these challenges, however, this book provides a comprehensive analysis of the opportunities and obstacles involved in achieving a sustainable energy future in Latin America, emphasizing the need for a collaborative and holistic approach to sustainable development goals in the region.

Indeed, the combination of these tensions provides insights into pondering global economic instability in the face of the sharp increase in the prices of energy, food, and essential intermediate goods for industrial production, and economic inflation. The risk of further aggravation of the cost of living crisis could affect the most vulnerable populations, pushing them even them below the poverty line. Therefore, it is necessary to focus on the challenges that need to be overcome in order to achieve the Sustainable Development Goals (SDGs). These challenges could be, for example, the tension to ensure short- and long-term energy security and advance in the energy transition, the need to expand efforts to mitigate the impact of the energy sector on the climate crisis, ensure affordable energy costs, mainly, and that this process becomes a vector of economic recovery in response to the negative effects on the labor market, poverty, and inequality that the Covid-19 pandemic increased in large vulnerable sectors of the world population.

In this context of global constraints with structural and long-term implications, how can we critically but purposefully discuss energy transitions for and from Latin America? Although this book reiterates the need to work in coordination with the three central dimensions of the energy trilemma, such as energy security, energy equity, and sustainability, including climate change, it also proposes to insert into the discussion and analysis of energy transition in the broader and more general framework of the region-specific problems. In this sense, it is understood that energy transitions are broader processes than the change in the energy system, driven by the substitution of fossil sources with low-emission energy. In the case of Latin America, energy transitions imply both a reflection on the dilemmas of high-income countries' dependence on oil and natural resources, as well as the inclusion of other aspects, for example, the job creation, whether the energy transitions will generate more and better jobs than in the current fossil-based society. Will the incorporation of renewable energies improve access to energy public goods for large sectors that currently use non-modern sources for heating and cooking? and will they allow a long-term reduction in energy tariffs reducing energy poverty? On the other hand, will the progress towards electromobility and electrification in general imply a new phase of extractivism for rare metals in the region? In this sense, will the incorporation of low-emission energies allow the promotion of the own technological developments in Latin America, increasing the productive chains that not only generate more and better jobs but also allow the dependence-breaking in the insertion of the global economy?

In short, in the current context of the climate crisis, we understand that energy transitions are an opportunity for Latin America to advance in a new model of sustainable development, improving well-being and human development while reducing inequality. These are some of the issues addressed in this book, which is a part of the discussions carried out within the working group "Energy and Sustainable Development" at the Latin American Council of Social Sciences (CLACSO). This Working Group is composed of more than 80 researchers from Latin American countries, many of whom participated in the writing of this book. In particular, the need to discuss the idea widely disseminated in academic circles in developed countries and international cooperation, energy analysis, and public and private financing organizations that there is a unique energy transition route to 2050 where countries must arrive, which is based on a model of policies and actions for mitigation and adaptation to climate change that are evident, and therefore, are presented as standardized for their application. In other words, emerged the need to review both the current state of the energy sector in Latin America compared to the world and its insertion in the discussions on the global transitions, thus understanding the particularities, difficulties, challenges, and opportunities to move toward low-carbon emission energies and contribute to achieving sustainable development.

São Paulo, Brazil — Lira Luz Benites Lazaro
San Martín, Buenos Aires, Argentina — Esteban Serrani

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About the Editors

Lira Luz Benites Lazaro holds a Ph.D. in Earth System Science from the National Institute for Space Research, Brazil. She also holds a Ph.D. and a master's degree in Latin American Integration from the University of São Paulo, where she has made significant contributions to her field. Lira was a Visiting Researcher at the Durham Energy Institute in the United Kingdom. She is actively involved in research on implementing the Sustainable Development Goals in Brazil, working at the Institute of Advanced Studies of São Paulo University. With a wealth of experience in both research and academia, Lira has demonstrated her expertise in various crucial areas. Her research interests encompass environmental governance, energy transition, policy analysis, energy and climate policy, institutions and management, and the water-energy-food nexus. She is a member of the Working Group on Energy and Sustainable Development of the Latin American Council of Social Sciences (CLACSO).

Esteban Serrani is a Sociologist. He has a master's degree in social research and a PhD in Social Sciences from the University of Buenos Aires, Argentina. He is a Researcher of the National Council for Scientific and Technical Research (CONICET) and Professor at the National University of San Martin, Argentina. He was Director of the Project "Approaches to the relationship between energy models and industrial policy in Argentina, 2002–2019" and "Analysis of the performance of large industrial companies in the energy transition in Argentina", supported by the National Agency for the Promotion of Research, Technological Development and Innovation. In Argentina, he is a Co-Director of the Center for Social Studies of the Economy, at the Interdisciplinary School of High Social Studies, National University of San Martin. In Latin America, he is the coordinator of the CLACSO Working Group on "Energy and Sustainable Development", he coordinates the energy transition and climate change working group of the International Development Economics Associates-Latin America (IDEAs-LAC), and he is member of the Academic Committee, Southern Cone Regional Center at Maria Sibylla Merian Center for Advanced Latin American Studies (CALAS).

Contributors

Rafael Almeida Ferreira Abrão Universidade Federal do ABC, São Bernardo do Campo, Brazil

Mariano A. Barrera Economy and Technology Area, FLACSO, Buenos Aires, Argentina

Celio Bermann Institute of Energy and Environment, University of São Paulo, São Paulo, Brazil

Energy and Environment Institute, University of São Paulo, São Paulo, Brazil

Reto Bertoni Universidad de la República, Montevideo, Uruguay

Eliana Celeste Canafoglia INCIHUSA-CONICET, Mendoza, Argentina

Daniel Sandoval Cervantes Universidad Autónoma Metropolitana-Cuajimalpa, Mexico City, Mexico

Flávia Mendes de Almeida Collaço Programa de Pós-graduação em Administração e Controladoria, Universidade Federal do Ceará e Instituto de Estudos Avançados, Universidade de São Paulo, São Paulo, Brazil

Ana Lía del Valle Guerrero Geography and Tourism Department (DGYT), Universidad Nacional del Sur (UNS), Bahía Blanca, Argentina

Clacso Working Group: Energy and Sustainable Development, Bahía Blanca, Argentina

Diego di Risio Global Gas & Oil Network, Buenos Aires, Argentina

Nora Fernández Mora Pontificia Universidad Católica del Ecuador (PUCE), Quito, Ecuador

Guillaume Fontaine Latin American Faculty for Social Sciences (FLACSO), The Comparative Policy Lab at FLACSO, Quito, Ecuador

José Luis Fuentes The Comparative Policy Lab, University of the Americas (UDLA), Quito, Ecuador

Igor Fuser Universidade Federal do ABC, São Bernardo do Campo, Brazil

Carlos Germán Meza González Universidad Americana (UAM) de Nicaragua y Centro de Análise, Planejamento e Desenvolvimento de Recursos Energéticos (CPLEN), Universidade de São Paulo, São Paulo, Brazil

Carolina Grangeia Production Engineering Program, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

Oscar M. Hernández-Carvajal Semillero de Investigación Estudios Sociales del Desarrollo y los Territorios, Universidad Nacional Abierta y a Distancia-Colombia, Bogotá, Colombia

Joselin García Hernández Benemérita Universidad Autónoma de Puebla, Puebla, Mexico

Martín Ariel Kazimierski Institute for Latin American and Caribbean Studies (IEALC), Buenos Aires, Argentina

Andrea Lampis Energy and Environment Institute, University of São Paulo, São Paulo, Brazil

Lira Luz Benites Lazaro Department of Environmental Health, School of Public Health, University of São Paulo, São Paulo, Brazil

Durham Energy Institute and Department of Anthropology, Durham University, Durham, UK

Mariana Fernández Massi IDIHCS-CONICET, Ensenada, Argentina

Pablo Messina Universidad de la República, Montevideo, Uruguay

Andrés Mideros Mora Pontificia Universidad Católica del Ecuador (PUCE), Quito, Ecuador

Lenin Mondol López Universidad Estatal a Distancia de Costa Rica, San José, Costa Rica

Eduardo Reina-Bermudez Semillero de Investigación Estudios Sociales del Desarrollo y los Territorios, Universidad Nacional Abierta y a Distancia-Colombia, Bogotá, Colombia

Isabel Rodríguez-Peña Facultad de Economia, Unversidad Nacional Autonoma de Mexico, Mexico City, Mexico

Diego Pérez Roig IPEHCS-CONICET, Neuquén, Argentina

Ignacio Mariano Sabbatella Facultad Latinoamericana de Ciencias Sociales (FLACSO) – Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina

Luan Santos Faculty of Business Administration and Accounting Sciences, The Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

Giorgio Romano Schutte Universidade Federal do ABC, São Bernardo do Campo, Brazil

Esteban Serrani National Scientific and Technical Research Council (CONICET), National University of San Martín (UNSAM), San Martín, Argentina

Raiana Schirmer Soares Institute of Energy and Environment, University of São Paulo, São Paulo, Brazil

Energy and Environment Institute, University of São Paulo, São Paulo, Brazil

Oscar Ugarteche Instituto de Investigaciones Económicas UNAM, Mexico City, Mexico

Karl J. Zimmermann Universidad Anáhuac México, Naucalpan, Mexico

1 Energy Transition in Latin America: Historic Perspective and Challenges in Achieving Sustainable Development Goals

Lira Luz Benites Lazaro and Esteban Serrani

1.1 Introduction

The energy transition is no longer a buzzword and has become an urgent and necessary action, at the center of which is the need to reduce energy-related carbon dioxide (CO_2) emissions to limit climate change (IRENA, 2022). In recent decades, the term has gained great interest in political and academic circles, and many businesses have appropriated it to promote the development of renewable energy sources under a techno-economist, utilitarian conception, and from an industrial format. Searching for geopolitical support in the face of growing public concern about climate change, in the growing process of wealth accumulation through new areas, maintaining existing power relations, and inequality (Bertinat et al., 2019; Gudynas, 2018). Energy relations can serve as possibilities for the development of a country or as a mechanism to consolidate the traditional asymmetric power relations and dependence (Schuldt & Acosta, 2009) as well as dependence in the international division of labor (Chang & Andreoni, 2020).

Energy transitions have already occurred in the past, such as when coal replaced biomass use, followed by the event that oil substituted coal in the automotive and aviation era, as a result of technological advances and transitions in economic systems without being anticipated or planned (Fouquet & Pearson, 2012; Serrani, 2020). However, the current energy transition is guided by the search for sustainable development agendas. Thus, the energy transition cannot only be understood as a change of fuel or just as progress in technological innovation. It must also be understood as a paradigm shift that concerns the entire system that includes a series of amendments and changes in life, prices, policies, and social factors of energy, as well as sets of structural changes in production, energy consumption, and reduction of inequalities in access to the benefits and welfare derived from modern energy sources (Miller et al., 2013; Sareen & Haarstad, 2018). One of the points that draw attention in the debates on energy transition is the absence of the need to reduce energy demand in developed countries, and many times, it is a secondary consideration. This absence of debate suggests the possibility of replacing all consumption based on fossil fuels with renewable energy, without a reduction in energy consumption. This

L. L. B. Lazaro (✉)
Department of Environmental Health, School of Public Health, University of São Paulo, São Paulo, Brazil

Durham Energy Institute and Department of Anthropology, Durham University, Durham, UK
e-mail: lbenites@usp.br

E. Serrani
National Scientific and Technical Research Council (CONICET), National University of San Martín (UNSAM), San Martín, Argentina

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situation enforces the need to consider energy transitions from the dissimilar historical particularities of the constitution of the energy mix, access to the energy public goods, and the differences in living conditions derived from the processes that show distinctions not only between regions or developed and developing countries, but also in different processes of appropriation of the benefits between the social markers of difference class, race, gender, and location.

The energy transition literature has focused more broadly on switching from a particular fuel source or technology, such as oil, coal, or gas, prompting some to criticize that it narrowly frames transitions as a way of excluding future changes or masking the social and political dimensions of energy systems behind the false appearance of limited technological options (Hirsh & Jones, 2014; Sovacool, 2016). In this regard, a growing body of literature has discussed the justice dimension of energy transition. Justice is a critical issue that is often overlooked and addresses the serious and conflict-ridden ethical and regulatory issues raised by energy production and consumption, including equitable access to energy, fair distribution of benefits, costs, and risks, and the right to participate in choosing if and how energy systems will change (Jenkins et al., 2017; Miller et al., 2013). Particularly, the distribution of energy production and consumption impacts are very unequal in Latin America, and some renewable energy technologies have negative impacts on human health, human rights, competition for land and water, and livelihood implications that jeopardize the lives and well-being of those already most vulnerable to the impacts of climate change (Howe, 2015; Martínez & Castillo, 2016).

Although renewable energy resources have become more central and have less negative environmental impacts compared with fossil fuels, more of these new renewable technologies are not accessible to the poorest in many places and can cause negative effects; for example, from the food security viewpoint, as the study of Brunet et al. (2022) showed in six African countries, solar panel installations had a negative nutritional impact mainly because the land where the power plant is located was previously used by women to grow food. Another study by Lazaro et al. (2022) showed that in Brazil, adequate spatial planning is absent for solar and wind energy expansion, which may occupy spaces destined for agriculture, thereby conflicting with food production and the associated demand for water and land. In this sense, the importance of intersectoral planning considers the trade-offs of the energy sector in relation to the others. This illustrates that the transitions require public policy planning that measures the totality of the impacts beyond a replacing energy source. Therefore, the solutions aimed at dealing with climate change and the scope of sustainable development are not contested in terms of the sustainability of the projects if the impacts at all levels and in different sectors are considered, as well as "the integration of science into the policymaking process, through the implementation of science-policy-society interfaces, where different forms of knowledge contribute to decision-making and policy" (Lazaro et al., 2021).

In this regard, the International Energy Agency (IEA) has highlighted an understanding of the water-energy nexus to avoid unintended consequences and underlines the importance of considering water use in energy policy decisions. It has also been emphasized that the fuels or technologies used to achieve the transition could, if not properly managed, exacerbate, or be limited by water stress depending on location, water availability, and competing users. Many countries in Latin America already face some degree of water stress, and there is greater uncertainty about the future water availability and the impact of climate change on water resources. For example, in 2000–2002, Brazil faced its greatest hydroenergy crisis due to water scarcity, which impacted hydroelectricity generation. As a consequence of this crisis was created the 2002 Program of Incentives for Alternative Electricity Sources (PROINFA) that boosted renewable energies in Brazil (Lazaro et al., 2022). Another example is Argentina, which decreed a "State of Water Emergency" (Decree No. 482/2021) in 2021 due to the rainfall deficit in the Brazilian basins of the Paraná River, the Paraguay River, and the Iguazu River, which led to a historical drop in water flow. It even paralyzed nuclear generation in Argentina for a few days, as it was unable to take water from the Paraná River. Hydroelectric power, which plays an important role in the renewable electricity mix in the region and the decarbonization plans of many countries, is particularly vulnerable to climate variability. Thus, the IEA urges a better understanding and planning of how climate impacts related to water will affect the energy sector (IEA, 2022).

The energy-climate relationship is beset with some peculiar problems known as the dilemma and trilemma. The energy dilemma is related to the link between energy consumption, emissions, and economic growth and has been one of the causes of economic transformations as well as environmental problems (Mose, 2020). For example, Antonakakis et al. (2017) indicate that no evidence that developed countries may grow out of environmental pollution; under this assumption, the authors question the effectiveness of recent government policies in several of those countries to promote renewable energy consumption as a means for sustainable growth. So, the dilemma is this, the energy system has the confounding characteristic as a force of both human welfare and ecological deterioration, and achieving sustainable economic growth has become a major global concern nowadays (Mose, 2020).

The energy trilemma addresses three fundamental challenges that recognize the complex interwoven links between the core dimensions: energy security, energy equity, and the environment, including climate change and sustainability. The trilemma concept is used differently in different contexts, and there are variations in its definition. The World Energy Council has been a leading institution in this regard and has prepared the world energy trilemma performance across three dimensions. Energy security measures a country's capacity to meet current and future energy demands reliably and the resilience of its energy infrastructure. Energy equity assesses a country's ability to provide reliable, affordable, and abundant energy for domestic and commercial uses. These dimensions capture basic access to electricity and clean cooking fuels and technologies, access to prosperity-enabling energy consumption levels, and electricity, gas, and fuel affordability. Environmental sustainability measures the transition of a country's energy system toward low carbon emission by reducing CO_2 emissions and avoiding potential environmental harm and climate change impacts. This dimension focuses on the productivity and efficiency of generation, transmission and distribution, decarbonization, and air quality (World Energy Council, 2022).

Similar to energy transitions, energy security can be understood and used in many different ways, such as self-sufficiency in renewable energy, owning fossil fuel reserves, having access to cheap energy, the vulnerability of energy systems from a technical point of view, the role of markets, investments in energy availability, and enough money to pay the electricity bill (IEA, 2023). Thus, energy transition should not be just about changing the energy mix or just the electrical installation; it also needs to focus on people, their involvement and acceptance of decisions in the energy industry, how much of the income of consumers goes towards maintaining this service, how much it affects their ability to cover other expenses, and whether energy production and supply are fair and sustainable improving human welfare, especially in vulnerable populations. A successful energy transition that achieves this trilemma requires the co-evolution of the policy dimension with the strategies of a heterogeneous market players. Understanding these challenges to frame future energy legislation, policies, and regulations can be a key to energy transition debates. The inclusion of social justice in the energy transition is present in the Sustainable Development Goals (SDGs); particularly the SDG 7 objective, which expresses the idea of an energy transition, that is, sustainable, modern, and affordable energy for everyone.

Therefore, the transition in Latin America must be understood much more than a change in the energy regime owing to specific restrictions and barriers to improving energy welfare and equality. Despite their interrelationships, energy security, energy equity, and environmental sustainability are regularly addressed as separate issues. Particularly in Latin America that faces the trade-off dilemma between economic growth, energy security, and environmental protection, as many critical scholarships from a Latin American perspective (for instance, Alimonda, 2011; Bebbington, 2015; Barrera et al., 2022; Gudynas, 2013; Leff, 2017; Svampa, 2013) refer that although the discourse of many Latin American governments has incorporated new concepts such as "sustainability," most policies are still determined by the pressure of economic growth and poverty reduction, even if achieving it means depleting or deteriorating natural resources. Historically, the regional economy has been based on exports of natural resources such as oil, minerals, and agricultural goods, among others, and some authors have called commodity-led development in Latin America (Ocampo, 2017) or "neo-extractivism" (Gudynas, 2018; Leff, 2017), which has reinforced the predatory nature of enclave economies in the global economy (Furtado, 2005).

Indeed, the dependent insertion of Latin America in the current phase of capitalism and material efforts to mitigate climate change are two vectors that should be reconsidered in a related manner. Global climate governance has agreed to place responsibility for environmental care on the principle of common but differentiated responsibilities according to respective capabilities, although not uniformly among its members. As Hickel (2020) demonstrated, the Global South (Latin America, Africa, the Middle East, and Asia) is responsible for only 8% of the climate breakdown and presents them as climate creditors vis-à-vis high-income countries. In Latin America, this position does not exempt it from making efforts to face the necessary changes that imply a long-term reduction of emissions toward increasingly lower carbon-intensity economies. However, it does allow us to put into historical perspective the financial efforts that the different countries must make to take measures to adapt to the negative consequences of climate change and, at the same time, to advance concrete actions to comply with its mitigation.

Hence, the energy trilemma can be a difficult but necessary objective that regional governments face to ensure energy supply, provide universal access to it, and promote environmental protection. Latin American countries, given their development agendas, must reconcile this energy trilemma, the need to grow, and provide the population with at least the minimum energy needed to reduce CO_2 emissions. Above all, they must resolve the tension of guaranteeing energy security and advancing the energy transition to reduce the negative effects of the climate crisis. Thus, energy transitions in Latin America must incorporate energy trilemma analysis into the more general framework of its specific problems, such as low long-term economic growth, high participation of raw materials in its export structure and the sacrifice zones that are organized around these activities, high rates of informality in market labor that imply low salaries and a social structure marked by inequality in the distribution of income and access to public goods.

Therefore, given the limitations of access to international financing as well as in the development of transition technologies, which reproduce the logic of exporting raw materials, importing technology and manufactures with high added value (e.g., from wind turbines, solar panels, green hydrogen, electro-mobility, and lithium batteries to the development of smart grids and the digitization of electrical systems based on the use of microprocessors, artificial intelligence, and the knowledge economy as a whole), it is necessary for Latin American countries to re-link the energy transition processes with the dynamics of the sustainable development model, its environmental and climatic impacts, and the results in the reduction of social inequalities. Consequently, it makes sense to insert this analysis into the discussion of the framework of the SDGs, since it is essential to understand the links between energy, the economy, the environment, and society in depth.

In this book, we aim to examine whether the energy transition actions and policies implemented in Latin American countries comprehensively promote sustainable development, taking into consideration not only the difficult social relations proposed under the energy trilemma, but also the difficulties and particularities of the region. The book is divided into four parts: Part I – Energy, Climate Change, and Sustainable Model: The Energy Matrix and National Decarbonization Plans – addresses the changes in energy mix in Latin America, the increasing participation of renewable sources in electricity generation, and the implicit geopolitical implications in terms of technology, production, and the actors involved. In this sense, it reviews China's diffusion of the renewable energy sector and its implications for the sustainable development model. Part II – Oil and Gas Dilemmas: Income's Dependence and Obstacles to Energy Transitions – presents the dilemmas faced by Latin American countries that depend on oil revenues to face energy transitions in the twenty-first century. The cases of Mexico, Venezuela, and Ecuador are discussed, as are country case studies on oil and gas extraction development, such as Brazil's Pre-Salt and Argentina's *Vaca Muerta*. Part III – Energy Transitions and Renewable Energies: Production, Technology, and Costs as Limits and Opportunities – describes the specificity of policies for the dissemination and expansion of renewable energies in different countries in the region, such as Argentina, Brazil, Uruguay, and Colombia. Public policies to promote transitions, the product mix and national industry involved in renewable energy projects, and the development of local technology, costs, prices, and financing are examined. Finally, policies to promote EVs as an important link to the transition are studied. Part IV – Energy Services: Access, Energy Poverty, Decentralization, and Democratization – addresses the problems of poverty and energy inequalities in Central America and Brazil, as well as the regulation and growth of distributed energy and prosumers as possible experiences of democratization in the generation and access to energy in Argentina, Brazil, Chile, Uruguay, and Nicaragua.

1.2 Energy Transition in Latin America from a Global Perspective

Latin America is one of the regions that has made progress compared to the world in terms of reducing the participation of the most polluting energy sources, both in its primary mix and in electricity generation. Latin America is the region that uses less coal in its primary energy mix at around 5%, while in Europe it represents 12%, in the Commonwealth of Independent States (CIS), 13%, in Africa 21%, and in the Asia Pacific, there is a participation of 47% in the energy mix, as Fig. 1.1 shown. When analyzing the primary energy mix by region (Fig. 1.1), the dependence on fossil resources is greater than the world average in the Asia Pacific and Africa by 73% and 60%, respectively. For example, in the Asia Pacific, the dependence on fossil resources is widespread among countries, and in three of the four most populous countries in the world, such as China, India, and Indonesia, they not only have a greater dependence on hydrocarbons in their primary mix than the world average, but the use of coal reaches 55%, 57%, and 37%, respectively, which far exceeds the world average of 27%.

As shown in Fig. 1.1, the constitution of the primary energy mix worldwide is still highly dependent on fossil resources. In the Asia Pacific region, there is still a strong dependence on coal, while in Africa, Europe, North America, and Latin America, oil has high participation. In the Middle East and CIS, the use of natural gas has expanded more widely. In Latin America and Europe, the energy generated from low-emission sources is higher than the world average (30% and 29%, respectively); even considering only renewable energies, wind, solar photovoltaic, and bioenergy sources, in both regions, these represent 12% of their primary energy mix, being the one with the highest penetration in the world. However, although this analysis at the regional level allows for an overall comparative view, it also makes invisible dissimilar national situations. For example, Brazil's dependence on fossil resources is

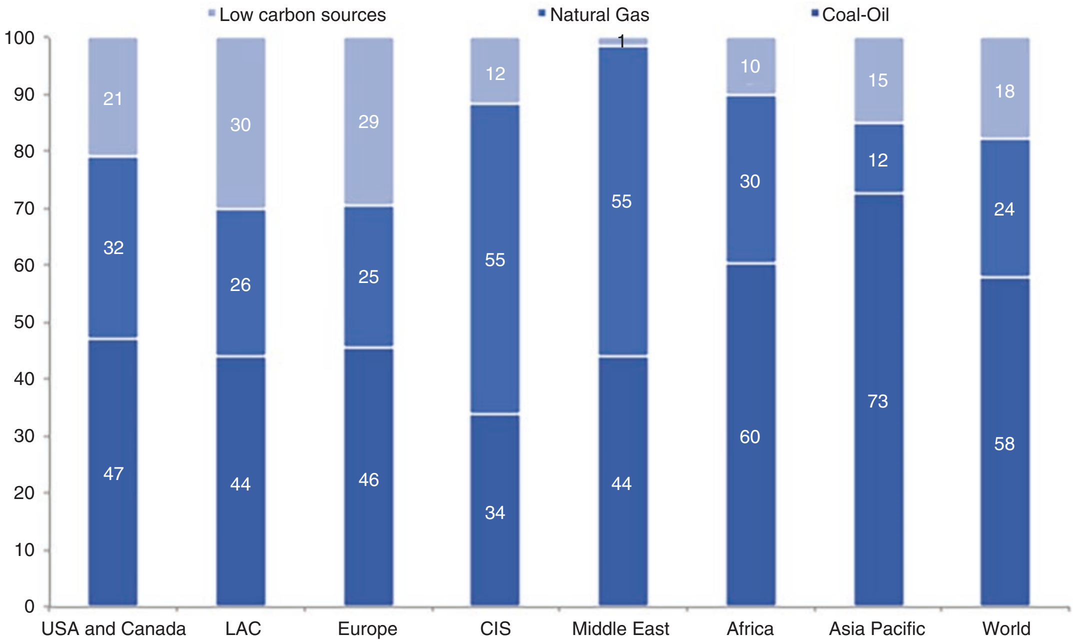

Fig. 1.1 World energy mix by sources in 2021 in percentages by region. (Source: BP Statistical Review of World Energy, 2021)

53%, while in Argentina, it is 84%, in Venezuela 72%, in Chile 73%, and in Colombia 67%.

One mistake we found when analyzing energy transitions is that the share of renewable in the energy mix is often confused with its participation in electricity generation. Globally, the participation of low-emission sources amounts to 39%, more than double the incidence of these sources in the primary mix (Fig. 1.2). However, this participation presents a significant disparity between regions. Low-emission sources in the Middle East is around 4%, and 24% in Africa, a continent where hydroelectric generation is significant, in the Asia Pacific and the CIS, its participation is even lower than the world average, 32% and 34%, respectively, and in Africa. The hydroelectric generation of Russia, China, and India stands out, while the nuclear generation of Russia, China, and South Korea stands out. In contrast, although the United States is on the world average (39%) and has a strong share of nuclear generation compared to wind, solar, and bioenergy, low-carbon emissions represent 82% of electricity generation, highlighting the strong impact on hydroelectricity, which represents 60% of the electricity generated. Finally, Europe has the largest share of low-carbon sources in its electricity mix (63%) and stands out for its considerable share of solar photovoltaic and wind energy, mainly in countries such as the United Kingdom (38%), Germany (37%), Spain (35%), and the Netherlands (33%) when the European average is 23% and the world average is 12%.

Europe and Latin America stand out as the regions with the least fossil dependence in their electricity mix, 41% and 37%, respectively, considerably less than the world average of 61% (Fig. 1.2). However, one of the main differences is the greater penetration of natural gas in Latin America than in Europe (which is the least polluting hydrocarbon). Likewise, the penetration in Latin America of renewable sources such as wind, solar photovoltaic, and bioenergy is significantly higher than that in Africa, CIS, the Middle East, and Asia Pacific, and even higher than the world average (17% vs. 13%, respectively), similar to the OECD countries as a whole, although lower than the European average (23%). This general overview of Latin America and its comparison with the rest of the regions and large

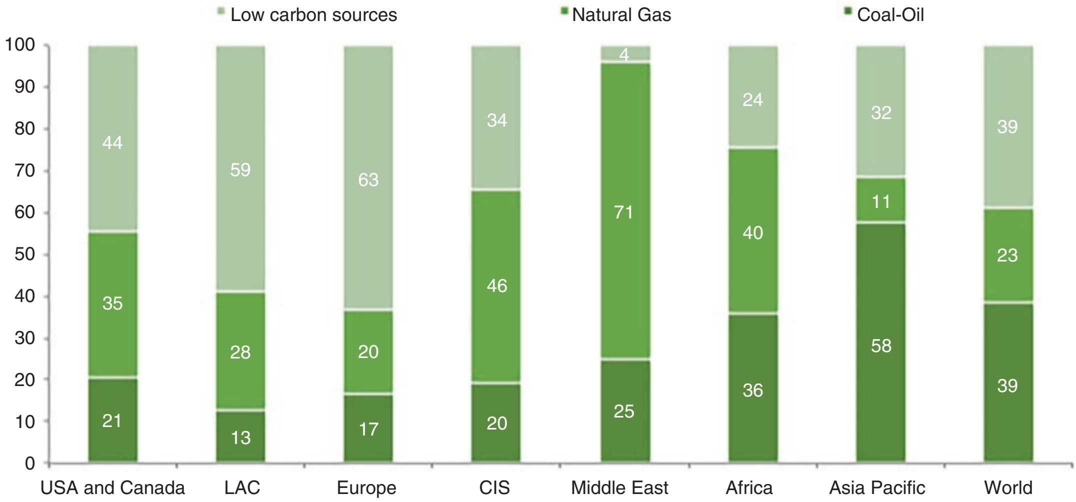

Fig. 1.2 World electricity generation matrix by sources in 2021 in percentages by region. (Source: BP Statistical Review of World Energy, 2021)

energy-consuming countries serves the purpose of having a first descriptive and structural approximation of recent energy performance.

1.3 Energy Transition in Latin America from a Historical Perspective

From a historic and regional perspective, Latin America faces the challenges of energy transition toward low-carbon economies as a climate creditor position due to the low incidence of historical and current CO_2 emissions in the energy sector and improvements in the reduction of the energy intensity of their economies in recent decades, mainly due to the low share of coal in its primary energy mix and a high share relative to the rest of the world's regions of low-emission sources in the electricity generation mix. This perspective allows us to capture the multiple realities that can be seen when examined at the country level, since the energy mix composition makes invisible dissimilar situations in realization with the endowment of resources and the national histories of their use. Thus, studies of the region have made it possible to understand the close relationship between the import substitution industrialization process and the imprint of state oil companies in the specific conformation of the energy matrices.

In Argentina, in 1922, Yacimientos Petrolíferos Fiscales (YPF) was created, the first state oil company, vertically integrated toward its entire production chain, which was born seeking to sustain and expand the supply of crude oil and its derivatives in the local market (Solberg, 1986), to support national development and counteract external dependence on energy imports (Gadano, 2006). One of YPF's reasons for being was that it should become a tool to achieve energy independence from the interests of the oil trusts organized around what would later become the identity of the Seven Sisters oil companies (Serrani, 2018) since independence energy and oil self-sufficiency would be the first step in achieving autonomous economic development. YPF's historical conflict with multinational corporations and its effort to secure new resources to support industrialization significantly shaped its trajectory. In 1977, the Loma La Lata mega-gas field, whose development allowed early gasification of the primary energy mix in the country (Serrani & Barrera, 2018), which would be driven by market reforms during the 1990s (Barrera et al., 2012; Serrani, 2013).

In Uruguay, the transition toward state positioning in the sector after the 1929 crisis was relatively "natural," since the state managed a large part of the industry before the creation of the state oil company, the *Administración Nacional de Combustibles, Alcohol y Portland* (ANCAP) in 1931. ANCAP was created to exploit and manage the national alcohol and fuel monopoly to import, refine, and sell fuel in the local market (Bertoni, 2011). Despite a lack of significant domestic oil resources, Uruguay has established its own state oil company, ANCAP. However, the absence of substantial oil reserves has highlighted the country's need to prioritize the transition toward a renewable energy mix. This transition gained significant momentum in the 2000s as Uruguay recognized the imperative to reduce its dependence on imported fossil fuels to meet its energy demands.

In Mexico, the history of oil dates back to the beginning of the twentieth century, with a strong presence of multinational companies that have boosted the industry internationally. However, it was not until 1937 that, after a series of conflicts between foreign capital and the oil faction of the labor union, a strike broke out against the multinational companies that paralyzed the sector, which served as a catalyst for the creation of a state-owned oil company, marking a turning point in Mexico's oil industry and asserting national control over its valuable resources (Puyana, 2015). After several legal processes in the Mexican superior courts, the Board of Conciliation and Arbitration ruled in favor of the workers, although the companies promoted an Amparo before the Supreme Court of Justice of the nation. By denying the protection presented in 1938, the Supreme Court ratified the sentence issued in favor of workers. After the companies refused to comply with the regulations, President Lázaro Cárdenas decreed the expropriation of the assets of 17 oil companies in favor of the nation, creating Petróleos Mexicanos (PEMEX) on June 7, 1938. In this way, the company became a central part of Mexican industrialization (De la Vega, 1999), and especially after the international oil crisis of 1973, it would become a source of central fiscal income for the country, a process that lasts until today (Puyana, 2015; Campodónico, 2008).

In Brazil, Brazilian oil industrialization with its state presence, began in 1938 when the National Oil Council (CNP) was created and the Oil Regime Law was launched to ratify the nationalization of the subsoil and limited access to deposits only for Brazilian companies (Furtado, 2010). However, the industry still did not have sufficient resources to set up a large-scale industry nor to achieve the self-sufficiency that would underpin the industrialization carried out by Getulio Vargas (Dias & Quaglino, 1993). In this sense, the industry ended up being forged around the state-owned company *Petróleos Brasileiros* (Petrobras), founded in 1953 under the constitutional government of Vargas, who established a state monopoly over the reserves and activities of the sector's primary market, considering it a strategic input in the manufacturing development of thriving Brazil. However, dependence on imports continued to be very high in the years following, which led the military regime to launch the National Biofuels Program (colloquially called Proálcool) in 1975. Ethanol production from sugarcane was driven by the need to improve the trade balance and national energy self-sufficiency in the context of an economic trade deficit caused by dependence on foreign oil and the 1973 international oil crisis (Benites-Lazaro et al., 2017). Proálcool became an important pillar of the great geopolitical ambitions of the military dictatorship to transform Brazil into a superpower while allowing a change in the energy supply matrix, which was made possible by its ability to produce food and energy simultaneously. In short, Proálcool caused the territory devoted to ethanol production to double between 1975 and 1985 and production almost tripled. Sugarcane expansion has been constant since 1975, and in 2003, the introduction of flex-fuel cars caused a significant increase in investments in ethanol production, further consolidating the local energy mix transformation (Benites-Lazaro et al., 2020).

In Bolivia, the state company Yacimientos Petroliferos Fiscales Bolivianos (YFPB) was created on December 21, 1936, under the YPF experience model in Argentina (Zuleta, 2013a). The company aimed to promote the exploitation, distillation, and commercialization of oil and derivatives, especially given the possibility of production in the Chaco boreal area, where there were supposed to be large oil reserves. However, the economic recession that plagued the country due to the confluence between the 1929 crisis and the defeat in the war led to drastic measures to try to achieve national supply. In 1938, the Bolivian government nationalized the facilities and reserves that Exxon had in the country, without outstanding oil results in the following years (Zuleta, 2013b). In 1955, the Petroleum Code was sanctioned, through which the Bolivian Gulf Oil Company obtained concessions to explore and exploit areas potentially rich in fossil resources with a widely favorable regulatory framework, to the detriment of the YPFB. After the discovery of the Colpa and Río Grande reserves, in 1968, the first purchase-sale contract was signed between Argentina and Bolivia, using Gas del Estado as the purchasing party and YPFB and Bolivian Gulf Oil as suppliers. However, the nationalization of Bolivian hydrocarbons in 1969 led to a contract revision. Finally, gas commercialization began in 1972, with a horizon of 20 years and an initial volume of 4 million m^3 per day, which would increase over the years. This agreement allowed Bolivia to significantly increase natural gas production over the years, placing all its gas exports on the Argentine market until 1998, the year in which Argentina stopped buying from it, and Bolivia began exporting to Brazil, a market that still exists to this day (Sabbatella & Serrani, 2021).

In Chile, with the entry into the government of the conservative Alessandri, an attempt was made to regain control over the natural resources that were conducive to advancing the ongoing industrialization process and breaking the dependency on imported crude oil and fuels (Garrido-Lepe, 2018). The government managed to create the first private national company in the sector in 1934, the Compañía de Petróleos de Chile (COPEP) with the purpose to ensure fuel importation after the serious supply problems that had occurred in the country after the 1929 crisis (Philip, 1984). With the Popular Front victory in 1939, the issue of nationalization of the oil tanker was raised again, with little success. However, like Uruguay, which did not have its hydrocarbon resources, imports were constant throughout the period. Moreover, between 1930 and 1960, coal continued to be the main source of energy for the country's economy, postponing the transition to oil consumption over at least three decades (Yáñez & Garrido-Lepe, 2015). Although the importance of coal in the energy matrix has decreased since 1953, abandoning industries and railways, its use has been concentrated on electricity generation, initiating a new cycle of the mineral, characterized by a close link with thermoelectric generation. Since 1990, with the increase in electricity demand, coal consumption would increase to levels never seen before (Yáñez & Garrido-Lepe, 2017). In recent years, this process has attempted to reverse itself by incorporating renewable energies that displace coal use in electricity consumption within the framework of the international climate commitments assumed by the country.

In Venezuela, the oil industry developed later in the region, when Petróleos de Venezuela Sociedad Anónima (PDVSA) was founded in 1976. The growing oil nationalism in the first part of the twentieth century led to the fact that in 1945, the country reached the historic 50–50 agreement to share oil income between the state and multinationals based in the country (Sampson & Shay, 1975). The signed "equal parts" agreement allowed Venezuela to capture a very important oil revenue portion, which years later would allow it to finance, among other things, the country's large hydroelectric ventures that would form part of the National Plan of Electrification (León, 2000).

Indeed, the creation of national oil companies and the energy development programs that sprang from them gave impetus to the transition from coal to the search for oil self-sufficiency, with substantive industrialization as the underlying economic process. To a large extent, this economic process and the high endowment of hydrocarbon resources in countries such as Mexico, Venezuela, Ecuador, Colombia, and Bolivia have led to the income of these state companies being consolidated as a source of highly relevant financing for most of these countries (Fajnzylber, 1990; Campodónico, 2008), a process that continues to the present day. This process has also collaborated with development since the end of the 1970s for the extraction of both gas resources associated with oil exploitation, as well as other energy sources, such as biofuels. This also helps to understand why the region has a more relevant share of natural gas in electricity generation than the rest of the hydrocarbons (28% and 13%, respectively). The countries with a high natural gas share are Bolivia (61%), Argentina (59.7%), and Mexico (56.7%), as shown in Fig. 1.3. In this context, in several countries of the region, the penetration of natural gas has grown steadily in recent decades and, to a large extent, has been consolidating the displacement of the rest of the fossil fuels by this source "of transition" for its potential to serve as a bridge in the energy transition.

In contrast, although the Latin American region has a penetration of low-emission energies similar to that of Europe, when analyzing the national energy matrices, different cases are also presented. In the first place, the very relevant participation of hydroelectricity stands out, a process that is quite widespread in a large part of the countries. The most singular case is that of Paraguay, which has 100% of its electrical mix powered by this source. Four plants operate in the country: the Acaray Dam came into operation in 1969; it currently has 210 MW of power, the Yguazú Dam, from 1977, and, in addition, there are two other large binational ventures: Brazil shares the Itaipu Binational Dam, inaugurated in 1984, which has 14,000 MW of power and, until 2011 was the largest plant in the world (Itaipu, 2022); when it was surpassed by the Three Gorges Dam in China. The second binational hydroelectric plant is Yacyretá, which it shares with Argentina, and was inaugurated in 1994, after several processes of increasing turbines, it currently has a capacity of 3200 MW.

However, there are other outstanding cases regarding the participation of this source in the electricity mix. Ecuador covers 79% of its electricity needs from hydroelectric plants, a process that was deliberately promoted by the national state since the 2000s, which has reused part of the oil revenue derived from exports in the context of rising prices in the international market, sought to achieve energy security for the country based on low emission sources (Fernandez & Mideros, Chap. 7, in this book). Thus, the hydroelectric system has approximately 70 dams with a capacity greater than 5000 MW, among which Coca elbow Sinclair stands out, which was inaugurated in 2016 with a capacity of 1500 MW, Paute Azuay, from 1998, and with 1100 MW, Sopladora (486 MW and 2016), and Minas San Francisco (270 MW, 2019) (Ecuador, 2022). In contrast, another country with a high-low emissions mix is Costa Rica, which accounts for 71% of its electricity consumption from hydroelectric generation. Costa Rica has a long history of using dams for electricity generation, which has led it to be identified early as a relatively sustainable country in relation to the other countries in the region. Reventazon, inaugurated in 2021, stands out with 305 MW of power, Embalse Angostura, inaugurated in 2002 with a maximum installed capacity of 172 MW, Embalse Cariblanco put into operation in 2007 and with 80 MW, two historic power plants set up in the Cachí Reservoir, which came into operation between 1966 and 1978 and has a capacity of 102 MW, and the Arenal Reservoir, from 1979 to 157 MW (ICE, 2022).

The case of Venezuela is unique; even though the oil industry plays an important role in the international oil market, eight large hydroelectric plants cover 68% of its electricity consumption and constitute the most important generation pole in the country, with an installed capacity that exceeds 15,000 MW. Among the main projects based on capacity, the "Simón Bolívar" Hydroelectric Power Plant stands out, located in the Guri Dam (formerly known as the "Raúl Leoni" Hydroelectric Power Plant), which was inaugurated in 1986, and after several expansions, reached a total of 10,000 MW of power. The second is the Macagua Dam, which comprises three plants on the Caroní River and currently has a capacity of 3150 MW. These complexes were part of the National Electrification Plan developed by Venezuela in 1956, which deliberately sought to increase

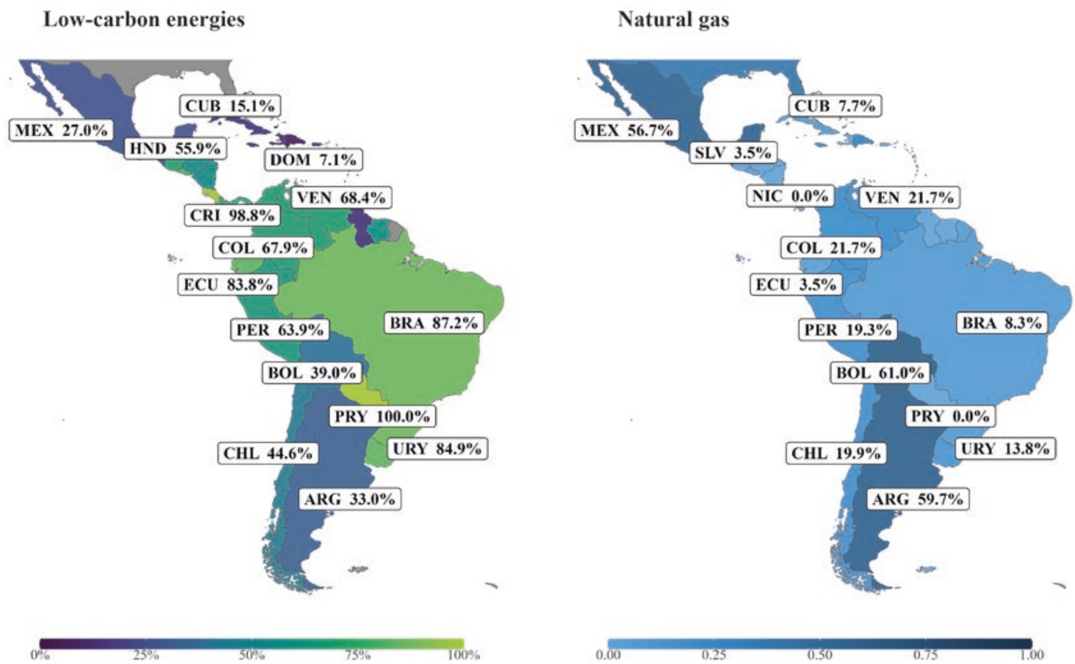

Fig. 1.3 Percentage share of low-carbon energy and natural gas in the electricity mix of Latin America and the Caribbean in 2021. (Source: BP Statistical Review of World Energy)

hydroelectricity to reduce fossil fuel consumption in the country's electricity generation (León, 2000). The Caruachi Power Plant, which was inaugurated in 2006, has a total power of 2160 MW (CORPOELEC, 2022).

Likewise, it is possible to understand that for the largest country in Latin America, the low natural gas participation in Brazil has been explained by the high incidence of low-emission sources, especially hydroelectricity in its electrical mix. With more than 109,000 MW of installed capacity in hydroelectric projects, this source accounts for 62% of the country's total electricity generation, most of which was built many years ago, taking advantage of the abundant water resources with which the country has projects that have not been without social and environmental conflicts, especially in the Amazon rainforest (Vainer et al., 1992; Sigaud et al., 1988; Zhouri & Oliveira, 2008; Werner, 2021).

Furthermore, the participation of large hydroelectric plants exceeds 50% of electricity generation, in Colombia, Panama, Peru, and Suriname, which exceeds 25% in seven other countries: Guatemala, Dominican Republic, El Salvador, Bolivia, Chile, Honduras, and Argentina. This allows us to understand the relevance of this source in the electrical mix. Second, based on the outstanding and widespread participation of hydroelectricity, the recent incorporation of other renewable energy sources, especially photovoltaic, wind, and bioenergy, has emerged in several countries in the region. Uruguay is the most recent and prominent case, which leads to more than half of the electricity in that country coming from wind and the energy generated by biomass derived from the installation of pulp mills in the country. In addition to wind and biomass, hydroelectric power plants contribute significantly to the electricity generation mix, accounting for almost one-third of the country's total electricity production. Combined with these renewable sources, approximately 85% of the country's electricity is generated from low-emission sources (Bertoni & Messina, Chap. 12, in this book).

Hydroelectricity account for 34% of electricity generation in El Salvador, which has a total of

80% of electricity generation derived from low-emission sources. Another Central American country in which over half of the electricity generation is derived from renewable sources is Nicaragua, where 43% derives almost equally from geothermal, wind, and biomass, having the source of solar photovoltaic a rather marginal participation. Nicaragua and Honduras generate over half of the electricity from low-emission sources, while hydroelectricity accounts for a quarter of the generation. The remaining 30% of wind and photovoltaic energies have preponderance, although it is also significant for the participation of geothermal and bagasse, which accounts for approximately 10% of the total generation (Honduras, 2021). Similarly, Costa Rica has almost all of its electrical mix derived from low-emission sources, and to the 71% share of hydroelectricity, another 28% is added from other renewable energy sources, with a similar share of geothermal and wind power. Other countries with a strong share of low-emission sources other than hydroelectricity are Belize (27%), Guatemala (23%), Brazil, and Chile (19%). Likewise, the Dominican Republic, Haiti, Puerto Rico, Jamaica, and Cuba account for fewer than 15% of electricity generation with low-carbon sources (Fig. 1.3).

1.4 Structural Obstacles to Energy Transition in Latin America

The transition toward sustainable energy systems in developing countries such as Latin America faces a significant structural obstacle: the scarcity of public resources to finance the necessary infrastructure transformations for achieving environmental and productive sustainability. The need to rely on international funds and private banks to develop renewable energy projects makes it challenging to generate virtuous synergies between green financing, industrial policy, and genuine job creation. Therefore, when analyzing the economic dimension of transitions, it is crucial to consider their fiscal cost, including new infrastructure and technologies required to move away from existing fossil energy sources. This also involves recognizing that energy transition requires a comprehensive approach, including policies that support Sustainable Development Goals, and effective global governance mechanisms that promote cooperation and financial support for energy transition.

In the global context, the reduction of GHG emissions, the finance of the energy transition and the fiscal costs derived from the stranded assets have become a complex topic. Moreover, the region is responsible for less than 10% of global CO_2 emissions, has had marginal participation in the historical stock, and possesses one of the world's largest hydrocarbon reserves. This situation puts pressure on the region to reduce the exploitation of its fossil resources to accompany the decarbonization agenda, resulting in fiscal impacts. This book explores some of these dilemmas, including the composition and magnitude of stranded assets. In the electricity sector, for example, the study by Bistend et al. (2019) estimated that an investment of 2.6 trillion dollars would be required between 2021 and 2050. However, the energy transition cannot be viewed in isolation from other sustainable development objectives, such as improving access to basic health services, reducing poverty and inequality, and conserving ecosystems. Galindo et al. (2022) highlighted that addressing these broader objectives would require between 7% and 19% of annual GDP to be allocated to infrastructure and social spending in 2030, which translates to a spending range of US$470 billion to 1300 billion. Specifically, the climate crisis would require spending between 2% and 8% of GDP on infrastructure services and between 5% and 11% of GDP on various social challenges.

The expense required to finance the energy transition is undoubtedly significant, but how can this investment be obtained? Galindo et al. (2022) propose a green tax reform and the elimination of fossil fuel subsidies as possible sources, which could contribute roughly $200 billion per year or approximately 3.6% of GDP in 2019. However, the study does not estimate the short-term fiscal impact that the erosion of the tax base in taxes on hydrocarbons would generate, putting billions of tax revenues at risk until at least 2035 (Solano-Rodríguez et al., 2019; Welsby et al., 2021). The economic viability of this green tax reform is further complicated by the additional loss of public income from taxes and rents that the public sector receives from mining and the extraction and sale of hydrocarbons. ECLAC estimates that the region's average public revenue from these activities between 2015 and 2020 was 8.6% of GDP, with 7.6% coming from the hydrocarbons sector and 1% from mining (Annex). Some countries are mainly dependent on hydrocarbons; for example, in 2019, it represented 27.7% of the GDP of Ecuador, 22.2% of Trinidad and Tobago, 11.8% of Bolivia, and 6.6% of Colombia. While mining represented 4% of the GDP of Chile, 3.4% of Bolivia, and 2% of Peru (Annex).

In recent years, carbon taxes have been promoted as economic incentives to reduce the reliance on fossil fuels in the electricity sector. There are some examples of carbon taxes in the region, such as in Mexico, Chile, Colombia, and Argentina, with values ranging from US$3.72/tCO2e to US$5/tCO2e in 2022 (World Bank, 2023). Although carbon taxes are gaining attraction in Latin America, they remain a marginal part of the green financing structure for the energy transition in the region. It is worth noting that the effectiveness of carbon taxes as a financing mechanism for the energy transition is limited, as they only generate revenue when fossil fuels are used and do not provide a stable source of funding for long-term investments in renewable energy infrastructure. Despite the urgent need for financing, the sources of funding for climate goals in the Latin American region remain inadequate. The World Bank, the Inter-American Development Bank (IDB), and the Andean Development Corporation (CAF) granted finance a total of US$40 billion per year in the region, while the economic and social infrastructure needs to meet climate goals represent between US$340 thousand and US$1100 billion by 2030 (Galindo et al., 2022: 8). Moreover, developed countries have failed to fulfill their promise to invest US$100 billion annually in mitigation and adaptation programs in developing countries since 2013. At the Climate Summit held in Glasgow in 2021 (COP 26), there were calls for developed countries to significantly increase their financing for climate adaptation, but this has not been met either. Even with the accounting of climate finance providers to developing countries, the promise was breached by US$17,000 million in 2020, according to the OECD (2022).[1] The adaptation finance gap in developing countries is likely to be five to ten times larger than current international adaptation finance flows, and it continues to grow (United Nations Environment Programme, 2022).

The financial challenges of decarbonizing economies in Latin America, including the need to analyze the opportunities and risks of stranded assets. Green taxes have been implemented, but they are not enough to achieve sustainable development and social and climate inequalities that have increased due to the Covid-19 pandemic. The insufficient efforts of regional multilateral banks in financing energy transitions and the gaps of climate financing promises by developed countries toward developing countries further reinforce relative inequities. The national energy transitions in many countries have been driven by market logic due to the restriction of public financing. Energy auctions and power purchase agreement (PPA) contracts have been used to incentivize investment in renewable energy and to shift the market toward sustainable energy sources (Viscidi & Yépes-Garcia, 2020; Barrera et al., 2022). However, this has shown little incentive for local companies to participate in the value chains of renewable energy projects. Policies such as carbon pricing, green financing, and renewable energy mandates have helped mobilize international and private financing (Stanley, 2021). Nonetheless, this has also increased the region's technological dependence on companies from countries that are leaders in innovation in the renewable sector, confirming the maxim that "who provides the financing imposes the technology." There are also insufficient requirements and standards to ensure that green finance funds

[1]The report explains that 37.7% of this financing comes from bilateral public banks, 44.3% from multilateral public banks, 2.3% from climate-related export credits, and 15.7% from private climate financing (OECD, 2022: 7). Likewise, 31% is invested in the energy sector, and of the total invested, 17% reaches the American continent, which includes the United States and Canada, so it is impossible to know the effective amount for Latin America.

are allocated only to green projects that prioritize social and environmental sustainability over economic benefits (Lazaro et al., 2023). This creates challenges for investors to assess the risks and opportunities of their investments.

Technological dependence on renewable energies is not only a challenge faced by Latin America. In recent years, the European Union, Japan, and the United States have implemented aggressive public policies to integrate their decarbonization strategies with industrial policies and large financing lines. Different from Latin America, these countries aim to promote the inclusion of local production and employment in the value chains of the green economy, to reduce the importation of widely used goods for strategic economic sectors, such as steel, aluminum, lithium, and copper.[2] They also aim to reduce the importation of capital goods, high-value-added manufacturing, and essential services required for advancing the digitization and decarbonization of their economies.

The dependence on external financing to promote renewable energy, combined with a marked absence of industrial policy associated with the green economy, has led to low direct job creation in Latin America. While there are studies that reflect on the potential of green employment (Saget et al., 2020; IADB, 2020) and the benefits that productive reconversion brings (Cedefop, 2021), there is still little literature that shows the generation of genuine employment. However, a report titled "Generation of Employment in renewable energy" (Argentine Secretariat of Energy in 2018) gives insights into the situation in effective jobs created in the renewable energy projects awarded in Argentina under the RenovAr Plan (2016 and 2018). According to the report, on average 2.6 workers are employed for each MW awarded in the construction phase of the projects, and 0.36 direct jobs for each MW in the operation and maintenance (O&M) stage, which means one job is created for every 3 MW. Analyzed by technology, wind power creates 1.9 jobs and solar parks create 2.8 jobs for each MW installed, and in the O&M stage of both technologies, 1 job is created for every 5 MW installed (Rijter, 2018: 16, 17). If 5025 MW of new power is needed to reach 20% of the electricity supplied by renewable sources by the year 2030 in Argentina, 13,274 jobs would be generated during the construction period and 1857 new direct jobs during the O&M stage, according to the work of Serrani and Barrera, Chap. 11, in this book. This confirms the argument that without public financing and without an industrial policy that promotes the generation of local production chains, it is unlikely that a green employment revolution will be generated because of the energy transitions underway in Latin America.

In developed countries, achieving carbon neutrality by 2050 involves reinvigorating their economies with a strong protectionist orientation and implementing industrial development policies that benefit their companies and promote local employment in renewable energy value chains. However, this approach has not been widely adopted in Latin America, partly due to limited public financing that makes it difficult for countries to obtain the necessary financial resources; as well as many Latin American countries have been reliant on foreign technology, limiting their ability to control the pace of technological development and participate in value chains. Latin America region faces a range of socioeconomic challenges such as poverty, inequality, and low levels of education and skills training, which can hinder the workforce's ability to participate in value chains. Moreover, there is limited local industrial capacity due to the lack of necessary infrastructure to develop local production chains that can compete with more established foreign companies in the renewable energy sector. These challenges underscore the need for policies that prioritize industrial development and local job creation in the renewable energy sector. Along these lines, in the following section, we discuss the priorities, emerging debates,

[2] Special reference is made to Japan and the Green Transformation (GX) Plan launched in 2022, the enactment in the United States of the Chip Act and the Inflation Reduction Act in 2022, and the launch in 2023 of the European Green Deal Industrial Plan, to name just a few of the industrial policy plans associated with the green economy and decarbonization strategies toward 2050.

and critical issues examined in the scientific literature in recent years in Latin America.

1.5 Energy Transition in Latin America: Emerging Debates

In this section, we present the published scientific literature on energy transitions in Latin America. The objective is to identify the main topics that have been published and how Latin American researchers address the different challenges of energy transition. We started by searching the keyword "energy transition" in the journal database Scopus. By limiting the search to only articles (no books, book chapters, or conference reviews), we identified 8684 articles worldwide from 1970 to 2022 (September 2022). By narrowing down the search to Latin American countries using the country/territory Scopus tool, we identified 398 articles (Fig. 1.4), which represents only 4.6% of the total. In Latin America, Brazil has the most publications with 146 articles (37%), followed by Mexico with 102 published articles (26%); most countries have less than 10 articles published (Fig. 1.4).

The second step in the search of the published articles was to analyze the abstracts of the 398 articles using T-Lab's topic model tool, which allows us to identify, examine, and model topics from the texts. As a result, we obtained 10 topics (CO_2_emissions, oil, biomass, solar, wind, economy, policy, justice, community, and household) (Fig. 1.5) from which we carried out qualitative and quantitative analyses by exploring the characteristics of each theme and extracting the elementary contexts from the articles to understand the topic. The 10 main topics we present by using correspondence analysis, in which in T-lab the analysis results are summarized through graphs that allow the evaluation of the relationships of proximity/distance or similarity/dissimilarity between the considered topics (Lancia, 2021).

For example, in Fig. 1.5, the "household" in the lower left quadrant is distant from the other nine topics, which can be explained in a certain way its non-proxy with the others that are topics

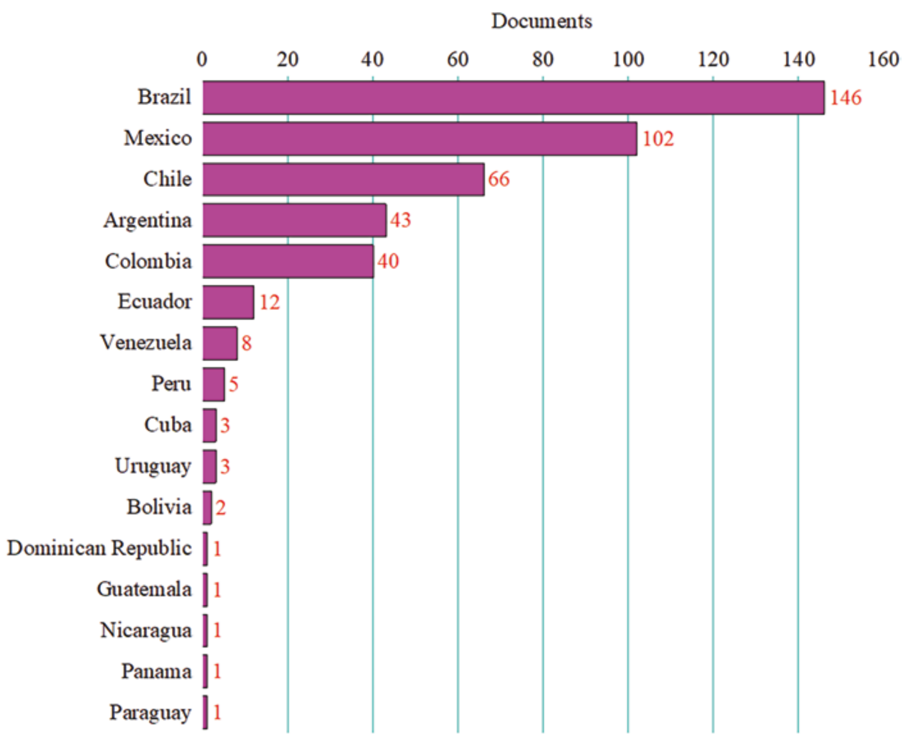

Fig. 1.4 Number of articles from Latin America. (Source: Scopus database)

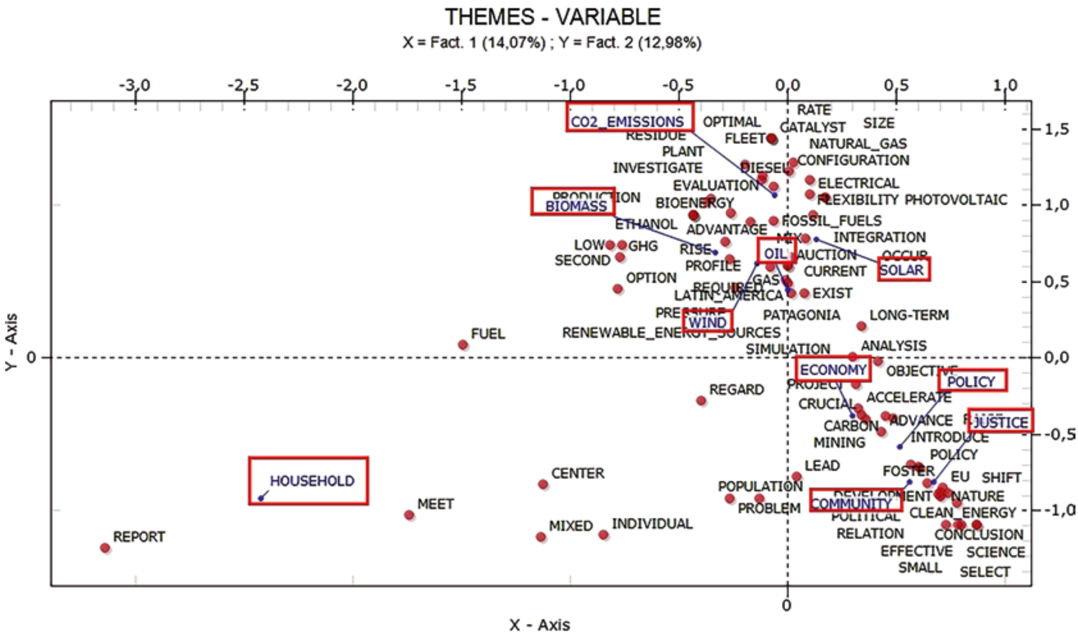

Fig. 1.5 The main topics identified in the energy transition articles from Latin American region. (Source: Scopus database)

related to the so-called modern renewables energies solar and wind power, as well as biomass, oil, and CO_2 emissions, in the upper right quadrant. The topics in the lower right quadrant are related to economics, politics, community, and justice. Articles on "household" topics describe the pace of the transition to clean household fuels as being far behind. Mainly because of the sharp increase in LPG prices in recent years, many households have reversed the trend toward reliance on wood fuels. Despite the energy transition of the home toward cleaner and more efficient devices and fuels, it has been proposed as an urgent solution for the population that depends on open fires for cooking. However, finding solutions that allow the complete displacement of traditional wood-burning devices has proven to be a great challenge (Betina et al., 2022; Gould et al., 2018; Medina et al., 2019; Shankar et al., 2020).

The topic "community" emphasized the importance of understanding the social actors, mainly from the communities and social movements, their perception and acceptability toward energy projects, as well as the need to empower the various social actors and local governments in urban energy management and planning (Cristián Parker, 2020; Villalba et al., 2021). Public policies are needed to guarantee, for example, prior consultation to build social consensus and protect the human rights of the indigenous population. The study by Dantas et al. (2019) can be illustrative in this regard, describing the social and environmental fragilities of local communities, which are often overlooked by exclusionary planning. This has led to opposition movements against the implementation of wind farms, and since their implementation in their surroundings did not change the socioeconomic conditions of the population, environmental issues require assessment by the government.

The topic "justice" encompasses a wide range of issues, including discussions on equity, legitimacy, poverty, and environmental justice. As a society transit to a new era of renewable energies, it becomes crucial to recognize that this transition can inadvertently perpetuate social injustices without appropriate planning. For example, wind farms are often celebrated for their environmental benefits. However, it is important to understand that they can also perpetuate existing injustices and give rise to new ones if not carefully managed and implemented (Ramirez & Böhm, 2021).

Furthermore, Latin American countries face a technological dependence, as they often rely on imports of solar panels, wind turbines, and other necessary technologies and final goods from other countries. This reliance on external sources underscores the need to develop further the region's domestic technological capabilities and manufacturing capacities. One of the dominant proposals in energy transition debates is related to wind energy and solar energy, proposed as low-carbon options, based on new techno-political processes, and as environmental and sustainable development ideals. However, there is a dichotomy between environmental protection and socioeconomic development promotion and pursuit through extractive policies and activities, such as extractive mining and energy dynamics, which are linked to modern renewables. Just as the extractive processes of appropriation, dispossession, territorial expulsion, and competitive use of other resources continue in their generation (Escallón et al., 2021; Lehmann & Tittor, 2021; Ulloa, 2021).

Articles on the topic "policy" highlight the need to understand the policy dimension of energy transition, and the implementation of specific public planning policies for the expansion of renewable energies. National pathways can improve coherence between national policies and plans with climate goals, incentives toward low-carbon technology investments, and policies that promote the substitution of energy-intensive fossil fuels for renewable energy through an active fiscal policy (Blanco et al., 2017; Lazaro et al., 2022; Gomel & Rogge, 2020; Pérez et al., 2017). For example, Gomel and Rogge (2020) mentioned that Argentina's energy transition was made possible by the adoption of a new policy strategy aimed at the diffusion of renewable energies in 2014, and how the combination of policies and socio-technical change contributed to new knowledge about the deficiencies of the energy transition policies, including the results of the policies, with a focus on taking advantage of the opportunities for developing a national renewable energy industry. Blanco et al. (2017) propose a policy formulation tool applied to the problem of multi-criteria decision energy policy in Paraguay for four policy options based on economic, technical, social, environmental, and political criteria arguing that the process of elaboration of public policies, particularly for emerging countries, implies a complex decision problem that involves several policy options with the potential to influence the welfare of the country and all dimensions of socioeconomic development. Lazaro et al. (2022) emphasize that despite a growing debate about the role of decentralized solutions, energy policy and regulation in Brazil still do not consider the responsibilities of local governments. In addition, cross-sectorial cooperation focuses on territorially oriented solutions to improve spatial order by integrating capacities at the local level in multilevel governance for energy transition.

Indeed, until now, there has been an opening-up in the literature that has analyzed how the policies of the energy transition in the region can become a vector that generates the conditions of possibility to deploy a new model of sustainable development, which includes economic growth, technological development, generation of genuine employment, environmental care, and reduction of inequality, which allow the region to break the dependent form of insertion in the global economy. The literature shows that the region is a fertile ground for studies on energy transitions, and several related issues deserve in-depth study. The future of global energy transition, even in Latin America, depends on national legislatures to manage energy security, energy equity, and sustainability. Sustainable energy transitions require the formulation of effective policies to promote SDG achievement.

1.6 Energy Transition in Latin America: Challenges to Achieve Sustainable Development Goals

Sustainable development discourses increasingly have gained prominence in recent decades, with numerous multilateral conferences focused on the topic, including the 1992 Conference on Environment and Development in Rio de Janeiro, the 2002 World Summit on Sustainable Development in Johannesburg, and the 2012 Conference on Sustainable Development (Rio+20). At this last conference, the challenges of achieving the Sustainable Development Goals

(SDGs) were discussed, which serve as an action-oriented framework for the international community to advance sustainable development in economic, social, and environmental dimensions. Given the pressing challenges and problems facing societies, economies, and the environment, achieving the SDGs and limiting temperature rise to 1.5 °C by 2050 requires a successful transition to renewable energy sources. This is particularly relevant for Latin America, which faces numerous challenges to achieving sustainable development and transition to low-carbon energy, such as addressing energy poverty, promoting social and economic equity, and reducing dependence on fossil fuels.

In this book, the chapters illustrate the various challenges of Latin American countries in the energy transition. In Part I, Sabbatella addresses the relationship between energy and climate policies by reviewing the evolution of the decarbonization process of electricity generation in South America. Considering that this is a region with a low historical incidence of GHG emissions, particularly regarding emissions from the energy sector. Guerrero emphasizes the complexity of the trans-scalar power relations in the contemporary energy transition. How the intertwining of geopolitics and social dimensions simultaneously seeks to obtain energy security and a just transition and is highlighted and synthesized in the idea of a green recovery built around energy transformation. Ugarteche discusses the incorporation of low-emission energies in the region and the growing participation of Chinese investments in this process, which, from an international political economy perspective, evidences the tension in Latin America's relationship with the United States, constituting a new scenario of geopolitical conflicts for the future.

In Part II, Sandoval discusses the Mexican case of the interdependent and constitutive relationship between fossil fuels and capitalism, which prevents transforming energy systems into alternative energy sources. In this sense, the production and economic growth of Mexico depend not only on income from fossil fuels, but mainly on the United States market, to which it exports a large part of its oil and imports gasoline. This situation reinforces the double dependency due to the unequal regional integration of Mexico in North America. In addition, Zimmermann proposes a comprehensive analysis of the nexus energy policy and climate change policy in Mexico. They found that energy policy undermines climate mitigation goals by compromising emission reductions, while climate policy affects energy security by hampering energy affordability. The main suggestion is to reduce trade-offs between the categories of policy objectives and overcome the historical bias of energy policy toward fossil fuels in order to consistently move toward an effective energy transition. Based on the energy transition process in Ecuador, Fernández and Mideros reinforce the relationship between the energy system and the development model. Ecuador was one of the few countries in the region that used a considerable part of oil income in the midst of the price boom to change the electricity mix toward low-emission sources, which included the construction of large hydroelectric projects. However, there was little progress in reducing the fossil fuel dependence. Furthermore, Fuentes and Fontaine examine the energy transition in Ecuador and Venezuela from a comparative perspective, considering the two oil-exporting countries with public finances highly dependent on oil income. They analyze the policies, strategic planning, intersectional coordination, and political interactions and show how the adoption of contradictory objectives makes the mix of sectorial policies inconsistent. In this way, the government cannot precisely coordinate the decarbonization policy, which allows the persistence of the hegemony of oil interest groups that, eventually, leads to the persistence of dependence on oil. Ferreira Abrão discusses how and to what extent the discovery of enormous marine resources in the ultra-deep waters of its southeast coast, so-called *Pré-salt,* would be affecting the energy transition in Brazil, and how, in the current climate crisis context, the hydrocarbon-producing countries are the "losers" of the current transition to renewable energy sources. Finally, Pérez Roig examines a central aspect of transitions at the local level from the case of the provinces of Neuquén and Río Negro in Argentine Patagonia, two regions from which hydrocarbons are extracted. The study highlights the continuous historical configuration of these regions as oil enclaves, while allowing an understanding of the reconfiguration of the pre-existing socio-environmental trends and impacts.

In Part III, Serrani presents the case of the transition in Argentina, as an alternative way of financing the energy transition, seeking to transform the income from natural resources into a factor that makes it possible to expand renewable energies, contemplating industrial policy, local value addition, and genuine employment generation. In this sense, they wonder what kinds of transition peripheral, semi-technologically dependent countries can carry out, with a scarcity of access to "cheap" financing for infrastructure projects. Bertoni and Messina examine the successful case of energy transition in Uruguay, which, wind energy together with other low-emission generation sources, accounts for almost all the country's electricity. Reina Bermúdez presents the case of Colombia, which is carrying out a transition with the intention of maintaining a liberalized market as competitive as possible, while complementing it with gas as an intermediate step. Several territorial projects are being financed through debt bonds (green bonds and sustainable bonds), issued by the private sector to support entrepreneurs in their decisions to become prosumers of renewable energies.

In relation to the impacts of the energy transition at the subnational level, Canafoglia emphasizes the need to review the idea that transitions are a relevant opportunity for the development of industrial capacities at the subnational level in the countries, not only to transform energy mix but also to boost local economies and employment. The chapter by Schirmer Soares identifies relevant factors that influence the diffusion of distributed solar energy in Brazil, by studying the case of Holambra, a city in the Macrometropolis region of Sao Paulo, which was considered an optimal case for photovoltaic diffusion. The study emphasizes the idea that to move toward a democratization of access to distributed renewable energy, falling costs are a central factor in the decision making of adopters of this technology. Finally, the part closes with the chapter by Grangeia that discusses the Brazilian government plans, the political orientations in the biofuel agenda, and electric mobility to understand the current state of energy and transport planning in the country. In this way, they conclude that the transition to electric mobility in Brazil is still taking place slowly, mainly due to the prominence and advances of the technological path of biofuels.

In Part IV, Kazimierski discusses the shift toward decentralized energy generation in Argentina, Chile, and Uruguay and raises questions about the impact of decentralization on the concentration of generation and the role of public-social experiences in the energy sector. Another chapter by Soares, Chap. 18, in this book addresses energy poverty in Brazil and the relationship between poverty and access to energy. By analyzing the dimensions of vulnerability through a three-level that focuses on chronic, recent, and inertial poverty, the study demonstrates that energy poverty affects the vulnerable population differently with respect to their energy experiences. Mondol-Lenin presents the study on energy inequality in Central American countries such as Costa Rica, Nicaragua, Honduras, El Salvador, and Guatemala, and how Central American governments continue to use price and income inequality approaches to address the energy vulnerability, historically segregated from access to modern energy for consumption. Finally, Collaço makes a literature review on energy planning studies, and by discussing the Nicaragua energy transition, it provides insights to reduce the trade-offs and to promote the synergies that exist between planning energy systems and sustainable development achievement.

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Annex: Government Revenues from Non-renewable Natural Resources as a Percentage of GDP

Country	Non-renewable natural resources	1990	2000	2010	2015	2016	2017	2018	2019	2020	Average 2015–2020
Latin America and the Caribbean	Total		8.9	16.9	10.9	6.3	7.4	9.6	10.3	7.3	8.6
	Upstream		8.1	14.4	9.9	5.5	6.4	8.4	9.2	6.3	7.6
	Mining		0.8	2.4	0.9	0.8	1.0	1.2	1.2	1.0	1.0
Argentina	Total	3.8	3.8	6.0	4.1	3.4	3.4	1.8	2.0	1.5	2.7
	Downstream	2.9	2.3	1.8	1.9	1.8	1.9				1.9
	Upstream	0.9	1.5	3.8	2.0	1.4	1.3	1.6	1.7	1.3	1.6
	Mining		0.0	0.3	0.2	0.1	0.1	0.2	0.3	0.2	0.2
Bolivia	Total	23.5	13.8	31.0	31.4	18.6	16.7	16.3	15.3	12.7	18.5
	Downstream	2.0	5.6	4.3	2.8	3.0	2.5				2.8
	Upstream	21.1	7.9	23.5	27.1	13.2	12.0	13.7	11.8	11.4	14.9
	Mining	0.3	0.3	3.2	1.5	2.4	2.3	2.5	3.4	1.3	2.2
Brazil	Total		4.2	4.6	3.2	2.8	3.2	3.8	6.1	2.7	3.7
	Downstream		2.5	1.8	1.7	1.7	1.7				1.7
	Upstream		1.7	2.2	1.3	0.9	1.3	3.5	5.6	2.0	2.4
	Mining		0.0	0.6	0.2	0.2	0.2	0.3	0.6	0.7	0.4
Chile	Total	13.7	3.7	13.4	3.9	1.2	2.9	4.3	4.0	3.7	3.3
	Mining	13.7	3.7	13.4	3.9	1.2	2.9	4.3	4.0	3.7	3.3
Colombia	Total	3.3	7.7	9.3	6.3	4.1	4.6	6.7	7.4	4.3	5.6
	Downstream	0.0	0.8	0.5	0.8	0.8	0.4				0.7
	Upstream	3.2	6.5	7.6	4.6	2.5	3.0	5.4	6.6	3.6	4.3
	Mining	0.1	0.4	1.2	0.9	0.9	1.2	1.3	0.8	0.6	1.0
Ecuador	Total	25.1	21.1	33.9	20.1	18.3	23.8	30.8	28.0	17.7	23.1
	Downstream	0.0	0.0	0.0	0.0	0.0	0.0				0.0
	Upstream	25.1	21.1	33.8	20.0	18.1	23.6	30.5	27.7	17.4	22.9
	Mining			0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.2
Guatemala	Total		0.8	0.8	0.5	0.4	0.3	0.3	0.2	0.1	0.3
	Upstream		0.8	0.6	0.2	0.1	0.1	0.2	0.1	0.1	0.1
	Mining		0.0	0.2	0.3	0.3	0.2	0.0	0.0	0.1	0.2
Guyana	Total									10.9	10.9
	Upstream									10.9	10.9
Jamaica	Total	6.6	2.5	0.4	0.5	0.4	0.1	0.1	0.1	0.1	0.2
	Mining	6.6	2.5	0.4	0.5	0.4	0.1	0.1	0.1	0.1	0.2

Country	Non-renewable natural resources	1990	2000	2010	2015	2016	2017	2018	2019	2020	Average 2015–2020
Mexico	Total	10.8	11.8	14.0	9.7	7.9	8.6	7.7	5.9	3.2	7.2
	Downstream	1.3	2.0	−0.8	2.4	2.8	2.0				2.4
	Upstream	9.5	9.8	14.4	6.8	4.7	6.0	7.0	5.4	2.7	5.4
	Mining		0.0	0.4	0.6	0.5	0.6	0.7	0.5	0.6	0.6
Perú	Total	6.0	4.6	9.3	3.8	3.0	4.5	4.9	3.5	2.8	3.7
	Total	5.7	2.5	1.2	0.7	0.8	0.9				0.8
	Downstream	0.3	1.7	3.4	1.8	1.2	1.6	2.1	1.5	1.1	1.6
	Upstream		0.4	4.7	1.3	1.0	2.0	2.8	2.0	1.7	1.8
Dominican Republic	Total				1.0	1.1	1.2	0.6	0.7	1.5	1.0
	Mining				1.0	1.1	1.2	0.6	0.7	1.5	1.0
Trinidad & Tobago	Total		21.6	40.5	25.8	7.6	8.4	11.7	22.2	12.3	14.7
	Upstream		21.6	40.5	25.8	7.6	8.4	11.7	22.2	12.3	14.7
Venezuela	Total	39.1	21.3	15.8	22.4	20.4					21.4
	Downstream	0.5	1.2	0.3	0.2	0.0					0.1
	Upstream	38.6	20.1	15.5	22.2	20.4					21.3

Source: ECLAC Statistics Division. Available in: https://statistics.cepal.org/portal/cepalstat/dashboard.html?theme=2&lang=es

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Part I

Energy, Climate Change and Sustainable Models: Energy Mix and National Decarbonization Plans

2 Energy Transition and Climate Justice After Paris Agreement: Achievements and New Goals in South America

Ignacio Mariano Sabbatella

2.1 Introduction

One of the challenges of decarbonizing the global economy in light of the climate crisis is the transition of electricity generation to low-carbon sources.[1] In terms of climate justice, the mitigation efforts of the global North should be greater than those of the global South. In this sense, some regions of the global South, such as South America, present the particularity of not only having a low level of historical incidence of greenhouse gas emissions (GHG) in terms of emissions from the energy sector but also a high degree of vulnerability to their impacts.

In a previous work (Santos & Sabbatella, 2020), the first round of Nationally Determined Contributions (NDCs) submitted by each country of the region to the United Nations Framework Convention on Climate Change (UNFCCC) after the Paris Agreement in 2015 was analyzed, and the existence of a wide variety of targets for the incorporation of renewable energies, different reference years, and conceptual definitions were observed. It was concluded that a process of diversification of energy sources was underway rather than a real process of energy transition. After the first 5-year period following the conclusion of the Paris Agreement, a good number of countries have presented their second NDC or an update of the first, seeking greater ambition in the decarbonization targets previously presented. At the same time, the countries of the region are facing, in different degrees, economic, financial, social, and political difficulties, which have been aggravated by the COVID-19 pandemic and in many cases are preventing them from achieving the climate targets they have committed to.

In this context, it is appropriate to ask some questions: To what extent has the decarbonization of electricity generation in South America progressed after the Paris Agreement compared to other regions? To what extent compared to the targets set in the first round of NDCs of the countries of the region? Does the second round of NDCs present more ambitious targets for the electricity sub-sector? What is their scope compared to the targets set by the countries with the highest GHG emissions?

Therefore, the objective of the chapter is to analyze the evolution of the decarbonization process of electricity generation in South America after the Paris Agreement in terms of climate justice. The hypothesis is that the region as a whole has progressed faster in the energy transition toward low-carbon sources with respect to other

[1] Low-carbon energy sources are the sum of nuclear energy and renewables – which includes hydropower, wind, solar, bioenergy, geothermal, and wave and tidal. This chapter also refers to them as clean or non-fossil energies.

I. M. Sabbatella (✉)
Facultad Latinoamericana de Ciencias Sociales (FLACSO) – Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina
e-mail: isabbatella@flacso.org.ar

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regions with higher sectoral emissions both historically and presently.

The gathering and analysis techniques are based on documentary research (Valles, 1999), using two types of secondary sources of information: on the one hand, quantitative data on installed power, electricity generation, and sectoral emissions obtained from the International Energy Agency (IEA), the Latin American Energy Organization (OLADE), BP company, and the Climate Watch portal; on the other hand, qualitative data from the NDCs that were submitted by each of the countries to the UNFCCC.

The chapter is divided into four sections. The first one presents a conceptual approach to climate justice and its implications for the energy transition. The second section presents the main statistics on the region's global position in terms of GHG emissions, energy consumption, and generation. The third section examines the incorporation of low-carbon energy sources after the Paris Agreement. In the fourth section, the NDCs of the South American countries and the main global emitters are analyzed comparatively in order to examine the degree of ambition of the proposed sectoral targets, the degree of compliance, and the obstacles or needs that are explicitly stated in order to achieve them. Finally, the conclusions bring together and synthesize the main findings of the chapter.

2.2 Energy Transition and Climate Justice

The conceptual framework on which this research is based recognizes different academic approaches in order to understand what a fair energy transition is in climatic terms and what implications it has for developing countries, like some in South America.

Generally, an energy transition is defined as a structural change in the system of energy supply and use (Carrizo et al., 2016). The particularity is that, unlike other energy transitions that arose as a consequence of the emergence of new technologies and/or resource discoveries, the current one is a purposive transition founded on the need to decrease GHG emissions (Kern & Markard, 2016). In other words, the ongoing climate crisis drives the shift away from fossil fuels toward greater use of non-fossil energies. However, the transition is not a homogeneous process but rather an uneven one, as far as climate change recognizes both differentiated responsibilities and heterogeneous impacts, in addition to dissimilar mitigation and adaptation capacities according to the degree of economic and social development of each country or region.

The principle of common but differentiated responsibilities has been in force since the formation of the UNFCCC, although it is not always properly applied at international climate summits. When global emissions are measured in the present, China topped the list in 2018 with 24% of the total as a result of the vertiginous development of the last decades, followed by the United States with 12% and then India with 7% (Climate Watch, 2022). On the other hand, in historical terms, the responsibilities change: in the accumulated emissions of the period 1850–2015, the United States is in first place with 28%, closely followed by the European Union with 25% (Hickel, 2020). The countries of the global North are responsible for 92% of the climate breakdown and are therefore climate debtors, while those of the global South are only responsible for 8% and are climate creditors. So there is a process of atmospheric colonization: a small number of high-income countries have appropriated substantially more than their fair share of the atmospheric commons (Hickel, 2020).

At the same time, impacts do not have the same intensity across the globe: Latin America is one of the most vulnerable regions due to its geographical, climatic, socioeconomic, and demographic characteristics (Bárcena et al., 2020). In this framework, it is pertinent to introduce just transition studies to understand the concept of climate justice. They are built on three areas of research: climate justice, energy justice, and environmental justice. Climate justice refers to sharing the benefits and burdens of climate change from a human rights perspective; energy justice refers to the application of human rights throughout the energy life cycle (from cradle to grave); and environmental justice aims to treat all citizens equally and involve them in the development, implementation, and enforcement of environmental laws, regulations, and policies (Heffronb & McCauley, 2018). Therefore, just transition is defined as "a fair and equitable process of moving towards a post-carbon society" (McCauley & Heffronb, 2018: 2). By its very nature, this transition must take place on a global scale, while effectively connecting with multiscale realities. It involves the development of principles, tools, and agreements that ensure a just and equitable transition for all people and communities.

Among the studies on fair and sustainable transition in Latin America and the Caribbean, it is possible to find the works of Garrido (2020) and Rivera Albarracín (2019, 2020). They expose critically the process of adoption of technologies and implementation of policies replicated from developed countries, when there should be a process of adaptation at the local level. A change in the generation matrix is necessary, but insufficient. So, public policies are needed to modify the energy system taking into account: sectoral conflicts, geopolitical alliances, business strategies, regulatory systems, and cultural patterns of consumption (Garrido, 2020). Rivera Albarracín (2020) highlights as main issues in the academic literature the problems of technology transfer, the need to reverse North-South asymmetries, the vindication of ancestral knowledge, the limitation of deforestation processes linked to monocultures, and the articulation of the demands of workers, indigenous people, peasants, and environmentalists; while in social movements, fair transition is understood under a transformative approach, as a tool that seeks to modify the political economy to advance the aspirations of sustainable development in the region. The author concludes that the concept of fair transition can mediate between development aspirations in the region and the need for climate change mitigation, but without leaving behind the countries most dependent on income from the production and export of fossil fuels. At the same time, directing greater amounts of public and private investment toward the development of renewable energies, seeking a multiplier effect in the economy: technology development, generation of quality employment, and sustainable infrastructure (Rivera Albarracín, 2019).

On the other hand, the literature on sustainable transitions in developing countries warns about the structural problems that place them at a different starting point than developed countries and, therefore, transitions in the former should be analyzed, managed, and supported with a higher level of critical reflection. In this regard, studies on the subject point out that developing countries tend to be characterized by less advanced industrial processes, dominance of low-technology (primary) sectors, dependence on extended family ties and clientelism, and employment in the informal sector. Therefore, they recognize dependence on technology, knowledge, and financial resources from developed countries (Hansen et al., 2018).

In this research, the geographical cutout was made on South America, a subcontinent made up of 12 countries: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, and Venezuela. If the 12 countries are taken as a whole, it has a volume of renewable and non-renewable energy resources that allow it to be characterized as a self-sufficient and even exporting region (UNASUR-OLADE, 2013). There are countries that are major exporters of crude oil, such as Venezuela, Brazil, Colombia, and Ecuador, but as will be analyzed in the following section, it has a predominantly hydraulic electricity matrix, in addition to a slow but persistent penetration of natural gas (Sabbatella, 2018; Sabbatella & Santos, 2019). Regional distribution of energy resources determines that some countries are exporters and others importers, which may help energy integration in order to optimize energy complementarity and security of supply (Corporación Andina de Fomento, 2013); balancing higher levels of variable renewable energies, which would help to have a more efficient system and the possibility of developing an electricity market at the regional level (Levy et al., 2021); and adopting a regional approach to take advantage of the economies of scale of renewable energies and strengthen the development of value chains (Di Sbroiavacca et al., 2019).

South America has a long history of integration and energy cooperation. However, it is going through a crisis of regionalism that has led to the paralysis of regional organizations such as the Southern Common Market (Mercosur) and the Andean Community (CAN), and even to the dismantling of others such as the South American Energy Council (CES), under the orbit of the Union of South American Nations (UNASUR) (Sabbatella, 2018; Sabbatella & Santos, 2019; Santos & Sabbatella, 2020; Guerrero, 2021). In this framework, the countries of the region have opted for national strategies to incorporate renewable energy sources to the detriment of a regional cooperation and integration strategy (Bersalli et al., 2018; Carrizo & Velut, 2018).

The proposed conceptual framework will make it possible to assess the evolution of the South American electricity sector from a climate justice perspective. In this way, the focus will be placed on the existing inequalities in terms of responsibilities, impacts, and sectoral response capacities for a region of the world that is a climate creditor and, at the same time, has economic, financial, technological, and institutional limitations to carry out an energy transition process.

2.3 Sectorial Emissions

This section prioritizes the comparison of South America with other regions of the world, although it should be clarified that all regionalization involves a geographical bias. In this case, the regions grouped by the Climate Watch platform were taken into consideration: East Asia and Pacific,[2] North America,[3] South Asia,[4] European Union – 27 countries (EU-27),[5] and Middle East and North Africa.[6] According to 2018 data, South America as a whole accounts for 6.1% of global GHG emissions, just below the share of the EU-27 and Middle East and North Africa, but far from East Asia and Pacific, which accounts for 36.8%, and it is followed by North America with 13.4% and South Asia with 8.6% (Climate Watch, 2022). The particularity of South America lies in the fact that its emissions structure is not totally dominated by the energy sector, as is the case in the rest of the world: only 37.4% of its emissions come from energy, since both agriculture and land-use change and forestry have a high incidence in national GHG inventories and together account for almost 54% of regional emissions. In contrast, 76.1% of global emissions belong to the energy sector and this average is far exceeded by all regions except South Asia (Fig. 2.1).

The low relative participation of the energy sector in South American emissions can be understood in two ways. On the one hand, the strong weight of agricultural and livestock activities in the region's economic structure, which expansion has repercussions on emissions linked to the loss of forest area that absorbs carbon dioxide. On the other hand, the region's primary energy consumption is cleaner than in other parts of the world: over the last 50 years, the proportion of low-carbon sources in the world average has remained constant at around 17%, while in South America it has increased by 13.1 percentage points (p.p.) to 38.6%. It should also be noted that coal,[7] the most polluting of fossil fuels, continues to be the second most polluting source in the world, with a marginal share in the region.

[2]Composed of China, Indonesia, Japan, South Korea, Australia, Thailand, Malaysia, Vietnam, Philippines, Myanmar, New Zealand, Cambodia, Singapore, Papua New Guinea, Mongolia, Solomon Islands, North Korea, Laos, Brunei, Timor-Leste, Vanuatu, Samoa, Tonga, Palau, Fiji, Marshall Islands, Kiribati, Cook Islands, Nauru, Tuvalu, and Niue.

[3]United States and Canada.

[4]Composed of India, Pakistan, Bangladesh, Afghanistan, Nepal, Sri Lanka, Maldives, and Bhutan.

[5]Composed of Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

[6]Composed of Iran, Saudi Arabia, Egypt, United Arab Emirates, Algeria, Iraq, Kuwait, Libya, Qatar, Morocco, Israel, Oman, Bahrain, Syria, Tunisia, Jordan, Lebanon, Yemen, Malta, and Djibouti.

[7]Coal emits 879 grams of CO_2 equivalent per kWh, higher than the emission of oil (713 gCO_2/kWh) and more than twice as much as natural gas (391 gCO_2/kWh) (Foster & Bedrosyan, 2014).

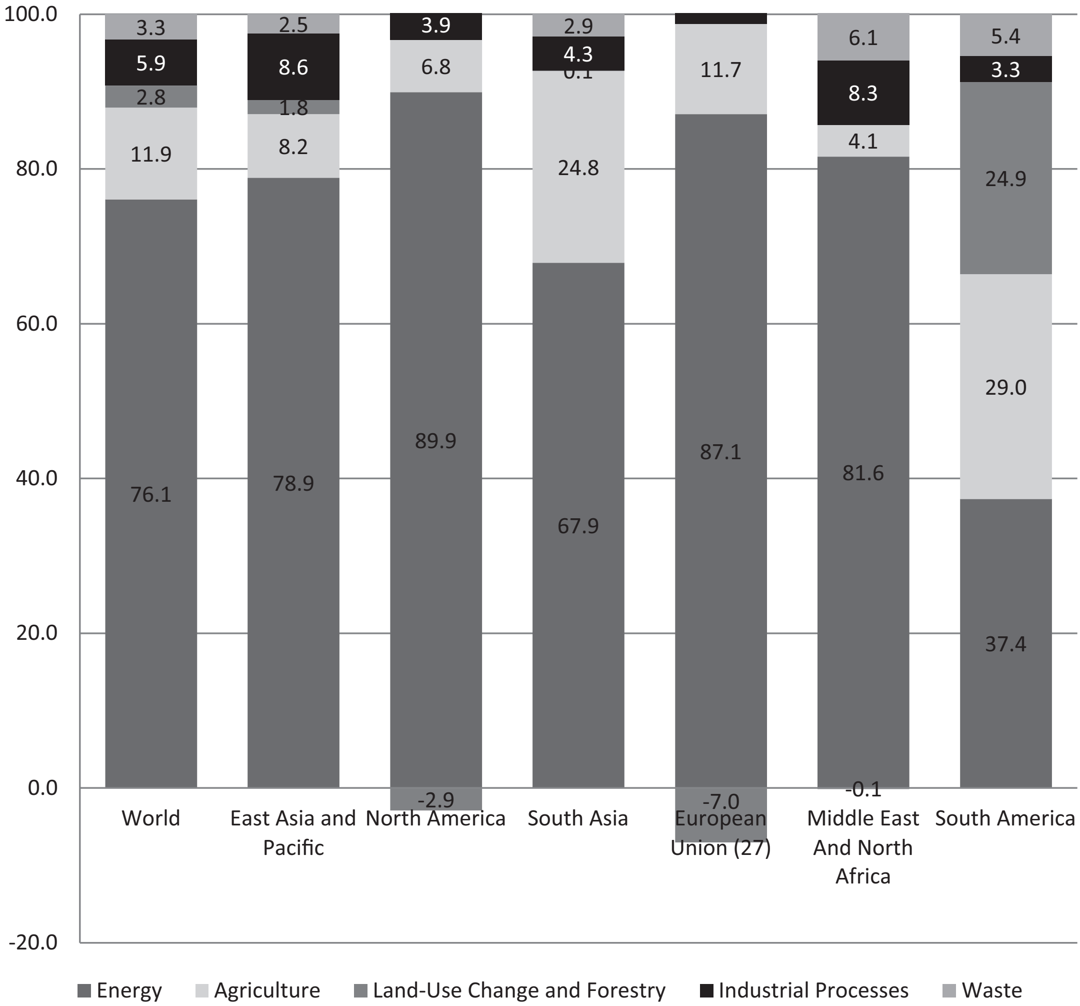

Fig. 2.1 Emissions by sector 2018 (%). (Source: Own elaboration based on Climate Watch data)

Finally, in both cases, the share of natural gas has increased to the detriment of oil, taking into account that the former is less polluting than the latter (Fig. 2.2).

Electricity generation corresponds, in part, to the primary energy mix. According to OLADE and BP data from 2020, electricity generation in the region as a whole has a share of clean sources of over 75%, although national disparities will be analyzed in the next section, while in the world average it does not reach 39% and, on the contrary, coal is the first source with 35%. This explains, in part, that South America's contribution to emissions from the electricity/heat subsector is just 1.9% of the global total in 2018, and, at the other extreme, East Asia and Pacific, which intensively consume coal to produce electricity, report 45.6% of the total, some 7 p.p. higher than in 2010. While North America contributes 14.8% of the total (5 p.p. less than in 2010), South Asia 8.7%, EU-27 7.1% (2 p.p. less than in 2010), Middle East and North Africa 2.4% (Climate Watch, 2022). However, a correct comparative analysis between regions requires incorporating demographic and economic variables, in other words, the level of emissions according to the amount of population and the efficiency of their productive activities. In per capita terms, sub-sec-

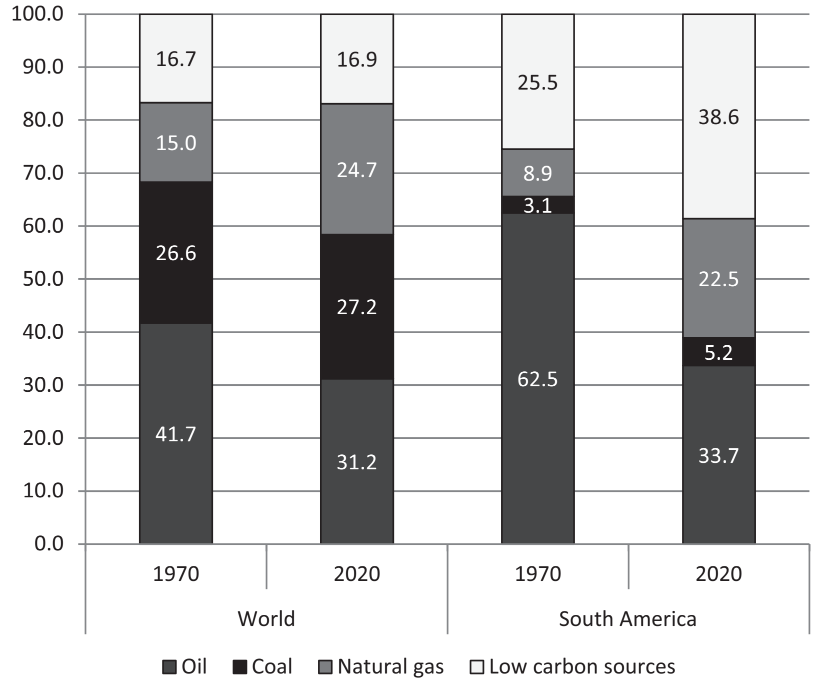

Fig. 2.2 Primary energy consumption 1970–2020. (Source: Own elaboration based on BP and OLADE data)

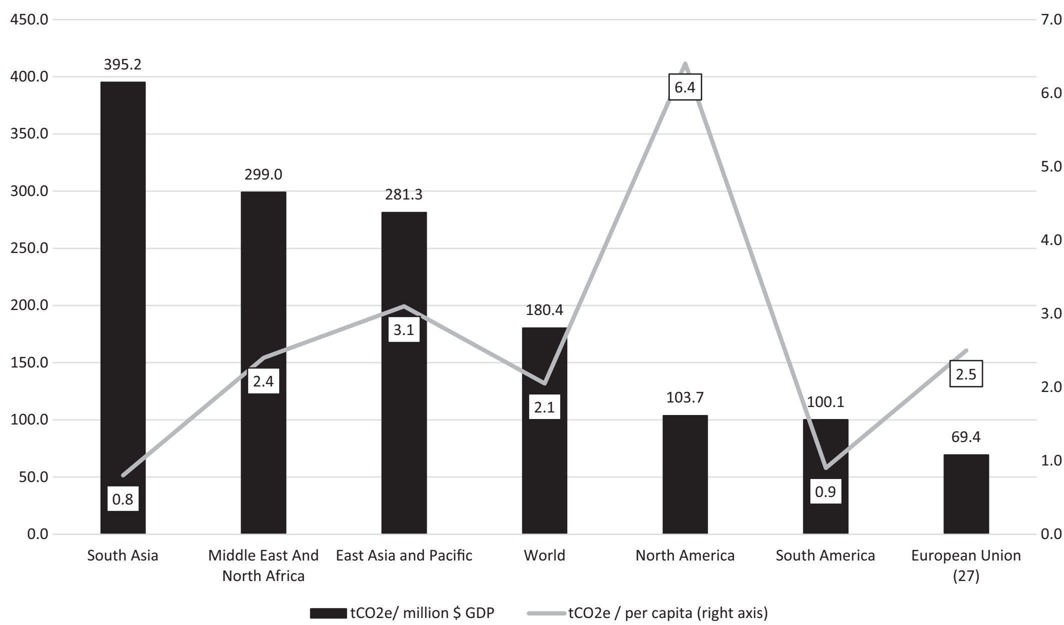

Fig. 2.3 Electricity/heat emissions (2018). (Source: Own elaboration based on Climate Watch Data)

tor emissions in South America are the lowest along with South Asia, while those of North America are the highest. When measured by gross domestic product (GDP), South American emissions are the second lowest, surpassed only by the EU-27, while those of South Asia are the highest, followed by Middle East and North Africa (Climate Watch, 2022) (Fig. 2.3).

From the above, it can be understood that the share of emissions from the electricity/heat subsector in the regional total is very high in the case of East Asia and Pacific (39.5%). A somewhat lower, but also important, share is observed in the regions of North America (35.3%), South Asia (32%), EU-27 (33.3%) and Middle East and North Africa (32%). In South America, on the other hand, the subsector represents only 10% of the regional emissions structure.

At the end of this section, South America's low contribution to GHG emissions in absolute terms, per capita, and per GDP can be seen. Even more evident is the low contribution of South American electricity generation to global and regional emissions. With this partial analysis, the next section examines the electricity mix and NDCs of the countries in the region.

2.4 Decarbonization After the Paris Agreement

In order to evaluate performance at the national level, the evolution of certain variables between 2015 and 2020 will be taken into account, the latter year being marked by the COVID-19 pandemic and its influence on the energy sector.[8] As shown in the previous section, the region has a clean electricity generation mix compared to the world average, mainly from hydropower, although it is also necessary to detail the situation of each country before analyzing the NDCs. At one extreme is Paraguay, which is self-sufficient in 100% clean electricity thanks to the binational hydroelectric power plants Itaipú (shared with Brazil) and Yacyretá (shared with Argentina). Uruguay also has practically clean generation in its entirety and its share remained at around 93–94% in the period, despite lower hydroelectric generation, as it will be seen below. At the other extreme, Guyana, one of the poorest countries in the region, has just 3.2% of renewable generation in 2020 and even lower compared to 2015. Suriname also lost share of clean sources (−2.1 p.p.), but they reach almost half of total generation (47%).

In the study period, it is notable that 80% of the additional installed power came from low-carbon sources, when in the previous 5-year period (2010–2015) it had been 65%. The increase in investments aimed at this type of sources is evident and, in the disaggregate, the source that has increased its installed capacity the most is solar (+1563%) by Brazil, Argentina, Bolivia, Chile, Uruguay and Perú in that order; followed distantly by wind (+145%) by Argentina, Bolivia, Chile, Brazil, Uruguay and Perú in that order; and hydroelectric with a modest growth (+15%) (OLADE, 2022).

Among the countries that have increased the most its share of low-carbon sources are Ecuador (+27.2 p.p.) and Venezuela (+22.6 p.p.), although this case presents a curiosity: total electricity generation collapsed 41% due to the energy crisis the country is going through (Pietrosemoli & Rodríguez-Monroy, 2019) and, in that framework, hydroelectric generation gained more share in relative terms with respect to thermal power plants. Perú, Brazil, Chile, Bolivia, and Colombia also increased the share of clean generation (+12.9, +9.8, +7, +5.6, and +5.2 p.p., respectively). On the other hand, the increase in Argentina was insignificant (1.1 p.p.), due to a lower hydroelectric generation that could be matched by the start-up of several wind and solar projects (Compañía Administradora del Mercado Mayorista Eléctrico, 2022).

A possible comparison of the performance of the countries in the region is to take the six top emitters in the energy sector: China, United States, EU-27, India, Russia, and Japan, which together account for approximately 66% of sectoral emissions both in 2018 and in the accumulated sectoral emissions in the period 1990–2018.

[8]Electricity demand dropped quickly across Europe and India with confinement measures but steadily recovered as measures were gradually softened. The end of the year was marked by a recovery of electricity demand, above 2019 levels after weather adjustment. Across all major regions, the power mix has shifted toward renewables following lockdown measures due to depressed electricity demand, low operating costs, and priority access to the grid through regulations. Electricity demand and mix went back to previous trends with lockdown relaxation (IEA, 2021).

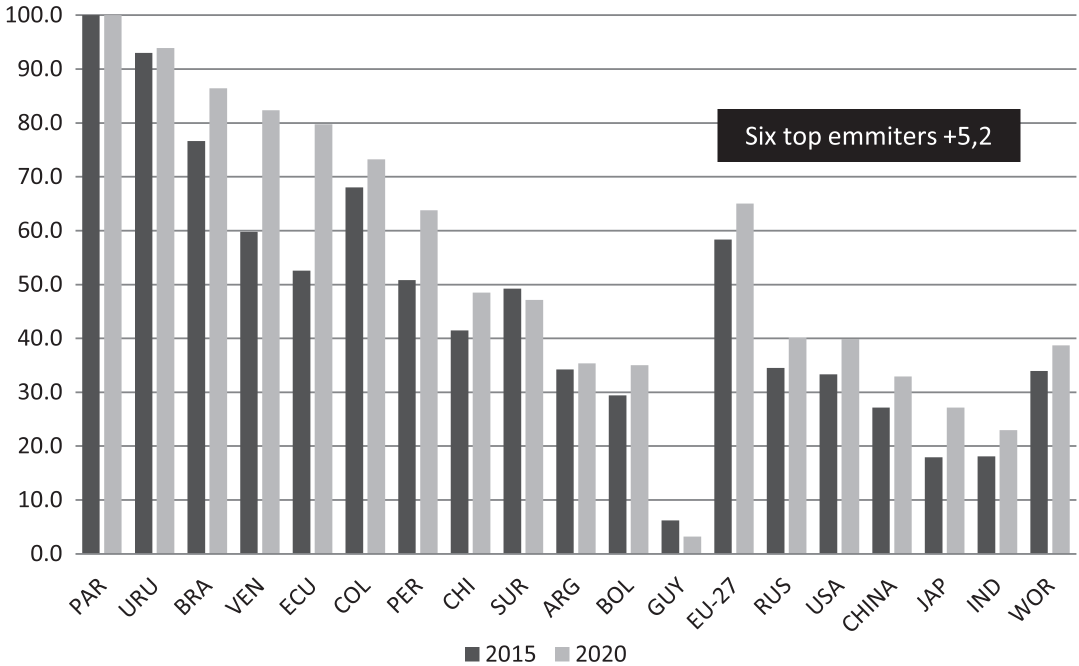

Fig. 2.4 Share of low-carbon sources in electricity generation. (Source: Own elaboration based on OLADE, BP, and IEA data)

According to data from BP (2022) and IEA (2022), the sum of China, USA, EU-27, India, Japan, and Russia results in a 38.5% contribution of low-carbon sources in total generation in 2020, in line with the world average, although with the outstanding case of EU-27 reaching 65% and a low contribution of India with 23%. In the period 2015–2020, all of them have increased the share of clean energy, but at a lower rate than some South American countries: from highest to lowest, Japan (+9.2 p.p.), EU-27 (+6.7 p.p.), USA (+6.5 p.p.), China (+5.8 p.p.), Russia (+5.6 p.p.), and India (+4.9 p.p.).

In short, South America as a whole has increased the share of low-carbon sources by 9.6 p.p., while the six top emitters as a whole have only increased their share by 5.2 p.p. (Fig. 2.4). Two warnings should be made: seven countries in the region started 2015 with a clean share above 50%, while among the main emitters, only the EU was above. In other words, the comparison floor between one group of countries and the other was very unequal and, even so, South America added more clean generation at the end of the 5-year period. In this sense, the unequal performance at the national level should also be noted. The second warning is that clean generation in the region is conditioned by climatic factors: the decrease in rainfall affected the flow of certain river basins and, thus, disadvantaged hydroelectric production. Previously, it was mentioned that the total installed capacity of hydropower in the region grew 15%, but generation only increased by 1.9% between 2015 and 2020 (OLADE, 2022). Among the countries that have expanded the most their hydroelectric capacity, it is possible to find Ecuador (+111%), Bolivia and Perú (both +53%), and Brazil (+19%), with a consequent increase in the generation of that source in each case. On the other hand, hydroelectric production in the same period fell sharply in Uruguay (−50%), Argentina (−42%), Venezuela (−18%), Paraguay (−17%), and Chile (−14%). The cause of the lower hydraulicity is due to an extensive drought in the region, attributable to climate change (Bárcena et al., 2020; WMO, 2021; IPCC, 2022), which has been partly compensated by other renewable sources, mainly wind and solar. A study of five river basins (Sao Francisco, Tocantins, Parnaiba, Parana, and Uruguay basins) indicates that the observed hydropower potential for the period 2014–2019 was 25% lower than the 1961–1990 reference potential, mainly due to drought conditions, and that rainfall and runoff projections for the coming decades warn that such losses in hydropower potential will be more frequent and more severe in the tropical and semi-arid river basins of South America (De Jong et al., 2021). A complementary examination of hydropower impacts in some countries can be made through the NDCs.

2.5 Goals and Progress of the NDCs

Only two countries in the region submitted their second contribution (Argentina and Suriname), while six countries updated their first (Brazil, Chile, Colombia, Paraguay, Perú, and Venezuela) and four did not submit new documents (Bolivia, Ecuador, Guyana, and Uruguay). Within this framework, only three countries updated or incorporated targets for the decarbonization of electricity: Chile, which announced the abandonment of coal by 2040 at the latest and the replacement of thermal power plants by renewable generation according to different scenarios; Suriname, which increased the share of renewable generation from 25% conditionally in 2025 to 35% unconditionally in 2030; and Venezuela, which had not previously set targets for itself but, in the latest update, quantified the incorporation of wind energy.

Regarding the fulfillment of the goals established in the previous NDC or in the new one, it is contrasted with OLADE data (2022). It can be seen that Argentina is far from reaching 25% renewable generation in 2025, since in 2020 the sources specified in Law 27.191 did not exceed 9%. Bolivia has made progress in the incorporation of renewable sources but is still halfway to the 2030 target: clean generation reached 35%, with alternative energies accounting for 5.7% in 2020. Brazil is close to meeting its goal set out in the first document, which established a 23% share of renewable generation other than hydroelectric. The 2020 data show that this share has reached 20.4%. Chile has complied early with the goal established by law to reach 20% of non-conventional renewable energies (NCRE) in 2025, since NCRE represented 21.9% of generation in 2020. However, the Chilean mix is still highly dependent on coal despite the fact that its share dropped from 37% to 31% of the total between 2015 and 2020 (IEA, 2022); for that reason, the new NDC sets as a target the abandonment of this source in the next two decades. In case of Colombia, the NDCs do not establish quantitative goals and only refer to the high hydroelectric participation that the country already has and the need to diversify generation sources. In another official document that presents an energy transition plan, wind, solar, and biomass are mentioned as sources of such diversification (Ministerio de Minas y Energía, 2021). Ecuador has not presented goals so far and has only expressed its intention to promote different clean sources; however, in the period under study, efforts were concentrated solely on hydroelectric energy, which doubled its installed capacity (OLADE, 2022). This allowed Ecuador to sell surpluses to Colombia and Peru and thus become a net exporter of electricity since 2016, reaching in 2019 and 2020 the historical maximum of energy exports (Ministerio de Energía y Recursos Naturales No Renovables, 2021). In the case of Guyana, its setback in clean generation has already been analyzed, although in its first NDC it was proposed as a conditional goal to reach a 100% renewable mix subject to the existence of financial support. Paraguay, thanks to its extraordinary hydroelectric power shared at the binational level and an economy with relatively low energy demand, produces totally clean electricity and has no diversification goals. Perú has not set goals and, even so, in the 5-year period studied it has increased clean generation, mainly hydroelectric and, to a lesser extent, wind and solar (OLADE, 2022). In the case of Suriname, the existence of targets that were expanded between the first and second NDC has also been mentioned, but it is not made clear whether these are renewable sources that include hydroelectricity or not: counting this source, clean generation rises to 47% and thus meets the targets set. On the other hand, if only renewable energies other than hydroelectricity are counted, they barely add up to 0.5% and, therefore, the country is very far from meeting its own targets. Uruguay, for its part, was the only country to set absolute targets and power percentage for installed capacity in its first and only NDC: in 2020 it had already reached the wind, solar, and biomass capacity projected for 5 years ahead, although in relative terms wind energy still had a share below 31% when it should reach 32%. In any case, it should be noted that renewable energies as a whole, without taking into account hydroelectric power which remained with a 31% share, increased their share by 17 p.p. in only 5 years: 27% in 2015 and 44% in 2020 (OLADE, 2022). Finally, Venezuela proposed in its latest NDC a modest target for the annual incorporation of wind energy, starting with 50 MW of installed capacity in 2020 (OLADE, 2022) (Table 2.1).

Finally, there are still some issues to highlight from the South American NDCs. Regarding the sources, four countries (Argentina, Ecuador, Peru, and Venezuela) explicitly mention the use of natural gas as a way to reduce emissions, mainly as a substitute for liquid fuels in thermal power plants, and one of them also mentions nuclear energy (Argentina). Concerning the obstacles in the process of decarbonization of electricity generation, there are few explicit mentions, but they are not less important for that reason. Argentina mentions the need for capacity building, technology transfer, and financing, and Guyana, financial support. Finally, three countries (Argentina, Uruguay, and Venezuela) crystallize the growing climate vulnerability of hydroelectric generation, a problem which, as we have seen, extends to a large part of the region and which must be addressed with greater urgency in the coming years.

With respect to the first six emitting countries, not all have submitted new documents: Japan and the EU-27 updated their first NDCs, the United States submitted its first NDC after rejoining the Paris Agreement, and, on the other hand, China, India, and Russia have not renewed their first NDCs.

After leaving behind the interregnum of Donald Trump's administration in which it had decided to exit the Paris Agreement, the United States resubmitted its NDC in 2021 and there it was set a goal of achieving 100% carbon-free electricity generation by 2035. In 2020, its generation was still highly dependent on fossil fuels, but it is worth noting, on the one hand, an 83% increase in renewable sources and, on the other hand, a sharp drop in coal consumption (−42%) offset, in part, by an increased use of natural gas (+22%) (BP, 2022). The EU-27 is one of the Parties to the UNFCCC that has most insisted on energy decarbonization and has increased its ambition on several occasions. In 2020, the share of gross final energy consumption from renewable sources reached 22%, 2 percentage points above the target level, as included in Directive 2009/28/EC (Eurostat, 2022). In the update of the first NDC, presented in 2020, the EU-27 did not set a particular target for electricity generation, but did aim to reach 32% of renewable energy in final energy consumption by 2030, which would represent almost double the 2017 levels. In that sense, by 2020 renewable generation had increased by 75% compared to 2015, while coal had been reduced by 50% and liquid fuels by 32%. It is also worth mentioning the 40% increase in natural gas consumption in electricity generation (BP, 2022). The new European climate taxonomy has incorporated not only natural gas but also nuclear energy on a transitional basis to achieve climate neutrality by 2050 (European Commission, 2022). For its part, Japan set as a target in its first updated NDC to reduce energy-related CO_2 emissions by 45% by 2030 compared to 2013, but does not provide any details other than the intention to introduce more renewable energy. Along those lines, renewable generation grew 104% in 2020 compared to 2015, although more important was the increase in nuclear generation with 311%, a remarkable recovery of the sector after the Fukushima accident in 2011 (Nippon, 2021). In parallel, both coal (−11.3%) and liquid fuels (−47%) and natural gas (−8.3%) decreased (BP, 2022; IEA, 2022).

Table 2.1 Goals, sources, and obstacles for decarbonization of the electricity sub-sector in the NDCs of South American countries

Country	Previous NDC		Last NDC	
	Submission date	Goals, sources, and obstacles to achieve decarbonization	Submission date	Goals, sources, and obstacles to achieve decarbonization
Argentina	First NDC (17/11/2016)	*Target:* by 2025 to reach 20% of renewable generation (Law No. 27.191). *Sources:* small hydro, biomass, wind, and solar. *Obstacle:* climate impact on hydroelectric generation.	Second NDC (30/12/2020)	*Sources:* electricity generation from renewable sources, hydroelectric, nuclear, substitution of liquid fuels for natural gas in thermal power plants. *Obstacles:* moderate need for capacity building, technology transfer, and financing. Climate vulnerability in hydroelectric generation.
Bolivia	First NDC (5/10/2016)	*Target:* 79% renewable generation by 2030. *Sources:* mainly hydroelectricity and, in particular, 9% participation of alternative energies (wind, biomass, geothermal, and solar) and other energy sources (combined cycle steam).	–	–
Brazil	First NDC (21/9/2016)	*Target:* 23% renewable generation by 2030. *Sources:* renewables other than hydroelectricity (wind, biomass, and solar).	First NDC (Updated submission) (9/12/2020)	*Sources:* hydroelectric, wind, solar, and biomass.
Chile	First NDC (10/2/2017)	*Target:* 20% of non-conventional renewable energy generation by 2025 (wind, small hydro, biomass, biogas, geothermal, solar, and ocean energy) (Law No. 20,698).	First NDC (Updated submission) (9/4/2020)	*Targets:* closure of coal-fired power plants by 2040. Renewable energies to replace thermal power plants: retirement of 2500 MW by 2050 in the reference scenario and 5500 MW by 2040 in the neutral scenario.
Colombia	First NDC (12/7/2018)	–	First NDC (Updated submission) (30/12/2020)	*Goal:* diversify power generation
Ecuador	First NDC (29/3/2019)	*Sources:* hydroelectricity, natural gas, wind, solar, and biogas from landfills	–	–
Guyana	First NDC (20/5/2016)	*Goal:* (conditional contribution) with financial support to reach 100% renewable generation by 2025. *Sources:* solar, wind, and hydroelectric. *Obstacle:* financial	–	–
Paraguay	First NDC (14/10/2016)	*Source:* hydroelectric power	First NDC (Updated submission) (16/7/2021)	*Source:* hydroelectric power
Peru	First NDC (25/7/2016)	*Sources:* replacement of fuels by natural gas, wind, solar, and biomass	First NDC (Updated submission) (18/12/2020)	–

(continued)

Table 2.1 (continued)

Country	Previous NDC		Last NDC	
	Submission date	Goals, sources, and obstacles to achieve decarbonization	Submission date	Goals, sources, and obstacles to achieve decarbonization
Suriname	First NDC (13/2/2019)	*Goal:* (conditional contribution) above 25% renewable by 2025	Second NDC (9/12/2019)	*Goal:* (unconditional contribution) renewables above 35% by 2030.
Uruguay	First NDC (10/11/2017)	*Goals:* (unconditional contributions) 1450 MW of installed wind power capacity to 2025 (32% of the National Interconnected System; from now on NIS); 220 MW of installed solar power capacity to 2025 (5% of NIS); 160 MW of installed biomass capacity in 2025 (4% of NIS). (Conditional contributions) 10 MW of installed capacity of small hydroelectric power plants by 2025. *Obstacles:* climate vulnerability in hydroelectric generation.	–	–
Venezuela	First NDC (27/2/2018)	*Sources:* substitution of liquid fuels for natural gas in thermal, wind, solar, wave, and tidal power plants. *Obstacle:* climate vulnerability in hydroelectric generation.	First NDC (Updated submission) (9/11/2021)	*Goal:* incorporate 1 MW of low-scale wind between 2022 and 2030 through UNERVEN's manufacturing capabilities. *Obstacle:* climate vulnerability in hydropower generation.

Source: Own preparation based on NDCs (UNFCCC, 2022)

As for emerging countries, Russia has not presented energy targets in its single NDC, although it does note a strong increase in renewable (+103%), hydroelectric (+26%), and nuclear (+10%) generation, simultaneously with higher coal consumption (+11%) (BP, 2022; IEA, 2022). In the case of China, a goal was set in 2016 to achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early. Despite the strong weight of carbon in its electricity generation, the first NDC did not establish specific targets for this source and promoted the use of natural gas, hydro power, nuclear power, wind, solar, geothermal, maritime, and bio-energy. In the 2015–2020 period, renewables led the increase in generation (+219%), followed by far by nuclear (+114%) and natural gas (+50%). Coal-fired generation also increased (+22%), even ahead of hydro (+18%) (BP, 2022; IEA, 2022). Finally, India has set a target in its first and only NDC dating back to 2016 to increase the share of non-fossil energy resources to 40% of installed electricity capacity by 2030 with the help of technology transfer and low-cost international financing, including the Green Climate Fund (GCF). Just as that proportion was 29% in 2015, in 2020 it reached 38% very close to the target, but virtually all fossil-installed capacity still corresponds to coal (Ministry of Power, 2021). Thus, renewable generation has increased 173% in the study period, hydroelectric 22%, and nuclear 15%, but also coal-based electricity by 13% (BP, 2022; IEA, 2022).

In summary, the countries with the highest emissions in the energy sector have strongly incorporated renewable generation in all cases, and in some cases natural gas, nuclear, and hydroelectric energy. It is worth noting that developed countries (USA, EU-27, and Japan) reduced coal-fired generation, while emerging countries (China, India, and Russia) increased it.

In any case, it is difficult to measure and compare the degree of compliance with the targets of both the South American countries and the major emitters, not only because it is still premature for long-term targets, but also because of the diversity of presentation modalities: a few countries presented specific targets for the electricity sector, others presented targets for the entire energy sector, and others did not present any at all. Also, within the group of countries that submitted targets of some kind, different target years were set: 2025 (Argentina, Chile, Guyana, Suriname in its first NDC, and Uruguay), 2030 (Bolivia, Brazil, Suriname in its second NDC, Venezuela, EU-27, India, and Japan), and even 2035 (USA). The presentations also varied between those referring to electricity generation (Argentina, Bolivia, Brazil, Chile, Guyana, Suriname, USA), those referring to installed capacity (Uruguay, Venezuela, and India), one country referring to sectoral emissions as a whole (Japan), and another to final energy consumption (EU-27). With respect to technological requirements, Argentina and India explicitly stated this, and with respect to financial needs, the two previous countries and Guyana also stated this. In South America, 3 countries out of a total of 12 (Colombia, Ecuador, and Peru) did not submit targets, in addition to Paraguay, which, for the reasons already mentioned, does not have to take sectoral measures for the time being. Among the main emitters, two countries out of six analyzed (China and Russia) did not submit targets.

The above-mentioned information on the NDCs does not allow us to reach definitive conclusions on the ambition and compliance of each country. From what has been analyzed throughout this chapter, greater efforts are expected from the major emitters. However, these efforts have not been fully reflected in the NDCs so far. In this sense, the definitive abandonment of coal should be the first and urgent goal of this group of countries. However, none of them has incorporated it in their respective contributions. On the other hand, Chile, a country whose contribution to emissions is lower, has set an expiration date for its own coal consumption. On the other hand, some countries support natural gas as a bridge to lower coal consumption (China and EU-27) or liquid fuels (Argentina, Ecuador, Peru, and Venezuela). In terms of clean or low-carbon sources, renewables such as wind and solar have the lead in the commitments made, but it is also noteworthy that many countries explicitly involve hydroelectric (Argentina, Bolivia, and China, in addition to the South American countries that already have a very high share of this source) and nuclear (Argentina and China).

2.6 Conclusions

The data analyzed in this chapter acquire relevance in the framework of international climate negotiations and in the delineation of energy transition plans at the national level. A just transition on a global scale must necessarily incorporate climate justice as a central principle, to favor rather than hinder economic and social development in the global South. In southern regions such as South America, the energy transition must serve the expansion of technological and industrial capacities, the creation of jobs, and the improvement of the quality of life of the population. The major mitigation efforts must be concentrated in the global North, due to its historical responsibility in the climate crisis and because it has a greater capacity to face a rapid reduction in GHG emissions.

The conclusions drawn for South America are several. In the first place, it was found that not only is it a climate creditor region in historical terms, but it also has a low incidence in current GHG emissions both in absolute terms and per capita and per GDP. Second, the energy sector and, in particular, the electricity sub-sector have a lower weight in the total than in other regions, so that mitigation measures in sectors such as agriculture and land use and change are as or more important than the former.

Third, the working hypothesis stated at the beginning was corroborated, since the region as a whole increased more rapidly the incorporation of low-carbon sources in its electricity generation with respect to the group of six most emitting countries, despite the fact that South America started from a higher floor in the decarbonization of the electricity mix and that climate change is affecting the generation capacity of its hydroelectric power plants. Likewise, nuances should be noted when analyzing the cases on a national scale, given that the faster progress of some countries compensates for the slower speed of others.

Fourth, the increase in installed capacity of low-carbon sources in the region during the period under study accelerated with respect to the previous 5-year period and was led by solar energy and followed by wind power. Hydroelectric installed capacity also increased, but as a result of the drought attributable to climate change, generation grew modestly and, in some countries, even fell sharply. Some of the most affected countries reflected this climate vulnerability in their respective NDCs.

Last, few countries presented new targets in the second round of NDCs and decarbonization strategies continue to have uneven approaches in terms of target years, the energy sources promoted and the references for the sector as a whole, installed capacity, or electricity generation. The same applies for the group of the six top emitters.

Among the public policy recommendations that can be made for South American countries, it is necessary to redouble the demands for technology transfer and financing for climate debtors in order to expand renewable generation sources other than hydropower. In this sense, subordinate new commitments in official documents to the needs of technology transfer and financing for renewable projects. Also, review energy decarbonization strategies based on national economic and industrial capacities, so that the transition becomes a leverage and not an obstacle to development. Likewise, recover spaces for regional cooperation to support endogenous capacities for the development and production of low-carbon energy technologies and also to gain margins of autonomy in international negotiations. Finally, study the technical and economic feasibility of greater regional electrical integration that takes advantage of synergies between base generation (hydroelectric and nuclear) and intermittent generation (wind, solar, bioenergy, and others).

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3 Geopolitical and Social Dimension: Geopolitics of Renewable Energy in Latin America

Ana Lía del Valle Guerrero

3.1 Introduction

In November 2021, world leaders met in Glasgow at the COP 26 climate summit, in order to set a course to reach zero global net carbon emissions by 2050. In contrast to this seemingly single, linear path, there are complex and heterogeneous processes in relation to transitions to renewable energies, which are presented in this chapter from a multi-scale geopolitical perspective.

Geopolitics has a dynamic and interdisciplinary object of study that seeks to achieve a prospective vision of reality. It requires the theoretical framework offered by Political Science, International Relations (concept of power), Geography (living space), and other sciences such as Economics (notions of wealth and resources) and History (conceptions of evolution and dynamics) (Dallanegra Pedraza, 2010, p. 16). Likewise, according to Méndez (2011):

> The characteristic geopolitical order of each historical period defines some dominant actors, a context of relationships and an institutional framework that affect not only the intensity and form of conflicts, but also their unequal location and the geostrategic value of the different territories based on changing criteria over time. Without denying that the internal keys are always important in the explanation of each conflict, the insertion of this local perspective in its regional context and in the current global scenario where actors with cross-border influence gain strength, allows us to offer a more adequate perspective than the exclusive attention to any of these scales. (p. 21)

In addition to the geopolitical order, there is an energy order, which has been changing over time, producing different energy transitions, due to changes in the type of fuel used (wood, coal, oil, gas, renewable), in general each one dominated by a country that possessed the resource and the technology to transform it into energy. In this sense, one of the axes that is deepened is that of the Geopolitics of Energy and, in particular, the geopolitical dimension of renewable energies, as part of the current energy transition.

From a theoretical-methodological point of view, its study is carried out from an interdisciplinary perspective, since the Global Energy System works in an integrated manner. In addition to geopolitics, the new political geography approach is included, which provides, through multiscalarity and multidimensionality as methodological strategies, the possibility of analyzing social actors beyond a single scale of political action, considering that the problems that affect one of its components affect the rest of the system. Thus, the multidimensional analysis allows us to examine the conflicts that are generated in the geopolitical, political, economic, social, and

A. L. del Valle Guerrero (✉)
Geography and Tourism Department (DGYT), Universidad Nacional del Sur (UNS), Bahía Blanca, Argentina

Clacso Working Group: Energy and Sustainable Development, Buenos Aires, Argentina
e-mail: aguerrero@uns.edu.ar

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environmental dimensions, in order to understand the underlying logics and power relations to energy transition, considering the dynamic and complex nature of the territory as a whole.

As for the methodology, this chapter is based on qualitative research, since the approach to the problem is carried out through theoretical knowledge and bibliographic review to know the state of the matter. Secondary sources such as specific scientific and technical books and articles are used, for data collection, analysis, and linking process, as well as reports from international organizations and web pages that address the subject. In accordance with the stated objective, its scope is exploratory-descriptive, then, based on the results obtained, it is proposed to reach a deeper understanding of the problem analyzed. In this way, meanings emerge that allow the energy transition to be recontextualized on a Latin American scale.

The energy transition, or more precisely, energy transitions, appear as an arena of conflicting ideologies and agendas where some States impose an unhistorical and impartial discourse that considers only the perception of the Global North on energy transition policies, leaving aside the social, political, and economic inequalities with the Global South, as well as the internal conflicts, needs, and vulnerabilities of each State or region, as in the case of Latin America.

In particular, it reflects on how different international organizations in Latin America incorporate the 2030 Agenda, in relation to SDG 7 (affordable and clean energy), 12 (climate action), and 9 (industry, innovation, and infrastructure, linked with technology). Undoubtedly, technology will play a key role in planetary strategies to mitigate the consequences of climate change, which is why there is already talk of the geopolitics of technology as soft power, with the capacity to act on territories.

In this context, the chapter is structured in two parts that complement each other to reach the final result. The first explores the geopolitical dimension of renewable energies to offer a comprehensive vision of the changes in the geopolitics of energy. The second analyzes the social-geopolitics dimension of renewable energies in Latin America, considering its role as a democratization vehicle that leads the State to guarantee the provision of affordable energy for society, in order to overcome inequality and achieve a just transition. Finally, the results obtained show the complexity of the trans-scalar power relations that act in the contemporary energy transition/transformation considering the needs and resources of each State, as well as the different speeds of such transition in each country and sector.

3.2 Focus 1: The Geopolitical Dimension of Renewable Energies

As mentioned above, the general approach of geopolitics has a dynamic and interdisciplinary object of study that seeks to achieve a prospective vision of reality. The geopolitical perspective is another way of approaching reality; its contributions stand out as a complementary analysis model in economic studies and the consideration of the territory as a territorial anchorage and not only as a productive enclave, since there exist, among others, resources and social actors as main protagonists (Guerrero, 2016).

The geopolitical approach seeks to complement the dominant economic perspective in the analysis of the energy issue. From a modern geopolitical view, international relations focus on power relations between states that, from a strategic point of view, imply relations between means and ends, which in turn generate dependency relations, where power is perceived depending on the degree to which the ends of one actor hinge on the means of the other, the latter constitute their bases of power (Delamer, 2005). In this sense, from the geopolitics of energy, as stated by Bordoff and O'Sullivan (2021)

> The energy system is the lifeblood of the global economy and underpins the geopolitical order… Failure to appreciate the unintended consequences of efforts to reach net zero will not only have economic and security implications, but ignoring geopolitical risks could undermine the energy transition itself. (p. 1)

From the approach of energy economy, Recalde and Guzowski (2016) point out that energy has a multidimensional nature that includes: (a) economic dimension—due to the relationship that exists between consumption, economic activity, and its incidence in the price of products; (b) social dimension—since energy consumption is relevant for social development, access to energy is considered one of the main policies for poverty reduction; (c) political dimension—considering that energy is a strategic asset for socioeconomic development; (d) environmental dimension—since it is linked to the environment at different scales and, in particular, to climate change. To these dimensions, Guerrero (2021) adds a fifth-dimension (e) Geopolitical dimension, because it means energy security, due to the importance of guaranteeing the energy supply of a country.

Consequently, from this broader perspective, the energy policy of the States must consider all the external and internal conditioning factors, on the different scales and in the different dimensions, to achieve the proposed goals in relation to the energy transition/transformation.

3.2.1 Energy Geopolitics

In the general framework of geopolitics, energy geopolitics in particular "seeks to analyze and understand the conflicts that arise in the use of energy resources, based on geographical factors associated with the availability for the development of transport routes and the construction of infrastructure, coupled with political and economic factors" (Hutschenreuter, 2008, p. 3). From a Latin American perspective of energy geopolitics, Guerrero (2021) adds to this definition that financial and technological factors, due to the dependency they generate in the Global South countries, where technology and financial support for infrastructure development are elements that are becoming increasingly important, are linked to the so-called "soft power."

In this sense, in order to achieve its development and energy security, a country must sometimes submit itself to decisions imposed by another country of which it depends on from a financial or technological point of view. The geopolitics of energy seeks to avoid or minimize the risks of this dependency. From a territorial view of energy, the resource constitutes the territorial anchor, which is then mobilized by social actors, through political and economic decisions that redistribute energy and power in the territory.

The quest for control of energy resources and their technology has been, and continues to be, a fundamental geopolitical axis through which trans-scalar flows of political and economic power move. From there the question arises: Will the rapid growth of renewable energies alter the power and influence of some states and regions over others and will it redraw the geopolitical map of the twenty-first century? In the last decade (2010–2019), it was observed a change in that direction, being renewables the only sources that increased their participation in the global energy matrix with +3.12 percentage points (pp) and natural gas with +1.74 pp, while oil, coal, and nuclear power reduced their share (Bp, 2021).

In order to increase the participation of new renewable energies such as wind and solar ones, it is necessary to have the support of the States, considering that the final cost of technology is linked to factors and variables of technical, regulatory, and fiscal nature as well as to energy policies that stimulate these investments and favor the development of their own technology. However, since solar and wind power are intermittent, they need to be backed up or supplemented by a power source flexible enough to meet sudden increases in demand.

Some organizations such as the IDB and OLADE point out that gas, being the least polluting of fossil fuels, can be the bridge fuel for energy transition. Gas is capable of providing the firm power needed for renewable energies to expand rapidly, without jeopardizing energy security. Hence, the Bp, 2019 report mentions that the contemporary energy transition is a dual-energy transition, because of the simultaneous growth of both energy sources (gas and renewable ones).

In addition to the low presence of coal compared to the rest of the world's regions and in relation to energy transition policies in the South American Region, oil has been replaced, to some extent, by gas as fuel for electricity generation as well as the use of hydroelectric energy (conventional renewable energy) stands out as a regional particularity. Thus, a diversification of energy sources is observed that goes in the same direction as on a global scale with a dual-energy transition (gas and renewables) and in particular a change in the electricity generation matrix (electrical transition) (Guerrero, 2021, page 10).

3.2.2 Geopolitics of Renewable Energies

Following the concepts and arguments raised so far, it is proposed in this section to reflect on the potential of geopolitical analysis of renewable energies, from the vision of the geopolitics of energy. This idea starts from recognizing the multiple dimensions that affect its growth and expansion dependent on political decisions of the States that impact not only its environmental dimension, but also in multiple political, social, economic, and geopolitical ones.

In this framework, the geopolitical dimension of renewable energies is explored to provide a comprehensive vision of the geopolitics of energy that includes them, with the emerging actors from the different resources and technologies used for the development of renewable energy in comparison with fossil fuels.

In addition, being a dual energy transition, it is highlighted that technological innovation has had an impact, in particular, on the electricity sector through the use of various less polluting sources. In this sense, the Ren 21 Report (2018) mentions that the contemporary energy transition is only an electric transition, since the largest incorporation of renewable energies (25%) occurs in this sector which has only 20% of consumption.

Another report, published in 2019, by the Global Commission on the Geopolitics of Energy Transformation, of the International Renewable Energy Agency (IRENA), with the support of Germany, Norway, and the United Arab Emirates, points out that in the current energy system there is not only a change from one fuel to another, but also different fuels in use are being incorporated into different sectors and at different speed in each country or region. The trend is toward the conformation of an "energy mix," where the use of different resources is distributed in similar percentages: 25% oil, 25% gas, 25% wind and solar power, and 25% other sources such as hydroelectric and nuclear energy (IRENA, 2019a). Likewise, due to its geopolitical, social, economic, and political implications that go beyond the energy sector, it is called energy transformation, since it is a deeper and more complex energy transition of the global energy system.

In this context of changes in the energy matrix of the States, we find different authors who analyze the geopolitics of renewable energies: Klare (2008), Rothkopf (2009), Criekemans (2011), Scholten and Bosman (2013), O'Sullivan et al. (2017), IRENA (2019a, b), Indra Overland (2019), Goldthau et al. (2019), Egenhofer and Elkerbout (2019), Jiménez Silva (2019), Indra Overland (2019), León Serrano (2020), Bordoff (2020), and Bordoff and O'Sullivan Meghan (2021, 2022) among others. Table 3.1 offers a brief synthesis of their opinions which state that a greater participation of renewable energies in the global energy matrix will include both opportunities and challenges.

To these characteristics identified in the literature review, Criekemans (2011) adds the question: Is the geopolitics of renewable energy different or similar compared to that of conventional energy? This can be answered, after reading the different authors mentioned, in three different ways: (1) that it is potentially different; (2) that it is similar; and (3) that it is a mix of both answers.

1. *It is potentially different*: (a) it is more decentralized in nature compared to conventional energy, more concentrated in certain areas of the planet; (b) some countries such as China, Germany, or the United States already have an advantage in the development of these energies in relation to the percentage they represent in their energy matrix and become future central players, geopolitically positioned, due

Table 3.1 Geopolitics of renewable energies: advantages and uncertainties

Geopolitics of renewable energies	
Advantages	Uncertainties
Increased use of R.E. will be a vehicle for democratization (decentralizes supply and empowers citizens)	All scenarios foresee the growth of R.E. but none anticipates that its use will exceed the consumption of fossil fuels in the coming decades
Energy efficiency (economic growth with lower energy consumption)	New uncertainties. New markets are created that are still unknown
R.E growth rate and electrification (electrical transition)	Technological uncertainty. R.E. involve the use of various energy sources
A global energy system dominated by R.E. would be more stable and peaceful than one dominated by fossil fuels and nuclear technology	As R.E. resources are abundant but diffuse, technologies to capture, store, and transport them will become more important, whatever their source
The new geopolitical map will be very different from the conventional fossil fuel-dependent energy map	The current E.T. depends on the development that both technology and innovation achieve in the future. Rate of progress at different speeds in each country and sector
R.E. exchanges will involve strengthening regional electricity markets as well as a greater dispersion of power. These exchanges will occur in both directions	Countries will tend toward energy interdependence where flows will depend on electricity interconnections between countries
Fewer risks related to transport bottlenecks	International energy competition can shift from controlling physical resources, their locations, and transportation routes, to technology and intellectual property rights

Source: Guerrero, 2021, based on previous research

to the greater technological development already achieved; (c) a financial shock could be created with significant consequences for the global economy. Workers and communities that depend on fossil fuels may be negatively affected; (d) RE technologies can simultaneously lead to a greater electrical interconnection between countries, as well as to a more widespread internal generation of energy with greater development of regional and non-global markets; (e) the reduction of GHG emissions should decrease the risk of conflicts and instability derived from an increase in the consequences of climate change, therefore bringing about a positive effect; (f) one of the most significant changes is that energy resources such as the sun, wind, and water will be virtually infinite being natural flows that have no cost and are not tradable as a natural resource, only as a form of final energy.

2. *It is similar to conventional energy*: (a) it may present problems of security and dependence on the technological development of other countries; (b) differences may arise as to who will maintain a privileged position and who will lose influence in the global energy system; (c) the transition to clean energy will also create new geopolitical risks even while mitigating others; (d) interdependence among countries could increase, therefore decreasing the risk of conflicts; (e) conflicts may arise over resources needed for the production of infrastructure and equipment causing new asymmetric dependencies between major producers and consumers; (f) growing seaborne trade in hydrogen and ammonia would carry similar disruption risks to oil transportation; (g) as more sectors shift from burning fuels to electricity, power grids will become more vulnerable to cyber-attacks through an increasingly interconnected digital network.
3. *It can be a mix of both possibilities*: In this context, countries must prepare for future changes, and develop strategies to face the uncertainty regarding the new challenges that these energies impose on them. In their favor, renewable energies currently have lower production costs although in Latin America the cost in dollars is still high; they obtain state support through the application of incentives and subsidies for their development; and support from society, which has become aware of the need to care for the environment. However, the problem of intermittency and storage of

renewable energies continues to limit their participation in the energy matrix.

3.3 Focus 2: The Social-Geopolitical Dimension of Renewable Energies in Latin America

The topic of the social-geopolitical dimension of renewable energies in Latin America arises from objectives of some international organizations, and the analysis of the discourse of their main referents in relation to the demands of society. Common objectives related to different dimensions of energy are identified, according to the multidimensional energy concept used in this chapter. In particular, it is highlighted how the geopolitical and social dimensions are intertwined to provide secure and affordable energy within a just transition.

To this end, some of the organizations that have the capacity to act in the region are characterized in relation to the concept of energy as a social and geopolitical good. Three key organizations are selected: at the international level, the International Renewable Energy Agency (IRENA); at the regional level, the Latin American Energy Organization (OLADE); and as a financial organization, the Inter-American Development Bank (IDB).

The International Renewable Energy Agency (IRENA) is the leading intergovernmental energy transformation agency that supports countries in their transition to a sustainable energy future and serves as the main platform for international cooperation, with 161 members (160 States and the European Union) and 22 additional countries in the process of joining. Actively engaged, they promote the widespread adoption and sustainable use of all forms of renewable energy in the pursuit of sustainable development, to provide secure and affordable energy.

The Latin American Energy Organization (OLADE) is a public intergovernmental cooperation, coordination, and advisory body that works for the integration, sustainable development, and energy security in the region, advising and promoting cooperation and coordination among the countries of Latin America and the Caribbean. It was established in 1973 and has 27 member countries.

The Inter-American Development Bank (IDB) seeks to improve the quality of life in Latin America and the Caribbean. It helps improve health, education, and infrastructure through financial and technical support to countries working to reduce poverty and inequality. It seeks to achieve development in a sustainable and climate-friendly manner. It was created in 1959 and is currently the main source of financing for development in Latin America and the Caribbean. It offers loans, grants, and technical assistance, and it also conducts research.

3.3.1 The Position of International Organizations: Energy as a Social and Geopolitical Asset

In the context of the Covid-19 post-pandemic, IRENA and OLADE set out to strengthen their ties to make renewable energy-driven transformation the backbone of economic recovery in Latin America and the Caribbean. Both organizations build on a Memorandum of Understanding, signed in 2012, that proposes to accelerate the development of sustainable energy considering that it could provide the Latin American region with a long-term strategy to address social inequality, and to provide secure and affordable energy.

To this end, OLADE and IRENA promote investment and financing, of renewable energies as well as energy integration in the region to support the achievement of deeper energy transitions. They believe they can stimulate the growth in the use of clean energy technologies in the industrial, agricultural, manufacturing, and transportation sectors, while reducing the region's carbon emissions to 21% by 2030, in line with the Paris Agreement.

In this regard, according to IRENA's Global Renewables Outlook (2020), investment needs in the region in energy transformation are estimated at US$45 billion per year between now and 2050, which implies an increase of more than 10% with respect to current plans and policies. The report states that the benefits for Latin America and the Caribbean (LAC) of an accelerated renewable energy-driven transformation could be: creating more than three million jobs and providing an economic return of between US$3 and US$8 for every US$1 invested by 2050.

OLADE's executive secretary stated that "…our fundamental priority is to help OLADE member countries improve energy access and energy supply security in socially, technically and economically convenient conditions, promoting the incorporation of clean energy resources and efficient technologies" (Blanco Bonilla, 2020). Reaffirming this position, the Director General of IRENA maintains that:

> We join OLADE to ensure that there is a collective regional recognition of the socio-economic potential of a green recovery built around energy transformation…while the region is diverse, all countries seek to benefit from increased R.E. participation, from increased energy security and reduced costs, to widespread job creation, improved health and economic growth. Policymakers' decisions today should seek to build a future of stability through a green recovery built around energy transformation, rather than prolonging unsustainable systems of the past. (La Camera, 2021, p. 1)

IRENA's (2019b) report on Future of Solar PV highlights that, with accelerated renewable energy development, comprehensive electrification, and increased energy efficiency, more than 90% of carbon dioxide (CO_2) energy-related emissions that will be needed by 2050 can be achieved to meet the objective of the Paris Agreement. It upholds that significant emission reductions in 2050, around 4.9 gigatons of carbon dioxide (Gt CO_2), representing 21% of the total emissions mitigation potential in the energy sector, can be achieved through accelerated deployment of solar PV alone. In relation to LAC, he says that, by 2050, solar power capacity could increase 40-fold to reach more than 280 GW, thanks to abundant resource endowment and strong support policies.

The executive secretary of OLADE noted that "Latin America has a significant concentration of hydropower, however, our efforts will focus on increasing the penetration of other renewable resources in the region, such as wind, solar and geothermal ones" (Blanco Bonilla, 2020). LAC has 61% of power generation capacity from renewables, and a share greater than 26% of renewable energy in the region's primary energy supply. This is the highest percentage of renewables compared to the rest of the world. However, as the International Energy Agency sustains, finance is the missing link in accelerating clean energy deployment in developing economies. Setting the world on a path to 1.5 °C requires an increase in annual investment in clean energy projects and nearly USD 4 trillion in infrastructure by 2030 (IEA, 2021).

In line with these arguments, the IDB presented the document "The role of the Energy Transition in the sustainable recovery of Latin America and the Caribbean." The authors propose reactivation plans with a long-term vision, consistent with the countries' energy transition strategies, that promote investments with greater potential to create jobs and reduce GHG emissions. It includes concrete measures such as: renewable energy auctions; modernization of hydroelectric plants; greater energy efficiency; incentives for storage; expansion and modernization of transmission networks; promotion of digitalization; distributed generation and response to demand; promotion of electromobility; local content and regional value chain; and universal access to electricity. It highlights that LAC countries present important comparative advantages for the transition toward more sustainable matrices due to the large amount of natural resources they possess for the production of biomass and wind and solar energy (Pérez Urdiales et al., 2021).

The most recent initiative, created in 2019 during the United Nations (UN) Climate Action Summit, is a climate action platform that brings together 15 countries in the region and international organizations called "Renewables in Latin America and the Caribbean" (RELAC), in which OLADE participates and the IDB serves as

Technical Secretariat. It seeks to accelerate carbon neutrality and aims to achieve 70% of renewable energies in the electricity matrix by 2030. The IDB study, "The Grid of the Future" (2017), estimated that to achieve this, approximately US$30 billion per year in investments in renewables is required. Considering that, on average, 23.5 billion have been registered annually in the last 5 years; investments would have to increase by around 30% to reach that goal. At the September 2021 meeting, the OLADE representative noted that

> Renewable energies in our region are more than a way to reduce greenhouse gas emissions… they are the engine of economic development and job creation. They help us to consolidate innovation, stimulate technology transfer, increase financing for new projects and strengthen training. (Blanco Bonilla, 2020, p. 1)

After analyzing the different proposals of the selected organizations and in relation to the concept of multidimensional energy, it is observed that, in relation to the economic dimension: IRENA points out the search for sustainable development; OLADE emphasizes economic integration and development; while the IDB is concerned with providing financing. In the social dimension, IRENA emphasizes access to energy, since energy consumption is relevant for social development and is considered one of the main policies for poverty reduction; OLADE adds the search for sustainable development; and the IDB specifically points out that it seeks to reduce poverty and inequality. In the political dimension; OLADE points out the importance of political integration, considering that energy is a strategic asset for socioeconomic development; and the IDB states that it seeks to achieve development in a sustainable manner. In the environmental dimension, it is surprising that it is only made explicit by the IDB, which intends to achieve development in a sustainable and climate-friendly manner.

In addition to the specific arguments of each organization, OLADE and IRENA jointly proposed in 2020–2021, to address social inequality—with emphasis on job creation—and to improve access to energy (both highlighted aspects of the social dimension) as well as to ensure the security of energy supply (Energy Geopolitics dimension). These results allow us to affirm the dense interweaving between the geopolitics and social dimensions of renewable energies in Latin America, since they appear as the two most highlighted dimensions, both by the reports of the different organizations and by their representatives. However, it is worth asking whether this leads to a just energy transition due to its processes, since they are the result of expert studies, but there are no spaces for participation and effective representation in a collective and inclusive way for society, despite being the main addressee of its objectives and proposals.

3.3.2 2030 Agenda: SDG 7 (Affordable and Clean Energy); 12 (Climate Action); and 9 (Industry, Innovation, and Infrastructure Linked to Technology)

This section reflects on how different international organizations in Latin America incorporate the 2030 Agenda in relation to the Sustainable Development Goals (SDGs): 7 (affordable and clean energy), 12 (climate action), and 9 (industry, innovation, and infrastructure linked to technology). The different proposals of IRENA, OLADE, and the IDB outlined in the previous section are synthesized in the idea of a green recovery built around energy transformation. These proposals are in harmony with some of the Sustainable Development Goals (SDGs) formulated in 2000, in the 2030 Agenda and, reaffirmed in 2015 with the Paris Agreement during COP21, in order to avoid the increase of global temperature above 2 °C.

The fulfillment of this agenda and its objectives strengthens the global response to climate change threat and constitutes the best response to the challenges of the contemporary socio-ecological crisis. As Pes (2019) argues, these goals seek to restore the ecological balance of the planet and address the most urgent societal challenges. These challenges are ending poverty, reducing inequality, and improving the living conditions of the population, in order to achieve the rapid transition to a low-carbon and climate change-resilient economy, where both processes are mutually reinforced. In this sense, the SDGs call on States, companies, and society to adopt a citizen commitment with the planet that will lead to a zero-CO_2 economy. To this end, energy transition is the necessary preliminary step to achieve the ultimate goal of a collaborative global energy transformation in which no one is left behind (NOLB), ensuring a fair and "just" transition.

The countries of Latin America and the Caribbean have also committed to establishing the 2030 Agenda as a State policy, articulating institutional frameworks to incorporate the 17 Sustainable Development Goals (SDGs) into their national development plans and policies. As ECLAC (2018) points out, the countries of the region seek to align both their policies and budgets in favor of renewable sources that meet the future energy demand.

The central goals identified in relation to energy, climate change, and environmental care are SDG 7 (affordable and clean energy) and SDG 12 (climate action). SDG 7 seeks to ensure universal access to modern energy services, improve energy efficiency, and increase the use of renewable sources to create more sustainable and inclusive communities and resilience to environmental problems such as climate change. In relation to this, Goal 12 (climate action) is transversal in nature, calling for the elimination of fossil fuel subsidies and other distortions that encourage the inefficient use of resources and propose the penetration of cleaner technologies and inputs supported by the necessary fiscal policies.

As for the technological changes required that the transition to an energy system based on renewable energies requires, an acceleration of the development processes of these technologies is foreseen, which will be included in the future in the agendas of governments, companies, and institutions. For this reason, SDG 9 (industry, innovation, and infrastructure) is included, which, although it does not explicitly mention technology, could be considered linked to it. As Guerrero (2020, p. 25) argues "…to achieve these goals, the use of renewable energies in different sectors will have to be increased, public and private investments will be necessary, as well as higher levels of financing and policies that facilitate their own technological development."

3.3.3 Geopolitics of Technology and Technologies of Energy Transition

From a geopolitical perspective, technology is an element increasingly linked to the so-called soft power. In this sense, Nye (2011) points out that countries can influence the behavior of others to make their behavior and decisions go in the desired direction. Hence, there is talk of the geopolitics of technology, considering that the technological battle for the control of key emerging technologies will continue in the future among the great powers. As León Serrano (2020) points out:

> Current technological conflicts may fall into the "gray zone" in which the sides involved in undeclared conflicts – companies, citizens and governments – are not always well identified, nor do they lead to direct war situations with human and material losses; but their socio-economic and behavioral consequences may be very high and persistent for citizens. (p. 334)

In this sense, he adds that these possible technologies can be classified into four large groups: (1) technologies that help reduce polluting gases; (2) technologies that help predict and model climate evolution; (3) technologies that help reduce natural disasters derived from climate change; and (4) technologies that help geotransform the planet, known as geoengineering, capable of causing substantial changes in very large areas by modifying solar radiation. These are still in the conceptual phase, but may be feasible in the long term if their development is channeled (León Serrano, 2020, p. 323).

From the economic perspective, in relation to technology, a recent IDB study entitled "Transition technologies: exploring trade flows in Latin America and the Caribbean" by Carvajal

Ledesma and Hallack (2021) asks: What are the enabling technologies of energy transition identified in international trade flows? And point out that they are those that allow greater flexibility in electricity systems both in supply and demand, at all stages. These technologies range from large-scale batteries, electric vehicles and chargers, Internet of Things, big data, mini-grids, and smart meters, among others. Contemporary energy transitions differ between sectors, and technological innovation has had a particular impact on the electricity sector leading, in the last 10 years, to a qualitative leap toward a low-emission system, through the use of solar panels or diverse wind turbines in electricity generation.

Latin American countries are not the main producers of these technologies and have only some industrial and technological capabilities. Understanding the flows associated with renewable energy technologies is essential for discussing the strategic positioning of countries, their value chains, and related policies, such as the need for incorporating local technology, thus avoiding dependence seen from the geopolitics of technology point of view. In this sense, Hurtado (2018) points out that

> From the geopolitical and geoeconomic perspective, the countries of the semi-periphery are presented as "markets" for technology coveted by advanced countries, which carry out foreign direct investment, buy packages of shares in local companies, set up subsidiaries, the companies "make "turnkey" sales, pay royalties", provide technical assistance or, increasingly, are spaces that receive the relocation of those segments of the global value chains that need cheap labor. Central countries do not transfer technology to them in an effort to peripheralize the semi-periphery, avoiding projects that develop their own technology. (Hurtado, 2018, Y/N)

Developing countries will require global cooperation and financial assistance to move to a low-carbon growth path, as well as technology transfer in order to avoid financialization processes in the renewable energy market. In this sense, the results of LAC imports between 2007 and 2019 show a global trade flow of solar panels and other photovoltaic components of around USD 22 billion (main supplier China) and in wind generation equipment for a total of USD 10.5 billion in the same period (Carvajal Ledesma & Hallack, 2021). These values exhibit how energy transition technologies neither benefit nor reach different countries in an equitable manner, highlighting the technological dependence of the region.

From the perspective of the geopolitics of renewable energies, China has become a new quasi-monopoly in terms of clean technologies in energy transition, due to the fact that most of the value chain that goes from mining extraction, to processing and manufacturing, is carried out there by Chinese companies. This implies an appropriation of trade flows that benefit more those countries that have already achieved development in key technologies for the production of renewable energies. This situation seems to confirm what Bordoff and O'Sullivan (2021, p. 1) stated: "It is true that clean energy will transform geopolitics-just not necessarily in the ways many of its champions expect."

Likewise, in the context of the Covid-19 pandemic, linking the geopolitical and the social, the importance of governments guaranteeing the population the availability of safe and affordable energy is reevaluated. As Hallack and Yepez (2020) explain, modern society depends on electricity, whether directly in hospitals (to operate ventilators, refrigerators, and other medical equipment), in communication between society and government, or indirectly to allow some continuity of production (through teleworking schemes), education (on-line studies), and entertainment to overcome isolation or quarantine (people connected through their telephones, computers, and other electronic devices).

The other side of recognizing this linkage is what Bordoff and O'Sullivan (2021, p. 1) explain: "If people come to believe that ambitious plans to tackle climate change endanger energy reliability or affordability or the security of energy supplies, the transition will slow. Fossil fuels might eventually fade. The politics -and geopolitics-of energy will not."

3.4 Energy Transition in Latin America: Conflicting Visions

Energy transition in Latin America poses the challenge of a more integrated and complex approach that seeks not only to mitigate climate change by increasing the use of renewable energies, but also to improve the quality of life of society and avoid energy poverty in order to achieve a just transition. This coincides with what is postulated by the IRENA report (2019) that states the need not only for a transition, but for an energy transformation, beyond the Energy System that considers the geopolitical implications of that change. From the Global South, the exploitation of some fundamental resources for energy transition, such as lithium, a key element for batteries and electromobility, is being debated. With a counter-hegemonic, resistance or alternative discourse, Svampa and Viale (2014) question whether the exploitation of lithium is a strategic bet for Argentina "… or if it only contributes to finance the transition of the Global North, while advancing in terms of dispossession of territories and indigenous rights" which they call "Areas of sacrifice" (p. 383). Thus, neo-extractivism emerges as a category born in Latin America to describe phenomena that are typical of the twenty-first century. This situation causes tensions with the local dwellers and the emergence of great social resistance among indigenous peoples, who inhabit those lands because they are victims of displacement and of the progressive violation of their rights (Svampa, 2019). In the dynamics of the conflict, part of these social movements demands the extension of their rights in the face of the expansion of the borders of capital.

Neo-extractivism includes not only the overexploitation of natural resources through extractive activities, but also those related to the construction of large hydroelectric dams or the processes of financialization of renewable energies, as pointed out by Fornillo (2021) in Uruguay and Kazimierski (2021) in Argentina. Likewise, from the global scale, Chaturvedi and Doyle (2015) consider that the atmosphere was also commodified, favoring an unsustainable development that highlights the asymmetries of power between the North and the Global South.

Following this line of thought, Svampa and Viale (2014) question the hegemonic extractivist development model where energy appears as a subsidiary of the extractive model and postulate alternative development paradigms in which concepts such as "good living," "common goods," and "ethics of care" become central. From the Global South, Bertinat (2016) posits the idea of energy as a social good and as part of common goods. He poses as a challenge to achieve a social construction of energy as a right and the decommodification of the energy sector.

However, as Guerrero (2021) points out, the reality in Latin America also shows internal contradictions between discourse and practice. Some actions of the countries of the region move away from the discourse of a post-extractivist energy transition when, in the context of the social and economic consequences of the Covid-19 pandemic, they prioritize obtaining profits thinking in the short term through the extraction of unconventional hydrocarbons in Argentina and Brazil, oil in Ecuador, or gas in Bolivia, among others.

In this framework, there are still difficulties for the massive use of renewable energies in the countries of the Global South where, in spite of the decrease in their costs, they still imply an expense that they cannot afford due to their reduced income. If the lack of financing and development of their own technology continues, the material owners of the resources will not be able to exploit them without the necessary participation of those who have the technical and financial means to carry out the exploitation, i.e., the scientifically and economically developed countries of the Global North… or China, as is already the case in Latin America.

Currently, in relation to the energy transition/transitions and as a synthesis of the two axes developed in the article, two conflicting visions are opposed. A view from above, which follows the traditional tendencies of the Geopolitics of energy, and another view from below, which identifies with the Global South and, in particular, with Latin America, with a counter-hegemonic view that questions the benefits of energy transi-

Table 3.2 Two visions of energy transition, from a multiscalar approach to the geopolitics of energy

Top-Down—Norte global	Bottom-Up—Global South/Latin America
Green capitalism and neo-extractivism reactivate dependency relations under the sign of extractivism	Questioning the hegemonic vision of development. Expansion of extractive megaprojects generates sacrifice areas that are impacted at the local scale in Latin America
A common extractive logic based on mega-mining, oil exploitation, mega-dams, and the financialization of renewable energies	Claim for an expansion of the extension of rights confronted with the expansion of the frontiers of capital. A new conflict is generated
Asymmetric trade with China that reprimarizes Latin American economies. Financial and technological dependence on China	Empowerment of indigenous peoples, who demand cultural recognition and land and territory claims
Cognitive capitalism. The core economies reserve for themselves the export of high value added in leading sectors through research and development, design and innovation, and control of the strategic nodes of global value chains	The peripheries are relegated to compete through static comparative advantages, natural resources, and low wages in conditions of overexploitation by foreign direct investment and reception as assemblers
Technology as soft power, struggles for control of emerging technologies considered key	Dependence on renewable energy technology. Purchase of foreign turnkey technology without local technological development

Source: Guerrero, 2021, based on previous research

tion, considering in particular the impacts at the local scale. Table 3.2 summarizes the main arguments of both visions of energy transition, from a multiscalar approach to the geopolitics of energy.

3.5 Conclusions

In Latin America, from a pragmatic view, the reality is that everything will slow down in a post-COVID 19 scenario after country economies were severely affected. There is no certainty that the necessary investments will arrive and the social consequences are serious. In this sense, the objective of energy transition in Latin America is more complex as it seeks not only to mitigate climate change, but also to guarantee social equity and well-being for society as a whole. It struggles to survive between economic debt, social debt, and climate debt, in the search for a fair energy transition that does not only involve defossilization, but also recognizes nature as a subject of rights and values the life of communities, as proposed by post-development.

The results obtained show the complexity of the trans-scalar power relations that act in the contemporary energy transition/transformation in its quest to achieve a just transition, which considers the needs and resources of each State, as well as the different speeds of that transition in each country and sector. In addition, it is intended to be collective and inclusive and to ensure that the benefits and costs of the transition are shared equitably among the various stakeholders. If energy transition is to be socially fair and inclusive, it must be designed based on the territorial characteristics and needs identified by the populations that inhabit and use that territory. However, as noted, they are not consulted when the experts' reports are prepared.

Technological advances and the decreasing costs of renewable energies have favored their penetration in the energy matrix, but it should be noted that the energy system in Latin America is one of those that uses the greatest amount of renewable resources. Furthermore, the development of clean technologies and "green" energies require scarce minerals whose extraction and transformation are energy-intensive, demand large quantities of water, as in the case of lithium, and generate social and environmental impacts on a local scale, mainly in the "South American lithium triangle," which becomes a sacrifice area to benefit energy transition in central countries.

The world we are moving toward is different and uncertain. Countries will tend toward energy interdependence where flows will be subject to electricity interconnections or other forms of final energy transport, two-way exchanges and the development of regional rather than global markets. Exchanges will involve strengthening regional electricity markets and greater dependence among countries implying a greater dispersion of power. As the United Nations maintains, coping with climate change and achieving sustainable development are two sides of the same coin.

Within this framework, the State must guarantee the population of LAC access to energy services at affordable prices (SDG 7). It must increase its participation considering that the final cost of technology is linked to technical, regulatory, fiscal, and energy policy factors and variables (SDG 12). It must support the development of its own renewable energy technology, considering that it subsidizes fossil fuels (SDG 9). Developing countries will require global cooperation and financial assistance to move to a low-carbon growth path as well as technology transfer to avoid financialization of the renewable energy market and technological dependency.

This chapter, for reasons of extension and thematic cut, addressed only the analysis of the actions of some selected organizations; however, it is necessary to expand in future studies how their proposals are related to the actions carried out by the States, society, and companies. States in their different levels of government (multilevel governance), including the supranational issue of regional energy integration projects, present a lack of joint cooperation initiatives in relation to renewable energies. It is of utmost importance to investigate how the States of the region promote investments in the energy sector create dialogue between different actors (society and companies) and generate political mechanisms that favor company actions. Likewise, it is necessary to delve into how Latin American society is aware of the importance of the transition toward a clean energy source, when meeting its basic needs is, at the moment, the priority, in comparison with the need to take care of the planet to face the climate change.

In Latin America, the recontextualization of energy transition, from the geopolitics of renewable energy perspective, highlights the interweaving between the geopolitical and social dimensions that simultaneously seek to achieve energy security and a just transition with affordable energy. For this reason, it is necessary to rethink energy transition/transformation, not as a single path, but as different transitions that occur in each country and sector, with different speeds, according to their resources, technical capacities, economic context, and available human capital. However, in an increasingly complex geopolitically world, strategic resources are disputed by old and new emerging powers such as China, winner of the dispute in Latin America. Therefore, beyond the social dimension of energy, its geopolitical dimension should not be neglected.

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4 Energy Matrix Transformation in Latin America: The Global Political Economy of Chinese Investments

Oscar Ugarteche and Joselin García Hernández

4.1 Introduction

This chapter presents an overview of the cooperation between Popular Republic of China (PRoC) and Latin America in energy transition in two objectives of Sustainable Development Goals, 7 and 9. Objective 7 tracks the region's access to affordable, clean, secure energy. Objective 9 takes stock of the investment in infrastructure modernization and innovation in Latin America.

PRoC trade and investment related to renewable energy have grown significantly over the two first decades of the twenty-first century, while FDI of the same origin is geared towards the production of mass transport electric vehicles in Colombia, Brazil and Argentina. From the angle of the global political economy, the market share in these branches is a struggle between the Chinese and US capital. Questions arise related to the size and dynamism of the Asian presence and the particular branches in which it has grown.

The basis for the analysis comes from the American Enterprise Institute database *China Global Investment Tracker* (https://www.aei.org/china-global-investment-tracker/). AEI argues that "The China Global Investment Tracker is the only comprehensive public data set covering China's global investment and construction, documented separately and together. It includes over 3800 large transactions across energy, transportation, metals, technology, property and other sectors (as well as 350 troubled transactions)." They point out energy as the leading investment sector in the world for PRoC capital.

Trade data come from the International Trade Centre database, which contains details about what firms traded and their location. It allows for precise analysis of how the energy matrix change occurs from both the demand side of vehicles and solar panels and windmills. For example, The City of Medellin, Colombia bought 64 buses, Cali bought 26 out of 136 electric buses plus gas motorized vehicles and Bogotá has the most prominent electric fleet outside PRoC with 470 buses. Guayaquil has its first 20 buses, while Quito and other Ecuadorian cities are testing, and the promise is that Quito will replace its mass transport fully; Sao Paulo has 15 operating and will increase the fleet to several thousand (ITC in Ugarteche & de León 2020a, b).

A project by the Chinese company Jiankang Automobile Co. promotes the installation of a lithium battery factory in Argentina and a man-

Obela intern with Conacyt. The text has the statistical assistance of Joel Reyes Ordoñez. Intern at OBELA, Instituto de Investigaciones Económicas UNAM. DGAPA Project IN303421.
The data source is Global Investment Tracker © Data compiled by The American Enterprise Institute and The Heritage Foundation.

O. Ugarteche (✉)
Instituto de Investigaciones Económicas UNAM, Mexico City, Mexico
e-mail: ugarteche@iiec.unam.mx

J. G. Hernández
Benemérita Universidad Autónoma de Puebla, Puebla, Mexico

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ufacturing plant for electric buses. This project connects the interest in the sale of electric mass transport with Argentina's production of lithium batteries.

FDI in metals refers to mining projects in the region. Lithium extraction agreements (2019) with the Chinese Xinjiang TBEA Group Company for industrialization in the Salar de Coipasa and the Salar de Pastos Grandes to produce lithium batteries and light metal. The Agreement with PRoC totals 2.39 billion dollars and involves constructing a lithium industrialization plant in Coipasa, Oruro. It will require an investment of 1.32 billion dollars for the installation of five plants: a potassium sulphate plant, with 450,000 tonnes per year (t/y); a lithium hydroxide plant, with 60,000 t/y; a boric acid plant, with 60,000 t/y; a pure bromine plant, with 10,000 t/y; and a sodium bromide plant, with 10,000 t/y. There are also plans to build a battery plant in PRoC, with 51% cent ownership for YLB and 49% for TBEA-Baocheng. In the Pastos Grandes salt flat, in the department of Potosí, the investment amounts to 1.07 billion dollars, where three lithium chloride, lithium carbonate and lithium metal plants will be installed (Pelcastre, 2019).

The loans to Latin America are mostly energy projects (69%), where hydroelectric plants in Ecuador, the solar park in Jujuy and oil production in Brazil and Venezuela stand out. There are also loans for infrastructure (18%), others (11%) and mining (1%) (Gallagher & Myers, 2021). Infrastructure's second most financed item refers to constructing bridges and roads throughout the region for communication and the movement of imported Chinese goods and raw materials for export.

4.2 PRoC and the Slow Transformation of the Energy Matrix in Latin America

The hottest year in the last decade was 2020, despite the COVID-19 confinement achieving a 17% reduction in Greenhouse Gas Emissions (GHG) (IDB, 2021). The concentration of GHGs in the atmosphere has been the highest since 2016. The United Nations Environment Programme revealed that even with the national mitigation commitments adopted by nations, global temperatures could rise by 2.7 °C by the end of the twenty-first century (IPCC, 2022).

The Paris Agreement goal by 2030 is a global temperature rise of no more than 1.5 °C. As far as possible, it would avoid irreparable damage on a climatic-ecological, social and economic level. To this end, the United Nations developed a series of tools to guide countries' actions.

The United Nations Millennium Declaration adopted in September 2000 contains eight goals (the Millennium Development Goals – MDGs) aimed primarily at reducing poverty, improving health and sanitary conditions and counteracting environmental degradation. The basis for the goals is the standards set in 1990, with the targets to be achieved by 2015, as poverty contracted by half and infant mortality rates lowered. However, the agenda was too general, and although it included the term "sustainable development", there were few concrete actions in practice.

In 2015, the United Nations General Assembly approved the 2030 agenda for sustainable development with Sustainable Development Objectives (SDOs), envisaging achieving the unfinished goals. This agenda, signed by 193 countries, contains 17 more specific goals that help nations achieve their social, economic and climate goals.

The international community expected the United States to lead the fight against climate change, like the fight for democracy or international security, but this has not been the case. Between Democratic administrations asserting their commitment to the environmental cause and Republican administrations refusing to ratify agreements, the country has lost the lead in this area. On the other hand, PRoC's commitment to environmental policies has been taken seriously since 1973 at its first national conference on environmental protection. This conference laid the foundation for her environmental policy, which by 1989 had in place an environmental protection law.

The World Bank published a report known as *Clear Water Blue Skies* (1997), which shows for the first time how costly pollution is. It delves into the costs of pollution in PRoC today. Will future economic growth impair or improve air and water quality? Moreover, what policies are needed to ensure that rising incomes translate into a higher environmental standard of living for current and future generations? This report was the first to suggest adaptation measures such as improving energy efficiency, diversifying energy sources and substituting coal within households.

Some of the report's findings were that particulate and sulphur levels in major Chinese cities are among the highest globally, exceeding World Health Organization and Chinese standards by two to five times (1997, 1). They also found pollution as one reason chronic obstructive pulmonary emphysema and chronic bronchitis have become the leading causes of death in PRoC, with a mortality rate five times that in the United States (1997, 2). Acid rain in the high-sulphur coal regions of southern and southwestern PRoC threatens to damage 10% of the land area and may already have reduced crop and forestry productivity by 3%. The overall picture of PRoC forced the country to take policies to correct the problems and, in the process, become the manufacturer of renewable energy technology, electric mass and private transport (*Clear Water Blue Skies* 1997) (see https://www.researchgate.net/publication/286933823_Clear_Water_Blue_Skies_PRoC's_Environment_in_the_New_Century).

In 2002, the Chinese government ratified the Kyoto Protocol, which initiated carbon emissions monitoring campaigns in PRoC. In 2005, the PRoC and the European Union established a climate change partnership (EU, 2005) that mainly aimed at promoting clean energy sources, energy efficiency, energy conservation and renewable energy. In 2006, the PRoC adopted two pollution-related targets in the 11th Five-Year Plan (2006–2010), and since then, the following five-year plans have included the most recent (Five-Year Plan XIII 2016–2020) climate mitigation measures. In 2013, as part of ASEAN+3, the Asian dragon committed to the Strategic Plan for the Environment, which promotes an institutional framework to integrate national procedures and policies, information registration and statistics by country in order to strengthen institutions and international agreements on the protection of ecosystems (Michel, 2014).

In 2016, PRoC ratified the Paris Agreement. However, Xi's speech at the 75th United Nations Assembly in September 2020 is considered the most ambitious climate commitment of the Asian giant (and the international community) on the issue; the Chinese president said:

> We human beings can no longer ignore nature's repeated warnings, nor stubbornly follow the outdated path of pursuing only development and exploiting nature, without paying attention to environmental protection and restoration […]. PRoC will increase its nationally determined contributions and adopt more effective policies and measures to peak CO2 emissions by 2030 and realize carbon neutrality by 2060. (Jinping, 2020)

The Asian economy is the largest investor in renewable energy globally, investing USD 102 billion in domestic generation in 2015 alone. PRoC is currently the world's leading manufacturer of solar panels, one of the largest manufacturers of wind turbines, and a prominent mass transit vehicle industry (Daley, 2018).

With Donald Trump's presidency, US liberal leadership declined sharply. His exit from the Paris Agreement cleared the way for the Asian Giant to position itself as a leader on climate change. Although, in 2021, the Biden administration brought the United States back into the Agreement and stated that it would seek leadership in this area, PRoC has the technology and financial capacity to assert itself as a leader in renewable energy.

4.2.1 Goals 7 and 9: Access to Sustainable, Safe, Clean Energy; and Industry, Innovation and Infrastructure

Latin America and the Caribbean are particularly vulnerable to natural disasters like hurricanes and droughts. In the coming years, heatwaves, floods and forest fires will put crop yields and transportation on the continent at serious risk (UN, 2020). Rising sea levels could also compromise Central America and the Caribbean territories and the population's access to primary resources such as food and energy.

With this scenario, Latin America and the Caribbean need to look for options to satisfy their energy demand while contributing to their climate mitigation goals.

Since 2000, energy demand in Latin America started to increase, and in 2010, this growth became more evident in Chile, Mexico and Brazil (Ding & Mano, 2021). However, the region still has severe problems of energy poverty, which is especially evident in rural areas and mainly affects the female population.

Electricity production sources on the supply side and public transport on the demand side are responsible for 62% of CO_2 emissions in Central and South America (ECLAC, 2021). Diversification, digitalization of the energy matrix, investment in new infrastructure and improved energy efficiency are essential.

The clean energy matrix in Latin America is mainly composed of hydropower. For governments in the region, the renovation and maintenance of these plants is a viable option for energy production. In the short term, this is a problem, as the periods of drought expected in the coming years will be longer, putting hydroelectric supply at risk in highly dependent countries such as Argentina, Peru, Brazil, Costa Rica, Ecuador and Paraguay (Calvo et al., 2021).

Hydroelectric plants are followed by solar and wind energy, which in 2020 represented a total investment of almost USD 20 billion (Bloomberg, 2022). Chile is the country with the most solar plants, most of which are in the Atacama Desert, followed by Brazil and, finally, Mexico with two solar plants: the Villanueva solar plant in Coahuila, considered the largest in Latin America with 2400 hectares, and the "El Llano" solar park in Aguas Calientes with 800 hectares. This last one operates under the management of French company Neoen, and its construction and maintenance belong to the Chinese company Synohydro, a subsidiary of the giant PowerPRoC (Neoen, 2022).

In 2020, Brazil produced the most energy from wind sources (17,198 megawatts), Mexico with 8128 megawatts and Argentina and Chile with 2624 megawatts and 2149 megawatts, respectively (Ember, 2022). However, this is a tiny part of the energy production of these countries. The green hydrogen industry is gaining importance in Latin America, with Mexico, Peru, Costa Rica, Argentina and Colombia being the countries with the potential to create this fuel. By 2025 the hydrogen market will reach US$ 2940 million (Markets, 2021), and Latin America will be able to satisfy its consumption and export it to Europe and Asia.

The region lacks the budget and technology to implement clean energy investments and initiatives on its own to move entirely away from dependence on fossil fuels, forcing it to diversify its options. Formerly financed by the United States and the EU, Latin America has become essential among PRoC's FDI destinations in the last decade. Initially, oil-related investments went to countries such as Venezuela and Brazil. From 2010 onwards, PRoC stopped being interested in buying only raw materials and hydrocarbons from the region and started to make loans and investments in other sectors. Between 2010 and 2016, the PRoC invested an average of USD 10817 million per year (Merino, 2019), and Chinese banks lent the region USD 35 billion (Dussel Peters et al., 2018).

The principal targets for Chinese investment in renewable energy are Argentina, Brazil, Bolivia, Chile and Peru. Most of this investment has been in the hydropower sector. The Chinese company Three Georges operates 17 hydropower plants in Ecuador, Bolivia, Chile and Brazil. In Argentina, constructing the Cóndor Cliff and Barrancosa dams had Chinese financing. By 2020, Chinese banks financed US$44 billion worth of hydropower projects worldwide (Gallagher & Myers, 2021). Solar energy also receives significant financing. In 2019, PRoC's

Import-Export bank provided $390 million to construct the Cauchari solar park in Jujuy, Argentina (Koop & Pike, 2019). PowerPRoC received a reciprocal concession to build two other solar projects (Cura Brochero and Villa María del Río Seco).

In the last decade, PRoC became the leading trading partner of almost all South American countries and signed free trade agreements with Chile (2005), Peru (2009) and Costa Rica (2010) (Benedictis, 2019) (see http://fta.mofcom.gov.cn/english/fta_qianshu.shtml). Its investments range from infrastructure, technology, to renewable energy. The Asian Development Bank and the Export-Import Bank of PRoC became Latin America's largest creditors between 2005 and 2015. They lent the region around USD 125 billion, of which 29.5% went to infrastructure, 16.5% to transport and 12.4% to hydropower. By 2020, trade between the PRoC and Latin America will go from USD 12 billion to USD 315 billion (Prazeres et al., 2021) and reach USD 700 billion by 2035, accounting for 25% of the region's trade (Prazeres et al., 2021).

4.3 PRoC: The Leading Foreign Investor in Latin America

The dynamism showed by Chinese firms in the American continent in the 2005–2020 period differs from the arrival of US firms that bought British firms initially and then invested; nor of the UK that essentially concentrated in railroads, mining, agriculture and banking and later in telephones and telegraphs (Miller). The current wave of globalization has speeded up the internationalization of capital and more so for Chinese capital and firms entering Western countries, more specifically Latin America. The data have four sections: North America, Central America, The Caribbean Islands and South America. The first five tables are the total amounts invested by rank from largest to smallest, by country, sector and within the energy sector, the total by country, fossil fuel and renewables.

The first evidence is the size of the investments and the number of operations by country (see Table 4.1). According to investment ranges, the total investment of 457 billion dollars spreads over 24 countries divided into 5 tiers. The first tier of three countries: the United States, followed by Brazil and Canada, has average investments of US$ 108 billion, with Canada having the least amount in the group, at US$ 58 billion. This group concentrates two-thirds (461) of all 685 individual investments in the Americas. The United States and Canada add 374 individual investments, half of the total in the continent. The next tier of two South American countries, Peru and Argentina, averages 26 billion each and 60 individual investments. The third tier has an average of 16 billion per country: Venezuela, Chile and Ecuador, and hold 72 individual investments. The fourth tier of eight Caribbean Basin countries has an average of US$ 3.3 billion, including Colombia, Bolivia, Mexico, Jamaica, Guyana, Panama, Trinidad y Tobago, Antigua y Barbuda and 76 investments. The last tier of eight countries from Central America and The Caribbean, plus Uruguay, have a meagre US$ 519 million-dollar average investment, with Uruguay receiving a tiny US$ 180 M and adding up to only 14 investments. All Caribbean Basin countries are in the under US$ 10 billion investment range, except Venezuela; that is to say, they are not significant countries for investment.

When the investment size per operating unit is measured (Table 4.2), Chile and Peru mining countries stand out with an average of US$ 1068 M each per investment unit. The mining activity has the largest firms. A second tier follows with seven countries; Brazil, Canada, Colombia, Venezuela, Guatemala, Argentina and the United States, where fossil fuel energy is essential and the average investment per unit is US$ 737 M, second most significant to mining and barely under the size of the mining companies. The third tier of 16 countries ranging from Antigua and Barbuda islands to Barbados, including Ecuador and Mexico, have investment averages per unit of only 302 million, with a range

Table 4.1 PRoC Buyout and green investments in the Americas by country, 2005–2022

	Country	Buyouts	Investments MUSD	Including green investments
1	USA	302	$193.250	44
2	Brazil	87	$73.750	16
3	Canada	72	$57.900	16
4	Perú	26	$28.430	3
5	Argentina	34	$23.230	4
6	Venezuela	28	$19.770	4
7	Chile	15	$15.650	6
8	Ecuador	29	$14.260	2
9	Colombia	8	$6.230	2
10	Bolivia	18	$5.060	0
11	México	17	$4.170	8
12	Jamaica	7	$2.960	0
13	Guyana	8	$2.750	2
14	Panamá	7	$2.390	0
15	Trinidad y Tobago	9	$2.280	0
16	Antigua y Barbuda	2	$1.000	1
17	Costa Rica	3	$810	0
18	Cuba	3	$740	1
19	Guatemala	1	$700	0
20	Nicaragua	2	$530	1
21	Barbados	3	$490	0
22	Honduras	1	$350	0
23	Bahamas	2	$350	2
24	Uruguay	1	$180	0
	Total	685	$457,230	112

Source: AEI PRoC Global Investment Tracker

from US$ 163 M in Barbados to US$ 500 in Antigua and Barbuda passing through Mexico with US$ 245 M, Bolivia with US$ 281 M and Ecuador US$ 492 M. The most significant average unitary investments are in polluting fields like mining and fossil fuel extraction.

The number of individual investments (Table 4.3) is most prominent in the highly polluting energy sector, 181; followed by transport, 107; highly polluting metal mining, 60; followed by real estate, finance, technology and other non-polluting activities with 11 investments in the chemical industry, also highly polluting. There are 685 Chinese FDI in the American continent, 252 pollute and the other 433 are non-polluting, like real estate and finance, or mildly so, like agriculture.

However, the proportion invested in the energy sector is only 21% of the total invested in 2005–2022 (Appendix I). The distribution of investments in the energy sector starts in Brazil with the most considerable total amount invested and the most significant number of individual investments. Canada, the United States and Venezuela are fourth in number and volume. Ecuador and Argentina come next in the volume of investments and are in 10 to 20 individual investments. The United States has 20, Canada has 23 and Brazil has 26. The low end in the energy sector starts with Peru, Mexico and Colombia, followed by Guyana, Bolivia and Chile, with very few investments.

Table 4.4 shows that energy investments in Canada concentrate mainly on oil and gas, like in Brazil and the United States. However, in Venezuela, there are two investments in coal, with twice the amount in gas investment, which is very polluting. There are no coal investments in the rest of Latin America save Colombia, with a tiny coal mine. It has no investments in any fossil fuels in Peru.

Table 4.2 PRoC's average amount invested by country per operating unit, 2005–2022

Amount invested MUSD	No. of investments	Amount invested MUSD	Average investment per unit MUSD
Peru	26	$ 28.430	$ 1.093
Chile	15	$ 15.650	$ 1.043
Brazil	87	$ 73.750	$ 848
Canada	72	$ 57.900	$ 804
Colombia	8	$ 6.230	$ 779
Venezuela	28	$ 19.770	$ 706
Guatemala	1	$ 700	$ 700
Argentina	34	$ 23.230	$ 683
USA	302	$ 193.250	$ 640
Antigua y Barbuda	2	$ 1.000	$ 500
Ecuador	29	$ 14.260	$ 492
Jamaica	7	$ 2.960	$ 423
Honduras	1	$ 350	$ 350
Guyana	8	$ 2.750	$ 344
Panamá	7	$ 2.390	$ 341
Bolivia	18	$ 5.060	$ 281
Costa Rica	3	$ 810	$ 270
Nicaragua	2	$ 530	$ 265
Trinidad y Tobago	9	$ 2.280	$ 253
Cuba	3	$ 740	$ 247
México	17	$ 4.170	$ 245
Uruguay	1	$ 180	$ 180
Bahamas	2	$ 350	$ 175
Barbados	3	$ 490	$ 163
Total	685	$ 457.230	

AEI PRoC Global Investment Tracker

Table 4.3 PRoC Buyout and green investments in the Americas by sector, 2005–2022

Amount in MUSD	No. of investments	Amount in MUSD
Energy	181	$175.630
Transport	107	$54.460
Metals	60	$45.810
Real estate	85	$40.440
Finance	37	$26.270
Technology	37	$25.770
Tourism	29	$22.880
Other investments	40	$17.220
Entertainment	32	$16.210
Agriculture	21	$14.130
Health	30	$8.780
Chemicals	11	$5.270
Logistics	6	$2.790
Utilities	9	$1.470
Total	685	$457.130,00

AEI PRoC Global Investment Tracker

Table 4.5 reflects renewable energy investments, where the total of USD$ 29 billion is only 38% of the amount in fossil fuels and 21% of the total invested in energy. The list of countries where PRoC invests in renewables differs in importance from the list of fossil fuels. There are two tiers of data range of total investments: The first tier includes countries between US$10 and US$1 billion invested amount. It includes Brazil, Argentina, Ecuador, Peru, Bolivia, the United States and Venezuela as target countries, with Brazil having the most investments and the most considerable amount, with more money placed in alternative energy than in hydroelectricity. The opposite is true for Argentina, Ecuador, Bolivia and Venezuela. In the United States, the six investments are in alternative energies. The second tier holds Cuba, Panama and Canada as alternative energy targets with under 1 billion investments. Colombia, Guayana, Chile and Honduras have investments concentrated in hydroelectricity. Electricity distribution is in the alternative category.

PRoC's first alternative energy investment project was in Japan in 2006, followed in 2009 by another in the Czech Republic, in 2010 in Italy, and in 2011 in Australia, Tanzania, Canada, the United States and Pakistan. At the start of 2012 was in Chile, the United States, Thailand, Germany, Turkey and Portugal. In 2013, Malaysia, Ethiopia, Romania and Poland. In 2014, Kuwait, Zimbabwe, Ghana, Poland, Pakistan, Norway, Russia and Brazil. Latin America took off as a target market for alternative energies in 2015 with Argentina and Brazil. In 2016, it created Vive Energia with 50% of the shares in Mexico and 100% in Brazil, Argentina and Chile. In 2017, only in Argentina. In 2018, Cuba, Argentina, Brazil and Mexico were the target. In 2019, Argentina and Brazil. In 2020, Panama, Argentina, Brazil and Chile. There is a clear trend where they started investing in alternative energies worldwide and taking on Latin America starting in 2015, with Chile first in 2012

Table 4.4 Investments in fossil fuel energy by the PRoC firms, 2005–2022

		Total	Total	Investments in:					
		Number of investment	Amount in MUSD	Oil	Amount in MUSD	Gas	Amount in MUSD	Coal	Amount In MUSD
1	Canada	21	$22.890	14	$14.900	7	$7.990	0	$0
2	Brazil	14	$22.830	8	$18.820	5	$3.580	1	$430
3	USA	14	$11.420	9	$6.130	5	$5.290	0	$0
4	Venezuela	10	$8.800	7	$5.300	1	$1.040	2	$2.460
5	Ecuador	7	$3.070	7	$3.070	0	$0	0	$0
6	Colombia	3	$1.650	1	$430	1	$980	1	$240
7	México	2	$1.390	2	$1.390	0	$0	0	$0
8	Guyana	2	$1.330	2	$1.330	0	$0	0	$0
9	Argentina	4	$950	1	$330	3	$620	0	$0
10	Jamaica	1	$760	1	$760	0	$0	0	$0
11	Trinidad y Tobago	1	$320	1	$320	0	$0	0	$0
12	Nicaragua	1	$230	1	$230	0	$0	0	$0
	Total	**80**	**$75.640**	**54**	**$53.010**	**22**	**$19.500**	**4**	**$3.130**

Source: AEI PRoC Global Investment Tracker

Table 4.5 Investments in renewable energy by PRoC firms, 2005–2022

		Total no. of investments	Amount in MUS$	Total no. in alternative energy	Amount in MUSD	Total no. in hydroelectric	Amount in MUSD
1	Brazil	12	$9.190	6	$2.310	6	$6.880
2	Argentina	9	$6.010	7	$1.990	2	$4.020
3	Ecuador	8	$5.050	0	$0	8	$5.050
4	Perú	4	$2.620	0	$0	4	$2.620
5	Bolivia	3	$1.420	0	$0	3	$1.420
6	USA	6	$1.380	6	$1.380	0	$0
7	Venezuela	1	$1.080	0	$0	1	$1.080
8	Chile	5	$950	3	$550	2	$400
9	Guyana	1	$510	0	$0	1	$510
10	México	3	$510	3	$510	0	$0
11	Canada	2	$410	2	$410	0	$0
12	Honduras	1	$350	0	$0	1	$350
13	Colombia	1	$230	0	$0	1	$230
14	Cuba	1	$140	1	$140	0	$0
15	Panamá	1	$110	1	$110	0	$0
	Total	**58**	**$29.960**	**29**	**$7.400**	**29**	**$22.560**

Source: AEI, PRoC Global Investment Tracker and the first investment in Brazil in 2014. The list above does not include the rest of the world starting from 2015.

4.4 A Review of Chinese Investments in Six Countries

The detailed analysis of where and in what PRoC invests in terms of the SDO 7 and 9 will allow a balance of the penetration strategies by Chinese FDI in the six largest economies in Latin America: Argentina, Brazil, Chile, Colombia, Mexico and Peru are the six selected and presented in that order. The six countries where PRoC has the most significant investments are another subset of countries: Argentina, Brazil, Perú, Venezuela, Chile and Ecuador. The economies that differ are Ecuador and Venezuela. The other four are the same: Brazil, Peru, Argentina and Chile. The two large economies where PRoC has invested little are Mexico and Colombia, both in the Caribbean Basin.

Table 4.6 Summary of investments by sector of activity, Argentina, 2005–2022

Type of activity	Number of investments	Amount of investments in millions of US dollars
Energy	15	12,530
Transport	5	6520
Metal mining	4	1690
Finance	4	1060
Technology	2	500
Agriculture	1	350
Real estate	1	280
Utilities	1	190
Chemicals	1	110
Total	34	23,230

Source: AEI PRoC Global Investment Tracker

4.4.1 Argentina

Argentina, the second-largest economy in South America and the third-largest in Latin America, is a prominent and promising economy with a highly qualified and educated labour market, an upper-middle-income economy, extensive grain-growing plains and mineral resources. Chinese investment in Argentina gears around the energy sector, and the relevance of renewable energy is evident as the total invested in energy adds US$ 12,530, over half the investment in the country (see Table 4.6). It has two equal shares of US$ 6520 million in fossil fuels and US$ 6010 million in renewables (see Appendix I). Renewable alternative energy generated 10.42% of the total energy in Argentina (Ember Report, 2021). Most Chinese energy investments are in renewables, and only one-quarter is in the fossil fuel field.

Four mines, three lithium and one gold in the country are highly polluting activities. The invested amounts are meagre, where the gold mine is larger than the three lithium mines. The balance is that most Chinese investments in Argentina are not pollutants, but those in fossil fuels and mining are highly so. The mining activities primarily relate to lithium batteries for electric vehicles, while the gold mine relates to hoarding or domestic industrial use.

4.4.2 Brazil

Brazil is the largest economy in Latin America and the most populated country, and the number 12 in the list of countries by GDP size (WB Gross domestic product 2020 – World Bank DataBank). It covers half of the South American territory, making it a continent country like the United States, PRoC, Russia, Canada and Australia. With 212 million people, it is the largest domestic market, followed by Mexico. PRoC is the country's leading trading partner and leading foreign investor. The amount placed in the country seconds the amount placed in the United States and is three times as large as the investments in Peru that follow in importance in Latin America (Table 4.1). Energy is ten times more important than the following field of interest in the country, transport, and has 411 individual investments. Metal mining is critical in third place with less than one-tenth in energy and seven investments; and less than transport with 13 individual investments. Agriculture is an area of interest, with less

Table 4.7 Summary of investments by sector of activity, Brazil, 2005–2022

Type of activity	Number of investments	Amount of investments in millions of US dollars
Energy	41	54,730
Transport	13	5440
Metal Mining	7	4850
Agriculture	6	3280
Finance	7	1670
Chemicals	1	1540
Real Estate	7	1140
Logistics	1	460
Technology	3	450
Utilities	1	190
	87	73,750

Source: PRoC Global Investment Tracker

than 7% of the amount put into energy and six investments.

The energy sector divides into two: (1) fossil fuels, oil, gas and coal; and (2) alternative renewables, hydroelectricity and electricity distribution (Table 4.7). The groupings show electricity distribution with the most investment, US$ 22,710, followed by oil with US$ 18820 M, hydroelectricity with US$6880 M, gas with US$ 3580 M, and alternative energies have a small amount of US$ 2310 M. The clean side of energy includes hydroelectricity, distribution and alternative renewables and adds up to US$31900 M, which is 58% of the amount put into energy. Renewable alternative energy generated 13.23% of total electricity generation in Brazil (Ember Report, 2022). The mining sector is of interest to PRoC in this country, as they export 65% of all the iron ore imported by the Asian country. Most of the investments in Brazil are non-polluting, and those in the energy industry are heavily biased towards distribution.

4.4.3 Chile

Chile reached a free trade agreement with PRoC in 2005, a small, high-income country with a small population, which opened up trade and investment possibilities. The energy sector leads the 15 investments PRoC has in the Southern Cone country that add up to 15 billion USD. Energy follows metals, agriculture, transport, health and technology. The amount is not large, but the investment's quality shows they are on the non-polluting side of energy creation and distribution. They have bought up a significant share of electricity distribution in that country from essentially a Spanish firm and two US MNCs. Chile, in 2021, generated 21.44% of its electricity from alternative sources.

Half of the total investments have gone into renewable energy generation and distribution. The real difference went into lithium mining associated with Sociedad Quimica y Minera de Chile. It is a very polluting activity in the mine, but the purpose of lithium is to create batteries for electric cars, so downstream, it is a clean activity. The other investments in the country are non-polluting and small. There is a carmaker. PRoC Railways invested US$ 800 to manufacture train cars for the Santiago Metro and the national train system. It is non-polluting as trains are electric and high-tech Chinese-made. Overall, PRoC's investments in Chile are the second largest per investment unit, non-polluting and clean energy orientated.

4.4.4 Colombia

A large country with a massive population, Colombia is number nine as a destination for Chinese FDI, but it is the fourth-largest economy after Brazil, Mexico and Argentina and the third most populated country in Latin America with 50 million people. The negotiation started in 2012 for an FTA with PRoC but derailed and obtained instead a US-Colombia trade promotion agreement that same year. Colombia is an exception in South America as its leading trading partner is the United States and not PRoC, possibly because they are in the Caribbean Basin and orientated towards the United States. It might explain the tiny amount invested in a country of that size in the energy sector.

Colombia has four energy investments in the country divided into each energy category: gas, oil, coal and hydroelectricity. The most significant amount is in gas in association with Total of France; the others are in the association. The coal mine is entirely theirs, with an investment of 240 million dollars. These are more polluting investments in energy than elsewhere (see Appendix).

The last sector is interested in transport, with a total of US$ 4.3 billion into railroads to serve Bogota and surrounding towns, plus Bogota's Metro system and the improvements of transport to ports. A 260 million dollars in road building under PPP schemes make up the balance. Clean energy generation with wind and solar equipment weighs only 0.36% of the total, and 65.71% comes from hydroelectric and bioenergy. The lack of Chinese investments in clean energies reflects the lack of importance of new alternative energies for the country.

4.4.5 Mexico

Mexico is the second-largest economy in Latin America, the second most populated country in the region, and the fifteenth economy in the world in terms of GDP in dollars. It has had an FTA with the United States since 2020, which prohibits it from having one with PRoC and other non-market countries. Chapter 32, article 32.10 of Mexico, Canada US Trade Agreement, Non-Market Country FTA, states, "5. Entry by a Party into a free trade agreement with a non-market country will allow the other Parties to terminate this Agreement on six months' notice and replace it with an agreement between them (bilateral Agreement)" (Agreement between the United States of America, the United Mexican States, and Canada 7/1/20 text seen on https://ustr.gov/trade-agreements/free-trade-agreements/united-states-mexico-canada-agreement/agreement-between) The country has an export structure centred in the United States and is the primary recipient of US FDI in Latin America. (https://www.bea.gov/data/intl-trade-investment/direct-investment-country-and-industry).

Table 4.8 Summary of investments by sector of activity, Mexico, 2005–2022

Type of activity	Number of investments	Amount of investments in US$ millions
Energy	6	2260
Metals	4	620
Other investments	2	560
Transport	2	210
Logístics	1	220
Chemicals	1	200
Tourism	1	100
	17	4170

AEI PRoC Global Investment Tracker

The country ranks in eleventh place after Colombia for Chinese FDI. It holds only 4 billion dollars versus 100 billion US investments, with 69% placed in energy and metals (see Table 4.8). The enormous energy investments in oil and smaller ones are associated with alternative renewables. These represent over half the total invested in the country, mostly in fossil fuels and highly polluting activities. Alternative energy does not appear relevant; a mere 14% of the total invested represented only 11.87% of the total electricity supply in 2020. The reduction in hydroelectricity pushed fossil-fuelled electricity up to 80% of the total generated. Investment in metals adds to 620 million dollars and spreads into four units, two dedicated to copper production and two to lithium clay. The two lithium investments are exploratory, as a true lithium mine would take up large amounts of money. There is also one investor in the car industry producing the JAC brand and one producer of spare parts, Jiangnan Mould and Plastic, that supply BMW, Mercedes Benz and Volkswagen.

4.4.6 Peru

The Andean country is the smallest in terms of GDP size among the six largest countries in Latin America, excluding Colombia. It has experienced a fast growth in GDP per capita from 2000 to

2020, but it faces a significant challenge due to a vast informal sector. This means that employment generation remains limited despite economic growth as the primary sector generates export revenues with minimal production chains inside the country. The engine of the economy is the mining sector. Brazil is the country in Latin America with the most Chinese investment (Table 4.1). It is almost more significant than Argentina and Venezuela, double neighbouring Chile, and seven times the investments in Colombia and Mexico.

Chinese investments in the Andean country are centred first on metal mining and energy (see Table 4.9). The first Asian mining investment made was a buyout by Shougang of the Marcona Mining Company iron ore mine in the 1990s. It had massive worker resistance at the time due to the deterioration of the labour conditions. The firm continues operating and using the port of San Juan in the South of the country to embark on its iron ore pellets. The massive arrival of these Asian investments happened after 2007 and went directly into the mining sector, where they concentrated on copper and iron ore.

Even though Shougang was the first to arrive and discover the mining sector to their investors, the most significant investment to date was when the Chinese consortium made up of PRoC Minmetals, Suzhou Guoxin, PRoC International Trust and Investment (CITIC), bought the Las Bambas copper mine in Peru from Glencore Xstrata for US$6 billion. This particular mine had had environmental conflicts since 2015, when it had just started. The communities there insist the environmental impact assessment study made was wrong. Those communities involved propose environmental monitoring and surveillance of air, water and soil with the participation of communities and environmental civil society. There is a problem with water used in the mine that cannot be used in the agricultural activities of the neighbouring communities because they are heavily polluted. They demanded the construction of a sewage purification plant. After the glaciers melted in the Andes, the water problem was severe for peasant communities. Trucks transport the minerals to the port of Matarani and not a mining pipeline. A dust road facilitates the daily passage of approximately 300 trucks loaded with minerals, which causes – according to the protesters – an environmental impact in the area (dust, noise, vibrations, among others). This mine alone produces 20% of the copper Peru exports annually. (https://www.actualidadambiental.pe/las-bambas-cinco-puntos-claves-para-entender-el-conflicto/ 31 de Marzo, 2019).

Table 4.9 Summary of investments by sector of activity, Peru, 2005–2022

Type of activity	Number of investments	Amount of investments in US$ millions
Energy	7	9660
Finance	1	110
Logistics	1	230
Metals	10	15,790
Other investments	1	120
Transport	4	2010
Public services (utilities)	2	510
	26	28,430

Source: PRoC Global Investment Tracker

Chinalco bought the Toromocho copper mine and made three significant investments in 2007, 2008 and 2018, adding up to US$ 4.2 billion. The following most significant mining investment is in Pampa de Pongo for a total of US$ 2.4 by Zhongrong Xinda. It is a copper, cobalt, iron and gold polymetallic mine and covers 263 square kilometres. It will use block caving technology to prevent some environmental costs open-air mining has. The water and transportation of the minerals are the environmental issues affecting the communities. There are other mining venues for copper and iron, though these tend to be polymetallic in the Andes.

The following important sector is energy. The most significant energy investment is recent and is the purchase of Luz del Sur from its United States owners. It adds up to US$ 4.1 billion, followed by oil extraction, in a joint venture with Petrobras for US$ 2.9 billion. This very polluting activity is in the jungle in the South of Peru in the Cusco area. The oldest investment is in energy and hydroelectricity and was made in 2012 jointly with Energía Azul, a Spanish renewables firm. The total investment in hydroelectricity is

US$ 2.6 billion. The investment in fossil fuels is one-third of the total investment in energy.

4.5 Conclusions

Since 2015, Latin America has been an essential recipient of Chinese investments in developing alternative energies. The leading presence of PRoC as an investment partner of most South American countries, except Colombia, has made it a leading generator of renewable energy, lithium, copper and iron mining, and the development of electric mass urban transport. Brazil, especially, is the Latin American country that has received the most investments in developing electric vehicles and infrastructure. On the other hand, Peru, Argentina and Chile are the countries that report the most Chinese investments in the renewable energy sector.

PRoC invests in many fields, including energy, transportation, metal mining, real estate, finance, technology, tourism, other investments, entertainment, agriculture, health, chemicals, logistics and utilities; all friendly to the environment, except mining and oil, whose primary investments are in the United States and Canada.

About SDG 7, access to sustainable, safe and clean energy is a crucial point of the energy investments reviewed in the six countries, where only Mexico, stopped by its Free Trade Agreement with the United States and Canada, leaves the pattern. However, a small amount invested in fossil fuels demonstrates the importance of geography in international relations. The rest of the countries develop mainly renewable energy or energy distribution, with a significant hydroelectric and solar power concentration.

SDG 9 indicates that Chinese foreign investment deals with industry, innovation and infrastructure, almost exclusively through loans. FDI in railways in Chile and Colombia, as well as the inclusion of Argentina, Brazil, Colombia, Chile, Ecuador, Peru, Panama, Uruguay and Venezuela in PRoC's New Silk Road project, demonstrates this. FDI enters countries that allow them to operate in the fields of their interest. Lithium mining extraction in Mexico and Bolivia paints a clear picture. The other evidence is that countries with a vital commercial link to the United States and a severe political relationship – war on drugs, prominent, heavily equipped armies – with geographies in the Caribbean Basin are reluctant to establish stronger ties with the United States (IDB, 2013).

The purchase of US companies in South America by Chinese firms resembles the 1940s and 1950s when US multinationals bought British companies in electricity generation. The speed of change in the energy matrix is much slower than the speed with which hydroelectricity is reducing its participation in the Latin American energy matrix, and this could push more Chinese capital to the region, given that US capital does not have a strong presence in this field and Spanish companies seem to withdraw.

Under these premises, it is possible to affirm that PRoC is undoubtedly the leader in the change of the energy matrix in Latin America, even though the United States tries to counterbalance the Asian giant, and that China is a significant pollutant and coal user. In the long term, solar and wind power will likely replace hydroelectric due to the water problems facing Latin America, and likely by 2024, the most important cities in Brazil, Colombia, Argentina, Chile and Peru will have already replaced their fossil fuel transport with fully electric ones of Chinese origin.

The geopolitical tensions derived are seen in the frequent visits from State Department officials to some countries with financing offers to seek to counterweigh the available resources and the increasing, but limited role, of the IDB under the guidance of a former Special Assistant to US President Donald Trump and Senior Director for Western Hemisphere Affairs at the National Security Council. Other signs have the press campaign warning of a China debt trap and pressing former president of Ecuador Lenin Moreno to give up the use of Chinese communication technology in exchange for alleviating them from the "Chinese debt trap". Ecuador now owes the United States instead. Realist analysis points in the direction of more conflicts and tensions in this field.

Appendices

Appendix I: Chinese investment in the Energy Sector in Argentina, 2005–2022

Year	Investor	Quantity in millions of US$	Transaction party	Sector	Subsector
2010	PRoC National Offshore Oil (CNOOC)	3100	Brides	Energy	Oil
2010	PRoC Petroleum and Chemical (Sinopec)	2470	Occidental Petroleum	Energy	Oil
2011	PRoC National Offshore Oil (CNOOC)	330	ExxonMobil	Energy	Oil
2017	PRoC Energy Engineering	3660	EISA	Energy	Hydro
2019	PRoC Communications Construction	360		Energy	Hydro
2016	PRoC Communications Construction	390		Energy	Gas
2013	PRoC National Offshore Oil (CNOOC)	120	Total and Wintershall	Energy	Gas
2016	PRoC National Petroleum Corp. (CNPC)	110	Electro Ingeniería	Energy	Gas
2017	Power Construction Corp. (PowerPRoC), Jiangsu Zhongli	390		Energy	Alternative
2019	Xinjiang Goldwind	370		Energy	Alternative
2015	Power Construction Corp. (PowerPRoC)	300		Energy	Alternative
2016	Envision Energy	290		Energy	Alternative
2021	PRoC Energy Engineering	290		Energy	Alternative
2018	Power Construction Corp. (PowerPRoC)	210		Energy	Alternative
2019	State Administration of Foreign Exchange (SAFE)	140	YPF Luz	Energy	Alternative
		12,530			

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Appendix II: Chinese Investment in the Mining Sector in Argentina, 2005–2022

Year	Investor	Quantity in millions of US$	Transaction party	Sector	Subsector
2017	April	Shandong Gold	960	Barrick	Metals
2018	March	Nextview New Energy	270	Lithium X	Metals
2019	August	Jiangxi Ganfeng	260	Lithium Americas	Metals
2021	October	Tsingshan Holding	200	Eramet	Metals
Total			1690		

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Appendix III: Investments in the Energy Sector in Brazil, 2005–2022

Year	Investor	Quantity in millions of US$	Transaction party	Subsector
2010	PRoC Petroleum and Chemical (Sinopec)	7100	Repsol	Oil
2010	Sinochem	3070	Statoil	Oil
2021	PRoC National Petroleum Corp. (CNPC), PRoC National Offshore Oil (CNOOC)	2940	Petrobras	Oil
2021	PRoC National Offshore Oil (CNOOC)	2080	Petrobras	Oil
2015	Industrial and Commercial Bank of PRoC	2000	Petrobras	Oil
2013	PRoC National Petroleum Corp. (CNPC), PRoC National Offshore Oil (CNOOC)	1400	Petrobras, Shell and Total	Oil
2017	PRoC National Petroleum Corp. (CNPC)	120		Oil
2008	PRoC Investment Corporation (CIC)	110	OGX	Oil
2016	PRoC Three Gorges	3660		Hydro
2017	State Power Investment Corporation	2260		Hydro
2014	PRoC Three Gorges	390	Terra Novo	Hydro
2013	PRoC Three Gorges	250	Jari	Hydro
2018	PRoC Three Gorges	190		Hydro
2013	PRoC Three Gorges	130	Cachoeira-Caldeirao	Hydro
2006	PRoC Petroleum and Chemical (Sinopec)	1290	Petrobras	Gas
2016	PRoC Investment Corporation (CIC)	1090	Petrobras	Gas
2018	Shangdong Kerui	530	Metodo Potential	Gas
2016	PRoC Investment Corporation (CIC)	410		Gas
2020	State Power Investment Corporation	260		Gas
2005	PRoC International Trust and Investment (CITIC)	430	Brazil Power	Coal
2019	PRoC General Nuclear Power	1030	Actis	Alternative
2019	PRoC General Nuclear Power	780		Alternative
2016	PRoC National Machinery Industry (Sinomach)	150		Alternative
2014	PRoC Three Gorges	140	EDP	Alternative
2021	Power Construction Corp. (PowerPRoC)	110		Alternative
2015	BYD	100		Alternative
2016	State Grid	4910	CPFL	Distribution
2011	PRoC Petroleum and Chemical (Sinopec)	4800	Galp Energia	Distribution
2017	State Grid	3440	CPFL	Distribution
2015	State Grid	2200		Distribution
2010	State Grid	1720	Plena Transmissoras	Distribution
2016	PRoC Three Gorges, PRoC Development Bank	1200	Duke	Distribution
2014	State Grid	970	Electrobras	Distribution
2012	State Grid	940	ACS	Distribution
2012	State Grid	550	Copel	Distribution
2021	State Grid	520	CEE	Distribution
2015	PRoC Three Gorges	490	Triunfo Participacoes	Distribution
2016	State Grid	450		Distribution
2018	PRoC National Petroleum Corp. (CNPC)	300	TT Work	Distribution
2016	State Grid	110	Mato Grosso	Distribution
2016	State Grid	110		Distribution
		54,730		

Source: PRoC Global Investment Tracker

Appendix IV: Investments in the Metals Sector in Brazil

Year	Investor	Quantity in millions of US$	Transaction party	Sector
2005	PRoC Minmetals, MCC	240		Steel
2006	PRoC International Trust and Investment (CITIC)	340	ThyssenKrupp	Steel
2009	Wuhan Iron and Steel	400	MMX Mineracao	Steel
2009	PRoC Investment Corporation (CIC)	500	CVRD (Vale)	Steel
2010	East PRoC Mineral Exploration and Development Bureau (Jiangsu)	1200	Bernardo de Mello Itaminas	Steel
2019	PRoC Communications Construction	220		Steel
2011	Taiyuan Iron, PRoC International Trust and Investment (CITIC), PRoC BaoWu Steel (Baosteel)	1950	CBMM	Steel
	Total	4850		

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Appendix V: Investments in the Energy Sector in Chile

Year	Investor	Quantity in millions of US$	Transaction party	Subsector
2020	State Grid	3030	Naturgy	Distribution
2018	PRoC Three Gorges	240	Cornelio Brennand	Hydro
2020	Power Construction Corp. (PowerPRoC), PRoC Three Gorges	160		Hydro
2019	State Grid	2230	Sempra	Distribution
2018	Southern Power Grid	1300	Transelec	Distribution
2021	Power Construction Corp. (PowerPRoC)	220	EDF and AME	Alternative
2012	Xinjiang Goldwind	190	Mainstream Renewable Power	Alternative
2016	State Power Investment Corporation	140		Alternative
	Total	7510		

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Appendix VI: Investments in the Metals Sector in Chile

Year	Investor	Quantity in millions of US$	Transaction party		Subsector
2018	Chengdu Tianqi	4070	Sociedad Quimica y Minera	Metals	Lithium
2010	Shunde Rixin, PRoC Minmetals	1910		Metals	Steel
2016	Chengdu Tianqi	210	Sociedad Quimica y Minera	Metals	Lithium
	Total	6190			

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Appendix VII: Investments in the Transport Sector in Colombia

Year	Investor	Quantity in millions of US$	Transaction party	Sector	Subsector
2021	PRoC Communications Construction-led consortium	3790		Transport	Rail
2015	PRoC Communications Construction	260		Transport	Cars
2020	PRoC Communications Construction	160		Transport	Rail
2020	PRoC Railway Construction	140		Transport	Rail
	Total	4350			

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Appendix VIII: Investments in the Energy Sector in Colombia

Year	Investor	Quantity in millions of US$	Transaction party	Subsector
2012	Sinochem	980	Total	Gas
2006	PRoC Petroleum and Chemical (Sinopec)	430	Omimex	Oil
2011	PRoC National Machinery Industry (Sinomach)	240		Coal
2018	PRoC Three Gorges	230	EDP	Hydro
	Total	1880		

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Appendix IX: Investments in the Energy Sector in Mexico

Year	Investor	Quantity in millions of US$	Transaction party	Sector	Subsector
2016	PRoC National Offshore Oil (CNOOC)	1110		Energy	Oil
2021	PRoC Petroleum and Chemical (Sinopec)	360		Energy	Oil
2013	PRoC Petroleum and Chemical (Sinopec)	280	Mexican Petroleum	Energy	Oil
2019	Risen Energy	230		Energy	Alternative
2019	Power Construction Corp. (PowerPRoC)	180	Neoen	Energy	Alternative
2016	Envision Energy	100	Vive Energia	Energy	Alternative
	Total	2260			

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Appendix X: Investments in the Metal Mining Sector in Mexico

Year	Investor	Quantity in millions of US$	Transaction party	Sector	Subsector
2008	Jinchuan Group	210	Tyler Resources	Metals	Copper zinc
2021	Jiangxi Ganfeng	210	Bacanora	Metals	Lithium
2007	Golden Dragon	100		Metals	Copper
2019	Jiangxi Ganfeng	100		Metals	Lithium
	Total	420			

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Appendix XI: Investments in the Metal Mining Sector in Peru

Year	Investor	Quantity in millions of US$	Transaction party	Sector	Subsector
2014	PRoC Minmetals, Suzhou Guoxin, PRoC International Trust and Investment (CITIC)	6950	Glencore	Metals	Copper
2008	Aluminum Corporation of PRoC (PRoClco)	2160		Metals	Copper
2018	Aluminum Corporation of PRoC (PRoClco)	1300		Metals	Copper
2007	Aluminum Corporation of PRoC (PRoClco)	790	Peru Copper	Metals	Copper
2007	PRoC Minmetals, Jiangxi Copper	450	Northern Peru Copper	Metals	Copper
2007	Zijin Mining, PRoC Nonferrous Metal Mining, Xiamen C&D	190	Monterrico	Metals	Copper
2018	Zhongrong Xinda	2360	Pampa de Pongo	Metals	Steel
2009	Shougang Group	990		Metals	Steel
2017	Shougang Group	500	Hierro	Metals	Steel
2009	Nanjinzhao	100	Cardero	Metals	Steel
	Total	15,790			

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Appendix XII: Investments in the Energy Sector in Peru

	Investor	Quantity in millions of US$	Transaction party	Sector	Subsector
2013	PRoC National Petroleum Corp. (CNPC)	2890	Petrobras	Energy	Oil
2018	PRoC Three Gorges	1390	Odebrecht	Energy	Hydro
2012	PRoC Energy Engineering	900	Energia Azul	Energy	Hydro
2017	PRoC Three Gorges	220		Energy	Hydro
2017	PRoC Three Gorges	110		Energy	Hydro
2019	PRoC Three Gorges	3590	Luz del Sur	Energy	Distribution
2021	PRoC Three Gorges	560	Luz del Sur	Energy	Distribution
	Total	9660			

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Part II

Oil and gas dilemmas: Income Dependency and Barriers to Energy Transition

5 The Dispute for Mexico's Energy Transition Under Dependent Conditions. A Critical Energy Studies Approach

Daniel Sandoval Cervantes

5.1 Introduction

The starting point for the analysis lies in the conceptualization of energy systems as sociotechnical systems (Van der Graaf & Sovacool, 2020), which allows energy studies to incorporate not only the technical and technological dimensions of decarbonization processes but also the social dimension, which considers the role of ideology and, within it, the regulatory framework. The critical energy studies literature has pointed out that this concept does not account for unequal power relations, both at the national level and at the level of the international division of labor (Newell, 2021; Mälm, 2018). Therefore, it does not take into account a crucial condition in the formation of energy systems, nor does it allow for adequate consideration of the mutually constitutive relationship between capitalism and fossil fuel-dominated energy systems (Di Muzio, 2015).

In this sense, the concepts of fossil capitalism (Mälm, 2012) aka petrol-market civilization (Di Muzio, 2015; Trommer & Di Muzio, 2015) constitute an advance from which our work benefits since they allow us to take into account the relationship between capitalism and fossil fuels. Within this critical perspective, it also seems important to highlight Mälm's (2018) analysis of the long waves of the economy, in which he relates the technological changes in the generation and consumption of energy with the transformations of the relations of production (organization of labor) and with the international division of labor. This is key to understanding both the way in which Mexico is inserted into the global energy markets as well as how the insertion imposes limitations on the possibility of an autonomous energy policy and, therefore, on an energy transition model that equitably considers the social, economic, and energy needs of the communities.

The foregoing articulates with studies that, considering the antagonistic interests between developed and developing countries, address the analysis of the regulation of energy systems through the concept of complex regulatory regimes (Alter & Raustalia, 2018; Newell, 2021). These studies indicate that the fragmented nature of regulation and, above all, the regulatory gaps are not the product of chance but, rather, of the centrality of the antagonistic interests of the most important actors. In particular, regarding access to oil and other fossil fuels using the traditional and still dominant concept of energy security (Cherp & Jewell, 2014; Rodríguez Padilla, 2018), which focuses on accessing resources with the

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D. S. Cervantes (✉)
Universidad Autónoma Metropolitana-Cuajimalpa,
Mexico City, Mexico

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highest energy intensity and at the lowest possible cost. This antagonism is currently shifting to technological and market competition for the dominance of renewable energies.

In this context, we also consider the concepts of just energy transition (Akizu et al., 2017; Urkidi et al., 2015), popular energy transition (Fornillo, 2017), and energy democracy (GeoComunes, 2021; Urkidi et al., 2015). The emergence of just energy transition discussions emphasizes the need to not only incorporate renewable sources into the energy matrix but also effectively substitute the use of fossil fuels. This inevitably raises the need to reduce energy demand in absolute terms; therefore, it is articulated with the paradigm of degrowth (Cosme et al., 2017; Weiss & Cattaneo, 2017) and the need for a parallel transformation of the mode of energy production and the capitalist mode of production. They imply the need to rethink the inequities of the global energy system, considering both the participation of communities in the decisions that build them as well as the equitable distribution of their benefits (GeoComunes, 2021).

The work articulates these critical analyses at a global level with studies on the recent history of Mexican energy policy and its current situation. Within these, we find studies on the effects of North American regional energy integration, and the way in which the dominance of the particular interests of the US government has deepened Mexico's structural dependence (Vargas Suárez, 2014; Rodríguez Padilla, 2018). This situation, which produces energy dependency on the importation of natural gas and gasoline from the United States, places the Mexican energy system in a vulnerable condition. This study also analyses the manner in which these transformations affect the concept of energy security and its role in the construction of Mexican energy policy (Puyana & Rodríguez, 2020).

An important aspect that articulates these studies—typically considered critical studies of energy in Mexico—is the discussion around energy transition policy in the country's recent history. The analysis of the situation opened by the current government's energy policy discourse indicates tensions and contradictions between the priority objectives of the national energy policy as of 2018 (Hernández & Bonilla, 2020). On the one hand, its articulation with national development policy is marked by the emergence of the concept of energy sovereignty, which has become visible in public policies focused on promoting state-owned energy companies and in the restructuring of the market-oriented regulatory framework (Sener, 2020a, b). On the other hand, the construction of a sovereign and democratic energy transition finds itself with narrow margins of negotiation and, to this day, without strategies and tactics clearly established in public policy instruments issued by the federal government (Tornel, 2020; GeoComunes, 2021).

In these conditions, the work constitutes a contribution to the conformation and consolidation of Mexican critical energy studies, as it provides a deepening of a global and national analysis of the margins of the political economy of energy, within which unequal regional energy integration is built. On the one hand, it joins the incipient literature that critically analyzes the structure of the energy policy of the current government, from the perspective of the need to transform both the mode of energy production and the capitalist mode of production. On the other hand, it incorporates articulation with the critical analysis of the regulation of the national and regional energy systems. Considering the absence of research that deals in depth with the critical analysis of the legal framework of energy in Mexico. In general, we can find studies that either critically address energy policy—but not its legal regulation—or those that address regulation technically but from traditional legal theory. For example, few studies explain the system of hydrocarbon exploration and exploitation contracts, the history of regulation, or the legal structure of public companies, with less frequent and almost non-existent analyses of the wholesale electricity market.

The chapter also constitutes a contribution to the incipient Mexican energy literature on the dispute over the transition model based on concepts such as just energy transition, degrowth, and energy democracy, a field that, until now, has been scarcely addressed by university research work and mainly investigated by organizations and communities that resist energy megaprojects. Thus, this chapter contributes to studies that deepen the possibility of building just energy transitions incorporating the efforts and work of communities and sectors hitherto excluded from energy policy decisions in Mexico.

Mexican energy policy is at a crucial juncture, especially for the definition of the energy transition model and its link with national development policies. The work is based on the hypothesis that the situation opens a discussion that goes beyond either the market or corporate transition model imposed by structural neoliberal energy reforms, and the state-centered one. We extend the argument to emerging discussions around energy transition models and transformations of national energy systems based on community projects and thoughts on the horizon of the degrowth paradigm. We are guided by the following research questions: In what way does the dependent condition of the Mexican economy limit the possibility of an autonomous energy policy and a sovereign energy transition? What is the horizon for a fair and democratic energy transition in Mexico that incorporates the communities and actors excluded in its decisions?

5.2 Critique of the International Economy and Just Transitions

5.2.1 Critical Energy Studies and Critiques of the International Political Economy of Energy

Energy in modern societies is a complex issue. It encompasses not only infrastructural and technological issues related to the production, transportation, and consumption of energy but also social and ideological issues that involve the construction of dominant and alternative conceptions of energy production and consumption (Van de Graaf & Sovacool, 2020). Further, energy is a highly internationalized issue in contemporary societies that transcends national and regional boundaries (Godlthau, 2013). It is also a strategic commodity that is fundamental to economic growth (Akizu et al., 2017; Smil, 2017; Van de Graaf & Sovacool, 2020). The literature has organized this complexity around the concept of sociotechnical energy systems.

This concept of sociotechnical energy systems organizes both the different phases involved in energy production and consumption and the fact that they include both material production relations and ideological and social constructions. In the first case, energy systems include not only the infrastructure and technological framework necessary for the physical production, transportation, and consumption of energy resources. It also includes the concept of energy services as the prime movers that enable the end-use of the energy produced, that is, oil pumps and internal combustion engine vehicles that enable end users to access oil consumption, or household appliances, such as blenders, heaters, and stoves, that enable domestic consumption of electricity. Sociotechnical energy systems also respond to the different forms of energy resources and their different production and consumption needs, for example, the complexity of electricity storage, transport, and consumption, or the geological risk associated with oil exploration and production. A more recent issue is the energy transition, even though oil and gas still provide about 80% of primary energy resources (Akizu et al., 2017; Smil, 2017; Van de Graaf & Sovacool, 2020).

Second, the concept of sociotechnical energy systems encompasses the cultural and sociological conditions of historical energy systems. This includes the prevailing ideological and regulatory frameworks that push toward particular models of energy production and consumption and, in part, determine the characteristics of energy systems. It also includes the differential social acceptance of different energy models across time and space, which means that energy systems are part of the construction of everyday life (Newell, 2021; Huber, 2013; Van de Graaf & Sovacool, 2020). In terms of time, this means that energy systems are historically contingent; as different social needs develop different social production relationships and ideological frameworks, they rely on different ways of producing energy (Mälm, 2018; Di Muzio, 2015). Lastly, it considers the national and regional diversity of energy systems, which relates to geographic, economic, political, and cultural differences, as well as the differentiated integration of local and national economies into world energy markets (Akizu et al., 2017; Bradshaw, 2013).

The literature addresses the complexity of energy systems and energy regulation using two related concepts. The first is global energy governance (Newell, 2021; Van de Graaf & Sovacool, 2020), which addresses the heterogeneity of actors and competing interests involved in energy regulation at both local/national and regional/international levels. The second concept is complex regulatory regimes, which deal with articulating different geographical levels and regulatory issues that intertwine in the control of energy (Alter & Raustalia, 2018; Shaffer & Pollack, 2010; Van de Graaf & Sovacool, 2020).

Currently, two main regulatory frameworks deal with energy. The first is the United Nations framework, which includes the General Assembly Resolution on Sovereignty over Natural Resources, a landmark that has helped solidify the importance of national regulation in the energy sector. More recently, the central UN framework for energy sector regulation has been structured around the United Nations Framework on Climate Change (UNFCC). The UNFCC builds on the conferences of the parties that have led the two main regulatory bodies for climate change affecting the energy sector: the Kyoto Protocol and the Paris Agreement (Azam, 2021; Minas, 2020; Minnerop, 2020; Rajamani & Werksman, 2018). The other regulatory framework is the World Trade Organization (WTO) framework and the international trade agreements derived from it, such as multilateral and bilateral trade agreements. This regulatory framework focuses on the progressive liberalization of the economic sector, including the energy sector, based on fundamental principles, such as national treatment, most-favored-nation treatment, and minimum standard treatment (Cameron, 2014; Selinova, 2014). The WTO framework focuses on protecting private investment around the world, particularly on creating appropriate investment conditions in developing countries by promoting regulatory liberalization reforms (Karlsson-Vinkuyzen, 2016; Konoplyanik, 2014).

Lastly, there is an ongoing process of the internationalization and homogenization of national energy law, influenced by regional and global market integration. These processes put national sovereignty over natural resources into perspective, as they imply the standardization of national regulation, which allows for deeper regional and international integration and the emergence and consolidation of regional and global energy markets through standard international contractual clauses and resolution procedures, such as commercial arbitration (Talus, 2014; Schill, 2014).

This study takes the foundational concept of sociotechnical energy systems from a critical energy studies perspective and a critique of the international political economy of energy that introduces the concept of regimes to highlight the importance of politics and unequal power relations (Di Muzio, 2015; Newell, 2021; Trommer & Di Muzio, 2015). These perspectives introduce an account of unequal integration into the global economy that leads to unequal exchange and relies on unequal power relations between national and regional actors and within economies (Dow, 2019; Graham, 2019; Mälm, 2018). This approach relies on the concepts of social classes and class struggles as its foundation.

Introducing social classes and class struggles into the analysis of energy systems accounts for both technological and social complexity by addressing the social relations of production thwarted by technological transformation. It also considers the role of ideology—in the form of dominant ideological frameworks, regulations, and institutions in class-divided societies—in the emergence and consolidation of historically contingent energy systems. This allows critical energy studies to view energy systems as contested social structures in constant flux; it also allows for the inclusion of social conflict and transformation in its analysis (Huber, 2013; Newell, 2021).

The literature on critical energy studies has introduced key concepts for understanding energy systems in modern societies, especially in times of climate change and energy crises. The first is fossil capitalism (Graham, 2019; Mälm, 2012) aka petrol-market civilization (Dow, 2019; Tromer & Di Muzio, 2015), concepts that invoke the fundamental relationship between energy systems and modes of production. In this case, there is a reciprocal relationship between an energy system dependent on fossil fuels and the capitalist mode of production based on a constant increase in the production of goods and, consequently, on a constant increase in energy demand and production. Here, the physical characteristics of fossil fuels (high-energy intensity, ease of exploitation, and transportation) were and are essential to the capitalist model of infinite growth (Mälm 2018; Tromer & Di Muzio 2015). Fossil capitalism and petrol-market civilization are also at the root of the political-economic relationship between capitalism and fossil fuels. The complex technological and social demands of fossil fuel production favor political and economic concentration and control and thus play an important role in the historical transformations and adaptations of fossil fuel-dependent energy systems to social conflicts and class struggle (Mälm, 2018; Urkidi et al., 2015).

This leads us to analyze the impact of fossil fuels on the climate in contemporary societies. Critical energy studies draw on the concept of the Capitalocene for this topic, a concept that emphasizes the role of unequal economic and social relations and their impact on climate change. Capitalocene builds on the concept of the metabolic divide (Clark & York, 2005; Moore, 2020), which states that the capitalist mode of production has altered and is altering the relationship between society and nature. This is especially salient as globalization and the proliferation of different phases of global value chains become the dominant model, requiring increasingly diverse exploitation of natural resources for the growing—and increasingly unequal—consumption of goods. Capitalocene points to a historically contingent link between not only fossil fuel dependence and the deepening of capitalism but also increasing ecological degradation (Mälm, 2014, 2018; O'Connor, 2002; Saxe-Fernández, 2018).

Climate change, however, is not the only critical impact of fossil capitalism; it represents only one side of a more general crisis, referred to by critical theory as the civilizational crisis (Bartra, 2013), which includes social, economic, and financial crises that represent the need for profound social structural change. This means that humans cannot overcome a crisis, such as that represented by climate change, without relying on a transformation of the mode of production and the prevailing social relations. This is a key idea in analyzing the conditions for a global energy transition, which is a long-term solution to our current climate crisis (Akizu et al., 2017; Clark & York, 2005; Mälm, 2018).

Lastly, the concept of the international division of labor implies that local and national economies play a differentiated role in integrating the economy of the world system. This concept also emphasizes the fundamental inequalities that permeate the different countries, dividing them into industrialized countries with access to the most advanced technology, and less industrialized countries that rely on the export of raw materials. In this division, Latin American Marxist dependency theory emphasizes the role of Latin American countries as one of the "barns of the world," whose role is to provide raw materials to European and North American industrialized countries at a low price, made possible by a lower value of labor and unequal exchange (Marini, 1973; Melgarito, 2019). In energy studies, the international division of labor articulates the unequal exchange between industrialized and under-industrialized countries with high energy consumption in the industrialized world. In this scheme, industrialized countries export energy resources with high added value, and less industrialized countries depend on the export of energy commodities, mainly oil, and rely on the import of technological goods and capital (Dow, 2019; Graham, 2019; Mälm, 2018).

5.2.2 The Concept of Energy Transition

These cross-national inequalities make it necessary to conceptualize energy transitions in plural terms. Whereas the energy trilemma, which includes climate change mitigation, energy poverty, and energy security, has a clear global scale that implies the urgent nature of a global energy transition, individual countries implement transition measures at different rates and in different ways, depending mainly on their technological progress and industrialization. This means that despite the differences in energy transition among countries (Bradshaw, 2013), it is of great importance to create and coordinate a global energy transition (Cherp et al., 2011; Newell, 2021).

To date, the prevailing model of the energy transition, within what is called green capitalism (Moreno, 2012), has focused on decarbonizing economies primarily through the implementation of two types of policies. The first is growing energy generation (mainly electricity) based on renewable energy technologies and, in some cases, transitioning from other fossil fuels to natural gas (a cleaner but still fossil resource) and energy efficiency measures. The second policy is the implementation of energy efficiency measures. Although the cost of renewable energy technology has continued to fall and a market for renewable energy has emerged (Van der Graaf & Sovacool, 2020), absolute CO_2 emissions have continued to rise worldwide. Although the share of renewables in the energy matrix has increased worldwide and at the global level, there has been little or no reduction in fossil fuel consumption. The COVID-19 pandemic led to a brief decrease in both fossil fuel demand and CO_2 emissions due to mobility restrictions around the world. However, this did not lead to a significant change in medium- and long-term energy consumption and GHG emissions (Kuzemko et al., 2020; Ocampo, 2021; Van de Graaf & Sovacool, 2020), and aspects of social inequality and unequal exchange and growth at the global level were not taken into account (Garcia-Garcia et al., 2020; Newell, 2021).

Thus, the dominant model of energy transition reproduces a concentration of capacities and a deepening of inequalities among actors and social sectors, since it focuses on technological breakthroughs and the diffusion of renewable energy technology and relies mainly on industrialized economies and international renewable energy companies. Given that this dominant model relies on market economics and promotes the status quo of current energy systems, some strands of the literature have coined this transition model with the term “market” or “corporate” transitions (Geocomunes, 2021).

The original lack of inclusion and consideration of social issues, such as inequality in access to energy services, energy poverty, territorial disputes over renewable energy megaprojects, or uneven integration into world energy markets, has been challenged by various methodological perspectives, including the perspective of critical energy scholarship. The critical literature has focused on the possibility that energy transition may involve not only an increase in energy sources but also a change in the structure of energy systems at the global level, taking into account the international division of labor (Akizu et al., 2017; Newell, 2021; Urkidi et al., 2015). Others, such as Fornillo (2017), call for a popular transition or an energy transition model that incorporates host communities’ needs (GeoComunes, 2021). Hence, some strands of the literature, particularly critical energy studies (García-García et al., 2020; Newell, 2021) and grassroots movements (Fornillo, 2017; Geocomunes, 2021; Urkidi et al., 2015), have developed the concept of just energy transition. This concept challenges the dominant model of energy transition and calls for the need for structural change, as well as to incorporate issues of global inequality, energy poverty, and socio-environmental conflict. Through this approach, it is also possible to call for structural social transformation and the democratization of energy systems.

Just energy transitions take into account the global inequalities that affect both climate change responsibility and energy consumption for industrial development. This challenges the dominant share of industrialized countries in current and historical energy consumption and their responsibility for CO_2 emissions and underscores the need for more coordinated governance of the energy transition, including discussion of technology transfer and financing of renewable energy technologies (Akizu et al., 2017; Newell, 2021; Urkdi et al., 2015).

Lastly, grassroots movements have put forward the concept of a popular or democratic energy transition, which focuses on the inequalities between production and consumption faced by host communities, often dismissed as sacrificial territories. In this sense, the concept highlights the importance of socializing the decisions and benefits of energy systems, especially with regard to the inclusion of those communities that suffer the negative consequences of energy megaprojects but are rarely included, either in decisions about these projects or in the benefits or energy they produce (Fornillo, 2017; Geocomunes, 2021).

Both the just energy transition and the popular energy transition contest the transformation of energy systems, arguing for the need to discuss the dominant paradigm of economic development, including issues such as degrowth (Kallis, 2019; Martínez-Allier et al., 2010). This concept means strategically limiting the growth of developed countries and favoring that of underdeveloped countries, as well as discussing the consumption of energy and other goods on a global scale (Alarcón & Chartier, 2018; Cosme et al., 2017; Weiss & Cattaneo, 2017). Just energy transitions and popular energy transitions require not only a structural transformation of energy regimes and energy systems but also a social transformation that recognizes their interconnectedness. Therefore, some of the critical literature uses the term transformation (Newell, 2021).

The concept of transformation signals that the crucial aspect of transitions is that they should go beyond adding energy sources to the current energy matrix. Rather, they should imply a discussion of energy systems and energy regimes at the national and local levels, as well as at the global level (Akizu et al., 2017; Geocomunes, 2021; Urkidi et al., 2015). The transformational aspect of the energy transition implies the struggle to overcome the "carbon lock-in." This term refers to the resistance of established actors who benefit from the energy status quo in the form of fossil capitalism or the corporate energy transition. It also considers the importance of technological research and development in underdeveloped or developing countries and the difficulties they face in accessing the financial and technological conditions necessary to do so (Unruh, 2000). They face great difficulties, especially as the WTO framework protects centralized industrial property and conflicts with the UN technology mechanism and North–South technology transfer.

5.3 The Limits of Fossil Capitalism: A Discussion of Mexican Energy Transition in Dependent Conditions

5.3.1 The Limits of Fossil Capitalism

The conditions described in the above sections lead us to consider alternatives for an effective and just global energy transition because fossil capitalism and green capitalism have shown that they are incapable of achieving sustainability. There are physical limits to fossil energy. The first limitation to the reproduction of capitalist society in the business-as-usual scenario is the systemic downward trend in the rate of energy return, which means that more technology, investment, and energy are required to produce less and less energy. This condition is a consequence of the depletion of conventional oil resources around the world, which has led to the exploration and production of unconventional resources, such as shale gas and oil and deep-water resources. The literature identifies this state of affairs as an age of extreme energy (Di Muzio, 2015).

However, the physical limits manifest not only in the structural depletion of oil resources but also in a growing contradiction between good extraction and climate destruction. This contradiction implies a growing rift in social and natural metabolism. This is because an ever-increasing production of goods, necessary for the subsistence of capitalist society, requires the ever-increasing exploitation of nature to a point where, due to the scarcity of natural conditions of production, the total cost of production is constantly rising, and at some point makes the possibility of further production of goods impossible. These tensions mean that the evolution of capitalist relations of production is becoming increasingly unsustainable, which has led to a growing urgency to transition to a decarbonized economy. Yet, the prevailing model of energy transition fails to address these structural constraints on capitalism, as it fails to recognize the physical limits of renewable energy. Notably, renewable energy technology, while cleaner than fossil fuels, still requires steel, plastic, and other components to produce. This means that renewable energy production still relies on fossil fuels to some degree, and as a result, energy transitions intertwine with the strategic use of fossil fuels (Ferrari & Masera, 2020; Newell, 2021; Ocampo, 2021).

The second physical limitation of the corporate energy transition is that it does not take into account the varying intensity and continuity of renewable energy. Thus, the prevailing energy transition model adheres to a development paradigm based on permanent growth in production and, consequently, in energy demand. Renewables do not have the same energy intensity or continuity as fossil fuels because they depend on natural weather conditions, such as sunlight and wind. This means that renewable electricity generation requires, to some extent, the complementary use of fossil fuel electricity generation. More likely, the electricity matrix will require a dominant fossil fuel presence in electricity generation due to ever-increasing demand that is unlikely to be met by renewables (Ferrari & Masera, 2020; Geocomunes, 2021; Ocampo, 2021). In the context of this constraint, renewables have phases that require a deepening of commodity capitalism because they rely on non-renewable rare minerals. This is the case for batteries, which are needed to store energy due to the intermittent nature of renewables, and for measures to decarbonize the transport sector, such as the use of electric vehicles. In addition to the need for renewable energy extraction and electrification, the non-renewable rare minerals needed for these processes are insufficient to meet growing global demand (Ferrari & Masera, 2020; Geocomunes, 2021; Ocampo, 2021).

Lastly, because renewables have a lower intensity than fossil-fueled sources, they require a larger territorial footprint for the massive generation needed to meet the growing electricity demand. However, the locations for implementing megaprojects for renewable energy are now scarce, as most of them are already in use. The literature points out this fact and refers to the diminishing energy returns of renewables, which means that renewables, such as fossil fuel power generation, will reach a maximum production point because there are few sites to develop renewable projects (Geocomunes, 2021). This limitation will eventually lead to the inability of renewables to meet the growing demand for energy (Ferrrari & Masera, 2020; Geocomunes, 2021).

The physical limits of renewable energy contribute to social tensions and conflicts in renewable energy production. One major tension that arises from the nexus of globalization processes and uneven development, which has led highly industrialized economies to externalize the most energy- and environmentally intensive phases of global production chains to underdeveloped or developing countries (Mälm, 2012). This externalization of production phases has led to an apparent paradox: whereas many developed countries have made progress in decarbonizing energy production, this is not the case for overall energy consumption, as the industrialized world's good consumption relies on intensive energy production phases carried out in other countries. Conversely, the underdeveloped and developing countries that host these phases of the global value chain have increased their greenhouse gas emissions and now have more carbon-intensive economies. This paradoxical situation is reflected in the absolute increase in global greenhouse gas emissions co-existing with a reduction in emissions in developed countries (Mälm, 2012; Newell, 2021).

The global trend toward the liberalization of energy sectors has not led to the coordinated regulation of resources. Rather, it coexists with fragmented and highly complex global energy governance that ultimately favors the interests of incumbent actors and perpetuates uncoordinated global governance. Conditions that hinder the possibility of a global energy transition. This uncoordinated governance confronts the conflicting interests of developed and underdeveloped or developing countries in relation to technology transfer and the regulation of foreign investment and international energy trade (Kircherr & Urban, 2018; Minas, 2020; Newell, 2021). This confrontation highlights the unequal effects of the two main frameworks that regulate—even though indirectly—energy systems on a global scale. A situation that benefits incumbent actors. In this regard, although the regulation of technology transfer and climate change mitigation has put these issues on the international public agenda, regulation in international law is rarely legally binding and is often limited to wishful thinking (Kircherr & Urban, 2018; Minas, 2020; Minnerop, 2020). However, international regulation, derived from commercial and industrial property regulation, has been a driving force both in reforming domestic regulation, which led to the homogenization of energy law, and in obtaining legally binding force through international commercial arbitration (Talus, 2014). This uneven effectiveness of international energy law occurs not only in the oil sector but also in the renewable energy sector, especially in the corporate model of energy transitions.

In the context of this last social constraint of capitalism, we find that the centralization of energy decisions and energy projects and the centrality of megaprojects lead to unequal benefits and responsibilities between actors with very different resources, as is the case with international energy companies and host communities. The literature has considered this through the concept of accumulation through expropriation (Harvey, 2005; Dunlap, 2018). Although various regulations have introduced social impact assessments to mitigate the consequences of unequal participation in energy projects, this has not prevented the displacement of communities and the increase in unequal access to both energy services and the social and economic benefits of energy projects. These negative social impacts of energy projects are particularly evident in the renewable energy sector, in which projects require large tracts of land and reproduce inequality in access to energy (Akizu et al., 2017; Geocomunes, 2021; Urkidi et al., 2015).

These conditions impede the emergence of a global energy transition that is both effective in reducing absolute greenhouse gas emissions worldwide and equally inclusive of underdeveloped or developing countries, as well as communities and social sectors historically excluded from energy progress. This leads to the consideration that there are economic and political incentives for established actors—such as international private energy companies or industrialized economies—to develop and massively incorporate renewable energy sources into the energy matrix at the global level. However, they do so without transforming the global energy system or the capitalist economic growth paradigm with which it associates (Akizu et al., 2017; Newell, 2021).

In this sense, the discussion on transforming the capitalist economic growth paradigm based on ever-increasing goods production plays a key role in building a global equitable energy transition. This would allow a focus not only on a viable solution to mitigate climate change but also on unequal development and social, energy, and environmental justice by addressing the need to reduce, in a strategic manner, goods production while taking into account the development needs of less industrialized economies. Thus, global equitable energy transitions require serious consideration of degrowth (Kallis, 2019; Mälm, 2012, 2018; Martínez-Allier et al., 2010).

5.3.2 Mexican Energy Transition in Dependent Conditions

This study argues that the Mexican energy reform and energy transition model are examples of dependent energy policies, focusing on world energy markets and reproducing vulnerable energy conditions caused by fossil dependence on external economies, mainly the United States. This double dependence on the US economy and fossil fuels has permeated long-term energy policies and solidified the conditions of carbon lock-in. A condition that persists to this day and structures the energy policies of the current Mexican government, even though the discourse on energy policy has fundamentally changed with the government of Lopez Obrador (Hernández & Bonilla, 2020; Sener, 2020a; Tornel, 2020).

As we have seen, neoliberal policies led to a radical shift in Mexican energy diplomacy from a policy of autarky and market diversification, which meant a failure to adapt Mexican energy policy to either OPEC or the IEA. In the 1990s, an emerging market-oriented energy policy gave way to a process of unequal integration of the North American region, guided by the interests of the United States. For Mexican energy policy, this meant a slow but steady change in its goals, which implied a dislocation of national development policy and shaped the Mexican energy system based on regional goals (mainly the US national and regional security agenda) (Rodríguez, 2018; Vargas Suárez, 2014).

This change in energy policy objectives led to a shift in the production logic of the Mexican energy system from then on, based on the perspective of comparative advantages and international energy trade (Rodríguez, 2018). This meant a shift from the production of energy resources for national development to the integration of the Mexican energy system into global production chains. This change has led to a decrease in oil reserve replenishment, oil production, transformation, and exportation, as it is commercially and economically more advantageous to import energy resources, especially those with high added value. This transformation led to greater dependence on imported energy, particularly natural gas and gasoline, from the United States. This has led to the vulnerability of the Mexican energy system, as the Mexican economy is not able to produce strategic energy resources itself, and therefore must import them. The dependence on US imports of these resources, especially natural gas, the dominant resource for electricity generation in Mexico today, makes it difficult to replace the import market and acquire these resources through other markets (Puyana & Rodríguez, 2020; Rodríguez, 2018).

Uneven regional integration, accomplished through trade agreements and other regional policy instruments, led to a reform of secondary legislation that slowly paved the way for a continuous process of liberalization of the Mexican energy sector, without the need for constitutional reform. Through these reforms, Mexican regulation allowed the participation of private investment even before the 2013–2014 energy reform. This also affected the energy transition model, mainly through the introduction of a captive power supply and independent power producers, as stipulated first in the NAFTA. These regulations allowed private companies to generate up to two-thirds of Mexico's electricity (Geocomunes, 2021).

This tendency, generated by regional integration processes, eventually led to the 2013–2014 structural energy regulatory reform, which introduced a new logic for the development of the Mexican energy system, now openly oriented toward the integration of Mexico into global energy markets (Rodríguez, 2018; Vargas, 2014). The new commercial logic of the Mexican energy system confirmed the separation between energy policy and national development policy. It also introduced a radically different regulatory framework based on the distinction between technical and political processes—a distinction that required the "depoliticization" of the energy sector (Rodríguez, 2018). Eventually, it changed the logic behind the functioning of renamed "state production companies," which are now focused on value creation within the horizon of competitive markets.

As for the energy transition, the structural reform enacted two important laws in the wake of the signing of the Paris Agreement. The first law is the Climate Change Law, which formalizes the Nationally Determined Contributions (NDC) of the Mexican government. The second one is the Energy Transition Law, which introduces a series of new regulatory instruments for Mexico's energy transition, such as the Energy Transition Strategy and the Special Energy Transition Program. From a general perspective, this was an obvious step forward toward an energy transition in Mexico (Tornel, 2020), even though a transition cemented on a corporation-dependent model.

However, the global legislative and constitutional reform raises nonconformities channeled by three main criticisms regarding the energy transition. The first is criticism of the central role of petroleum policy in the new framework, focusing on the importance of foreign investment in deep water and shale gas development and the central role of natural gas in electricity generation (Carbonell, 2019; Vargas, 2014). The second criticism focuses on the lack of a government role in shaping the energy transition and reliance on market mechanisms, such as auctioning resources for long-term energy and foreign investment. The third criticism stems from the definition of clean energy in the Energy Transition Act, which includes combined cycle power plants and large hydraulic power plants. The first type of power generation is cleaner than electricity generation from fuel oil, but it is, nonetheless, still a fossil source of electricity. The second type of electricity generation creates socio-environmental conflicts due to the scale of its production and raises important questions in terms of its sustainability (Ferrari & Masera, 2020; Tornel, 2020).

These criticisms, and the continued dominance of fossil fuels in the Mexican energy matrix, suggest that structural energy reform contributes to the emergence of renewable energy, but it is doing so in an additive rather than a transformational way, that is, without challenging or changing the centrality of petroleum. Mexican literature on energy security highlights this and points to the durability of carbon lock-ins in domestic energy policy. The argument is that energy reform has not changed the centralized, oil-focused energy policy or the predominant power of the federal executive in defining and implementing energy policy (Geocomunes, 2021; Puyana & Rodríguez, 2020; Rodríguez, 2018).

The current Mexican administration is calling for a structural change in energy policy centered on energy and technology sovereignty and a return to self-sufficiency. Further, advocacies for the reconnection of energy policy and national development are based on reclaiming the dominant position of state-owned energy companies in both the oil and power sectors (Sener, 2020b). This has led to legislative reforms related to the organization of the energy sector and a government proposal for constitutional reform that has created tensions between international energy companies, the US government, the European Union, and the Mexican government (Jiménez et al., 2021).

In this context, it is worth noting that the policy of oil exploration, production, and refining is at the heart of the current government's energy policy. This led to the vertical and horizontal integration of stated-owned companies Petróleos Mexicanos (PEMEX) and Comisión Federal de Electricidad (CFE)—a measure that contradicts the unbundling model set by the 2013–2014 reform—and the strengthening of the Mexican refining system, both through the construction of "Dos Bocas" and the acquisition of the "Deer Park" refinery in the United States (Hernández & Bonilla, 2020). Lastly, some of the most important features of the energy reform relate to this process, such as the change in the order of priority in the supply of electricity to the national energy grid, which favors state-owned companies, and the elimination of the priority given to renewable energy plants (Vázquez, 2021).

Even if the energy transition policy announced in the sector development plan generates a discussion of the model by changing from a corporate to a sovereign energy transition, few public policies address the specific actions through which this sovereign transition will occur. In this sense, there are still policy instruments, such as the Special Energy Transition

Program, that have not yet been published. Other instruments that are critical to the sovereign transition were announced but not officially published, such as the Agenda for Scientific, Technological, and Industrial Sovereignty of the Mexican Energy Sector, an instrument that should define important policies related to research and development instruments that would lead to overcoming technological dependence in the energy sector.

The published transition policy instruments offer only a limited perspective for transformative change in the Mexican energy sector, or transformative policies that need to be further developed. For example, the Energy Transition Strategy offers a clearer perspective on the transformative nature of the current government's transition model, based on self-sufficiency and on the concept of energy security linked to the strategic nature of energy resources for the holistic development of the country. This, of course, represents a departure from the corporate transition model based on foreign investment and the liberalization of the energy sector (Sener, 2020a, b; Tornel, 2020). Nevertheless, it also offers a transitional model based on energy efficiency and conservation that does not challenge the inequalities in energy consumption or the tensions between capitalism's endless need for good production and the environment. This is because the strategy offers an outlook in which energy consumption, especially in the industrial sector, will decrease not in absolute terms but only to the extent that energy efficiency increases (Ferrari & Masera, 2020; Geocomunes, 2021; Sener, 2020b).

The strategy does not offer a clear panorama of the relationship between private and public investment in the renewable energy sector, especially considering that state-owned companies have little presence in the sector, mainly because most of their plants function on natural gas rather than renewable sources. This condition does not change the government's energy balances and outlooks (Sener, 2020a, b). There is also little evidence of how the government will contribute to the growth of renewable energy and its role in the gradual replacement of fossil fuels in the power sector. In this sense, energy policy will continue to rely on fossil fuels in the electricity sector through the dominance of combined cycle plants; the strategy also proposes the growth of hydroelectric plants (Puyana & Rodríguez, 2020; Sener, 2020b). The Strategy also has significant gaps in terms of social impact and democratization of the electricity sector. Although the energy sector program offers a perspective for a democratic and just transition, the strategy does not provide a concrete model (Sener, 2020a, b). First, it contains only very general statements about the social impacts of energy projects and only points out the importance of internalizing social and environmental impacts and ensuring the efficiency of social impact assessment and socialization of the benefits generated by the project (Sener, 2020b). Second, even if the importance of distributed generation is noted, there is still a need for energy policy instruments to shape its growth and integrate distributed generation into a transformational process, for example, through community energy generation programs (Geocomunes, 2021; Tornel, 2020).

Some of the most problematic issues in energy policy are structural and seem to permeate not only the last administration but also the current one. The first, as we have seen, is the centrality of oil in both political and economic terms. Throughout Mexico's recent history (1980–2021), petroleum has been one of the main sources of foreign exchange, being one of the main exports. Even though in recent years, especially after the 2013–2014 energy reform, there has been a structural decline in oil production and exports, and a negative balance of trade in the energy sector, oil remains at the center of Mexico's energy policy (Ferrari & Masera, 2020; Puyana & Rodríguez, 2020; Rodríguez, 2018). This hinders the possibility of an energy transformation and allows transition policies to take a back seat.

A second problematic aspect of Mexico's energy policy is the growing dependence of the Mexican economy on key energy imports. In general, the negative energy trade balance is due to the increasing imports of high value-added energy resources from the United States, particularly gasoline and natural gas. This creates vulnerability in Mexico's energy system. Further, the Mexican economy's dependent integration into global energy markets and uneven regional integration hinder the possibility of an autonomous energy policy (Rodríguez, 2018). In this sense, international trade commitments under the WTO regulatory framework render the meaning of energy sovereignty and subordinate national energy policies to the logic of competitive markets. This means that any redesign of energy regulation that alters compliance with trade commitments could face international trade arbitration in Mexico, which could lead to high compensations for investors (Vázquez, 2021).

Finally, there are structural social injustices in the design of government energy policies. One is the inability to consider social equity in the socialization of benefits (Geocomunes, 2021; Social Impact Assessment). This is due to unequal regulation of the territorialization of energy projects, which puts the community and, in general, any type of use of the territory other than energy-related ones in a weak position vis-à-vis energy projects. The priority legal character of energy projects, introduced by the 2013–2014 energy reform, maintained and promoted by the current energy policy, hinders communities' territorial rights (Zamora, 2015). Despite the introduction of social impact assessment in energy regulation, communities do not have the opportunity to receive a fair share of the benefits of energy projects (Tornel, 2020; Geocomunes, 2021). The main features of possible compensation are limited to employment opportunities and compensation for the use of the territory measures that limit community participation in the decision-making process. Even this limited share of benefits is hardly effective. In this sense, a large number of socio-environmental conflicts are due to the vulnerability of municipal territorial rights and the ineffectiveness of the limited benefit-sharing system.

5.4 Conclusion

This work has shown that the current global governance of energy tends to carbon lock-in, mainly for two reasons: The first one is the interdependent and constitutive relationship between fossil fuels and capitalism signaled by the term fossil capitalism. The second reason is the fragmented governance of energy systems, a condition that favors incumbent actors who profit from fossil fuel production and prevents the possibility of transforming energy systems into alternative energy sources by allowing only the addition of renewables in a fossil-dominated global energy matrix.

This global tendency is rooted in the history of Mexican energy policy. Oil policy has always been a key element not only in energy policy but also, in a more general sense, the central aspect of national growth and foreign policy. The 2013–2014 energy reform introduced a corporate energy transition model, which only led to the addition of energy sources to a matrix heavily dominated by oil. Although the current energy policy announces a sovereign energy transition based on the promotion of national technologies, it has yet to publish the key policy instruments needed to implement this project. In this regard, the key energy policy elements introduced by the government focus on the replenishment of oil reserves and production, as well as the renewal of Mexico's refinery system. Moreover, the published policy instruments of the energy transition do not provide a transformational picture of the desired transition but rather a transition based on the energy efficiency of industry and transportation.

This inability to imagine and design a transformational model for energy transition is largely due to Mexico's structural dependence on oil and the US economy. In this sense, Mexico's economic production and growth depend not only on fossil fuels—which are an important source of income and a key element of political domination—but also mainly on a foreign market, that of the United States, from which Mexico obtains important energy resources and to which it exports most of its oil. This dual dependence has deepened because of Mexico's uneven regional integration in North America. One of the implications of regional integration and the integration of Mexico's economy into global markets is that a sovereign energy policy—including a transformative energy transition model—that changes the terms of Mexico's energy system could have serious short-term economic consequences because of the WTO legal framework.

This chapter highlights the global, regional, and local difficulties for an equitable and/or popular energy transition due in part to the complex intertwining of fragmented legal systems and the dominance of fossil capitalism. This leads us to consider that a transformation of energy systems that can effectively mitigate climate change while providing adequate alleviation of energy poverty (in line with Goal 7 of the 2030 Agenda) must necessarily take into account the need to challenge the capitalist mode of production. This leads us to consider that the necessary transformations must start from an energy transition model from below, supported by grassroots movements, local communities, and subaltern social classes. Although the implementation of such models is a long-term goal that is particularly difficult because it challenges the interests of established actors deeply rooted in dominant global energy policies, such models exist not only in our imagination but are developed in the present based on concepts such as just transitions and popular transitions. The current situation of Mexican political society offers interesting conditions for the emergence and consolidation of a popular movement and/or a movement for just transitions.

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6 Contradictions Between Energy and Climate Change Mitigation Policy in a Country with Oil Reserves: The Case of Mexico

Karl J. Zimmermann and Isabel Rodríguez-Peña

6.1 Introduction

Mexico's present-day heavy dependence on fossil fuels rests on the discovery and exploitation of national stocks in the twentieth century. The Cantarell field, discovered in 1958, was of predominant importance here. Its vast reserves incentivized the consolidation of an oil-based energy policy. As a consequence, the energy matrix became weakly diversified. On the other hand, the discovery of the Cantarell field generated steady revenues from crude oil exports, topping 40% of overall federal revenue in the 1980s and averaging roughly 22% between 2012 and 2021.[1] To a very large extent, these rents were used to finance running public expenditure (Campos, 2016). Consequently, investment in exploration and restitution of fossil reserves fell far behind, and even more so, the improvement of energy resilience through the diversification of the energy matrix.

These realities, heavy fossil-fuel dependence and run-down discovered stocks, will be central in addressing the evolution of energy security in Mexico. We thereby hinge on the current perspective on energy security, which emphasizes the need for low greenhouse gas (GHG) emissions from energies consumption and generation, as well as from extraction processes (World Energy Council, 2018, 2020; Ang et al., 2015; Podbregar et al., 2020; Sovacool, 2013; Cherp & Jewell, 2014), which argues that energy security must be sustainable.

The extant literature finds that Mexico's energy security has declined in recent decades (Puyana & Rodriguez, 2020, 2022; Rodríguez, 2018). This is explained firstly by a fall in oil production owed to declining reserves, secondly by a high dependence on oil derivatives, and thirdly and foremost by a high dependence on natural gas.

Looking at the current energy matrix from a climate policy perspective, the poorly diversified energy matrix translates into high and persistent levels of GHG emissions. Complying with international commitments to curb GHG emissions will thus be hard and mitigation objectives could be at risk, even when these merely consist of halting the growth of GHG emissions as in the case of Mexico. Mitigation policies spare large parts of the energy sector despite its heavy impact on

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[1] Author's own calculations based on Banco de Mexico (2022).

K. J. Zimmermann (✉)
Universidad Anáhuac México, Naucalpan, Mexico

Umweltbundesamt, Dessau-Roßlau, Germany
e-mail: karl.zimmermann@uba.de

I. Rodríguez-Peña
Facultad de Economia, Unversidad Nacional Autonoma de Mexico, Mexico City, Mexico
e-mail: isabelrp@economia.unam.mx

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emissions. This may be due to a lack of policy integration between the energy and climate change policy, as well as a lack of collaboration by policymakers involved in either one of the policy domains, see Ortega and Casamadrid (2018).

In this context, the objective of this chapter is to analyze the nexus of energy and climate-change policy on the one hand and the policy goals of energy security and climate-change mitigation on the other hand. The hypothesis we propose is that the disconnection of both policy areas causes severe contradictions, which in turn hinder the achievement of policy goals. For the part of the energy policy, the disconnection can be explained by the oil reserves that were added with the discovery of the Cantarell field. This situation has led to a lack of interest in diversifying the energy matrix and significantly increasing renewable energies. Therefore, it seems that energy policy has been focused on strengthening fossil fuels, even today and due to the recent energy reforms in 2013. Meanwhile, climate policy mainly saw advances in institution building and, as of now, fails to lead to a turnaround in GHG emission trends. However, this may be so because climate policy came into being much more recently than energy policy.

We chose the interaction of these two policies, because, historically, the energy sector is the leading CO_2 emitter in many countries. In the case of Mexico, the energy industry contributed 68% of net emissions and is therefore critical when it comes to mitigation efforts. For the analysis, we took up the methodological proposal of the Energy Trilemma (World Energy Council, 2018, 2020), which proposes a vision of energy security and gives an essential role to sustainability through the promotion of renewable energies. Its approach to evaluating the evolution of energy security consists of three dimensions (energy security, energy equity, and environmental sustainability). However, for our analysis, we redefined the trilemma into four categories to consider the Mexican context (Energy Independence, Energy Resilience, Energy Affordability, and Reduction of emissions). Qualitatively assessing how policy measures contribute to each of these categories enables us to evaluate to what extent the instruments of both policy fields are aligned. To do so, we searched public documents and academic literature to gather evidence of the impacts of single policy actions. The analysis considers the energy policy at three levels (Upstream, Midstream, and Downstream). It is expected that some of these strategies trigger changes in one of the most polluting sectors, thus reducing CO_2 emissions.

After this brief introduction, the chapter is organized as follows. The following section presents a short review of the bases of the energy security concept to take up the approach proposed by the World Energy Council (2018) and define the categories that we will consider to carry out the qualitative analysis of the energy sector and environmental policies. In Sects. 6.3 and 6.4, we present a brief review of the evolution and conformation of the energy sector and environmental policy. Section 6.5 applies the four categories to analyze the alignment of both policy fields. The last section brings together the main findings of this research.

6.2 Concept of Energy Trilemma and Methodology

Energy is central to any nation, regardless of its development, hence the importance of energy security. Evidence can be found in the OPEC supply cuts of the 1970s, causing oil prices to rise sharply and high inflation in various countries, especially developed oil-import-dependent countries. By means of its strategy, OPEC caused significant economy-wide and energy-sector-specific impacts prompting political changes. In the affected countries, the discussion focused on oil due to its predominance in energy matrices around the globe. The International Energy Agency (IEA) – in its beginnings a club of oil-importing countries – defines energy security as uninterrupted access to energy sources at an affordable price. To guarantee energy access, strategies focused on avoiding unplanned interruptions in oil supply that could bring economies out of balance by affecting the entire supply chains (IEA, 2022). To guarantee energy security in the 1970s, the measures implemented by most of the oil-dependent nations, especially the United States, were (1) to diversify oil markets with new domestic and foreign suppliers in order to limit imports from OPEC; (2) to promote other energy sources: coal, gas, and nuclear energy; (3) to reduce energy consumption and the energy intensity of the national economy, and only in the 1990s renewable energies began to be promoted (APERC, 2007).

The foundations of energy security between the 1970s and the end of the twentieth century focused on maintaining access to energy at affordable and fair prices. However, at the beginning of this century, discussions broadened toward environmental sustainability in response to environmental movements that associate temperature increase with fossil energy extraction and consumption processes (World Energy Council, 2018, 2020; Ang et al., 2015; Podbregar et al., 2020; Sovacool, 2013; Sovacool, & Mukherjee, 2011). In this context, current views on energy security make reference to (1) global factors that affect all countries and that are largely immune to policy responses, (2) country-specific factors such as the resource base, stage of economic development, population density, climate, and others, (3) technological innovation and adoption, and (4) energy policies.

Taking into consideration this new vision of energy security, for the present analysis, we consider the Energy Trilemma's methodological proposal, which is a concept developed by the World Energy Council starting in the 2000s, and much of its underpinning was the early reports of the International Panel on Climate Change (IPCC). This methodology states that for an energy system to become sustainable, its three axes must be considered: energy security, energy equity, and environmental issues. It should be noted that all of these are interrelated, and in order to achieve sustainable and fair energy security, an optimal point between the three must be found. Figure 6.1 shows the three categories of the analysis and the variables included in each.

Each category includes the following topics: Energy security consists of guaranteeing that the

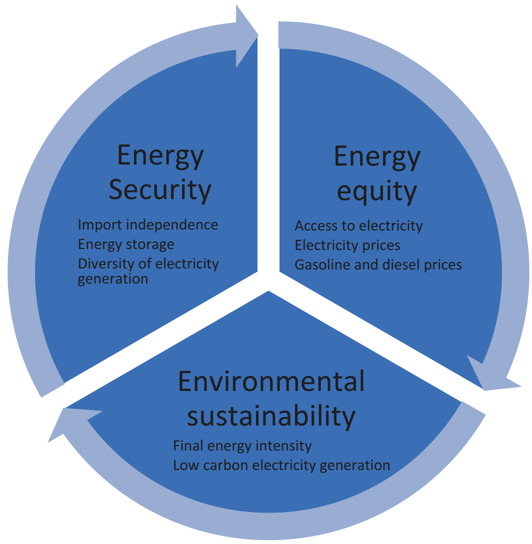

Fig. 6.1 The Energy Trilemma. (Source: Authors Elaboration based on World Energy Council, 2022)

energy system is highly reliable from all points of view, from the supply of primary energy to the delivery to the end user, that it is resilient to climatic phenomena and cybernetic attacks, etc. On the other hand, energy equity refers to ensuring that the entire population has physical access to commercial energy, as well as economic access, that is, ensuring costs that allow accessible prices to the entire population (Heffron, McCauley, & Sovacool, 2015). And the environmental issue is to minimize, as far as possible, emissions of GHGs and local pollutants. These three vectors must be balanced, moderating existing trade-offs such as affordability on the one hand and energy transition toward renewable energy sources on the other.

This new energy security vision specializes in the inclusion of energy equity and sustainability issues. In this way, a holistic concept of energy security is proposed, in which each category is related, and their related mechanisms are created to guarantee energy security. For example, the diversification of sources and, mainly, the promotion of renewable energies allow reducing emissions from one of the most polluting sectors. Additionally, it positively affects energy independence, especially if the country is an importer of fossil energy sources. Other factors, such as energy intensity and efficiency improvements, are strategies that reduce energy consumption and help improve energy security.

Based on the notion of the Energy Trilemma and in the 4 A's (Availability, Accessibility, Acceptability, and Affordability) proposed by the Asian Pacific Energy Research Centre (APERC, 2007), we define four categories of policy goals: (1) Energy Resilience, (2) Energy Independence, (3) Energy Affordability, and (4) Reduction of Emissions (see Fig. 6.2). The first category is formulated from the most basic view of energy security, which considers the diversification of sources a central element in guaranteeing energy access. In this case, it is of utmost relevance that the energy system ensures access to energy through renewable sources. This vision of resilience, based on increased renewable sources, allows for better integration between energy and environmental policy. The second category is justified by the strategies that can be implemented in the energy system to reduce energy dependence; therefore, any policy aimed at reducing energy imports will have a positive effect. The third category addresses the issue of access by cost, so any measure that puts upward pressure on the price of energy can have a negative impact. In this case, the collateral effects of environmental policy can have significant repercussions on access to energy due to the (excess) financial burden incurred by the energy transition, which ultimately has to be paid for by society at large. Finally, the sustainability category reinforces the basis of the new vision of energy security based on increased consumption of renewable energy. Therefore, any progress in improving the share of renewable energies positively relates energy policy to environmental policy.

We performed a screening of the extant literature strictly concentrating on the Mexican context on the one hand and on policy instruments of both domains (energy and climate) on the other hand. Based on the evidence presented in the selected literature, we qualitatively assess each instrument as to whether it supports or compromises any of the policy goals. Based on our find-

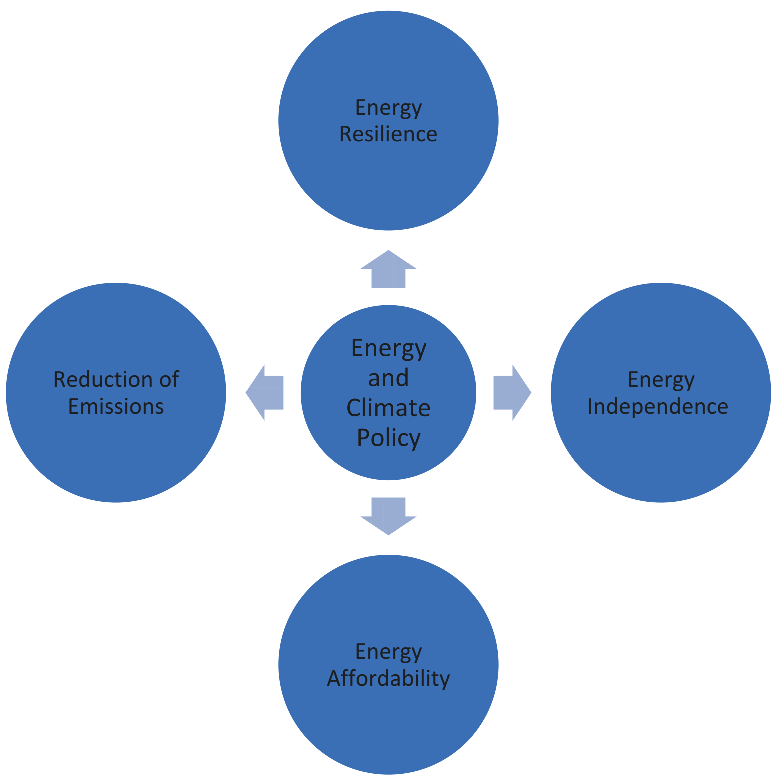

Fig. 6.2 Four categories of policy goals. (Source: Authors' elaboration)

ings, we synthesize by identifying inconstancies of across the totality of instruments.

6.3 Structure of the Mexican Energy Sector

In the introduction, we mentioned that a large part of the evolution of the energy sector and energy policy is explained by the discovery of the Cantarell field in the 1970s. Figure 6.3 shows that despite a downward trend over the past two decades, in recent years, the share of oil still exceeds 50%. On the other hand, the share of natural gas has grown about seven percentage points in the period under analysis. For electricity generation, it has even become the most important source (SIE, 2022). Lastly, renewable energy sources constitute for barely more than 10% of the energy mix, despite the implementation of dedicated policies, including the 2013 energy reform. In sum, in terms of energy production, no considerable changes have occurred and less polluting primary sources, in this context natural gas and renewables, continue to occupy minor shares.

The depletion of oil reserves, coupled with the fall in the production of this resource, which is still central to the energy structure, has caused a setback in energy security (Puyana & Rodríguez, 2020). This is explained by the exploitation of 85% of its proven reserves between 1990 and 2018 and a decline of 45% in crude oil production between 2008 and 2020 due to the depletion of Cantarell and the lack of investment in exploration (SIE, 2022). This situation was the main reason behind the formulation and implementation of the energy reform in 2013, which aimed to increase oil production to 3.0 million barrels per day, thus continuing the role of Mexico as a crude oil net exporter. It should be noted that after 10 years since the energy reform of 2013 was signed (Peña Nieto Administration, 2012–2018), the private investments in exploration have been meager, and PEMEX continues to be the largest investor in exploration and production. On the other hand, the lack of investment in petrochemicals and natural gas has increased the dependence on gasoline and natural gas imports for power generation. This situation also contributes to the loss of energy security, since, on the one hand, imports increase and, on the other hand, these imports come from only one country, the United States.

Natural gas has occupied a central place in the energy matrix, and this evolution has to do with its participation in electricity generation.

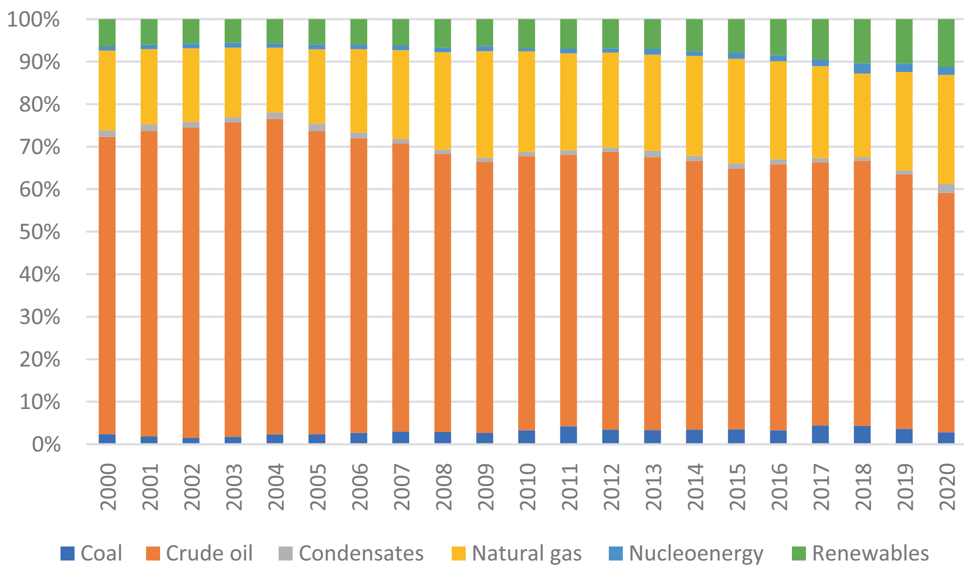

Fig. 6.3 Composition of energy supply by source. (Source: Author's elaboration based on SIE, 2022)

According to SENER (2021), electricity generation rests to 81% on fossil fuels (60% natural gas, 11% coal, 10% oil), to 3.8% on nuclear power, and the rest is composed of different renewable energy sources (10% hydro, 2.6% wind, 2% geothermal, 0.5% biofuels and waste, 0.1% solar). The growth of natural gas consumption in Mexico has been possible thanks to imports from the United States. Until 1990, domestic production of and demand for natural gas were in balance in Mexico. From that year onward, consumption began to grow at high rates and skyrocketed from 2010 onward, without domestic production being able to keep up in the same pace. Between 2014 and 2018, imports from the United States doubled to an average of 4.9 billion cubic feet per day, mostly from South Texas (SIE, 2022). Statistical evidence clearly shows the extent of import dependency: In 2017, 94% of natural gas imports in Mexico depended on a single country, the United States, and by 2019, this figure had risen to 96% according to data from the National Hydrocarbons Commission (CNH). The growth of imports from the United States and the construction of infrastructure have run in parallel: interconnections and pipelines, as well as processing, storage, and distribution facilities. According to EIA (2018), the pipeline capacity between the United States and Mexico increased by 226.47% between 2011 and 2018, from 3.4 billion cubic feet per day (MMcfd) to 11.1 MMcfd.

Despite a higher share of renewable energies at present (19%), the composition of the energy matrix shows a higher percentage of gas and little reduction in coal consumption. Additionally, oil still represents more than 50% of the energy matrix. Thus, the few changes in the energy matrix in the last decades show little energy transition in the country, even though Mexico has recognized and ratified every international agreement against global warming (the following section breaks down the various environmental policies applied in the sector).

Specialized information shows a very slow transition in the energy matrix, and something similar happens in electricity generation. According to SENER data (2021), the largest source of electricity generation in 2019 is of fossil origin, 81% (this percentage includes fuel oil and gas), and renewable energies, 19%, generate only a minor proportion. It is worth noting that of this proportion, hydropower (10%) has the largest share, while solar and wind combined only contribute 2.1%. In the best-case scenario, the share of the latter two sources is expected to grow to 8% by the end of 2022. From the perspective of climate policy, the origin and evolution of greenhouse gas (GHG) emissions are central. According to the Mexican national GHG emission inventory, total emissions have grown from some 466 $MtCO_2e$ in 1990 to 736 $MtCO_2e$ in 2019. However, the increase slowed down in recent years. While in the 1990s and 2000s, the running 5-year average for overall emission growth was between 1.6% and 3.3%, in the 2010s it dropped to 0.1–0.5%. Looking at the sources of emission, it becomes clear that Mexico's GHG emissions are driven by energy-intensive economic growth (Pulver, 2009). The national emission inventory reveals that energy production, as well as transportation, had a higher share of total emissions in 2015–2019 (26% and 22% respectively) than in 1990–1994 (23% and 21% respectively). Moreover, industrial processes, as well as waste treatment, gained, while the share of agriculture (gross emissions) diminished.[2]

6.4 Climate and Energy Policy in Mexico

Energy Policy As outlined above, Mexico's energy policy was and still is based on oil extraction and consumption because it possessed abundant and cheap oil reserves. Therefore, oil becomes and consolidates as the primary energy source for the energy matrix and as a source of economic resources to sustain economic and social development. Despite being at the center of energy and fiscal policy, oil was not given the treatment of a strategic resource, as reflected in

[2]For the emission data, which also permitted the authors calculations of the emission growth rate, see INECC and SEMARNAT (2021).

the lack of restitution of reserves due to the low level of investment in exploration.

SENER's reports reflect a concern about the loss of energy security. Additionally, the importance of investing in exploring new areas, the non-conventional resources found in shale basins and deep waters, has been recognized by policymakers to reverse the reserve trend. However, one of the characteristics of this type of resource is that it requires more significant technological, financial, and execution potential to extract this type of hydrocarbons. Given this situation, the energy reform in 2013 consisted of modifying the institutional framework to open the sector to private investment and thus obtain the resources to finance the exploration of more expensive wells. In addition to opening the sector to private investment, the following objectives were also added to the energy reform: (1) To maintain the Nation's ownership of the hydrocarbons in the subsoil; (2) to modernize and strengthen, without privatizing the state-owned companies PEMEX and the Federal Electricity Commission (the Spanish acronym is CFE); (3) to reduce the country's exposure to financial, geological, and environmental risks in oil and gas exploration and extraction activities; (4) to allow the nation to exercise, in an exclusive manner, the planning and control of the national electric system, to benefit a competitive system that allows reducing electricity prices; (5) attract more significant investment in the Mexican energy sector to promote the country's development; (6) to have a sufficient supply of energy at better prices; (7) to guarantee international standards of efficiency, quality, and reliability of supply, transparency, and accountability; (8) to effectively fight corruption in the energy sector; (9) to strengthen the administration of oil revenues and promote long-term savings for the benefit of future generations; (10) to promote development with social responsibility and protect the environment.

Each of these proposals had the following objectives (according to the executive summary of the reform)[3]: (1) To lower electricity fares and lower natural gas prices; (2) to achieve restitution rates of proven oil and natural gas reserves higher than 100%; (3) to increase oil production to 3.5 million barrels per day by 2025. In addition, it will increase natural gas production to 10.4 billion cubic feet in 2025; (4) to generate nearly two percentage points more economic growth by 2025; (5) to create close to half a million additional jobs in this six-year term, reaching 2.5 million jobs by 2025; and (6) to replace the most polluting power plants with clean technologies and promote the use of natural gas in electricity generation. As can be seen, the envisioned outcomes of the energy reform in the medium term can be summarized as increasing reserves and extraction of crude oil and, to a lesser extent, of natural gas through public or private investment. On the other hand, renewable energies are mentioned, but the strategy to increase their participation in electricity generation is unclear.

Two elements were central despite the breadth of the energy policy proposed in the 2013 reform and the attempt to shift towards renewable energies to incorporate environmental issues. On the one hand, the participation of the private sector in extraction and, on the other hand, the integration of long-term auctions and clean energy certificates in electricity generation (Alpizar-Castro & Rodríguez-Monroy, 2016; Comisión Reguladora de Energía, 2017). In both cases, the results were meager. The current administration under President Andres Manuel Lopez Obrador has made its position clear: the oil industry must be revived as a trigger for the nation's development (DOF, 2020). In the same line, the energy policy supported by the current administration comprises (SENER, 2021) (1) a (partial) departure of the energy reform of 2013; (2) a commitment with OPEC Plus to maintain production of 1.753 million barrels per day of crude oil without cuts; (3) a rehabilitation of the National Refining System and the construction of the Olmeca refinery in Dos Bocas; and (4) allocating some 54% of electricity generation through renewables is granted to the CFE and

[3]For further details of the executive summary, please visit the following link: https://embamex.sre.gob.mx/suecia/images/reforma%20energetica.pdf

46% to private companies. The oil sector is considered a critical sector for the country's development. According to the abovementioned points, we can argue that the current administration's energy policy is to strengthen fossil fuels again (greater oil extraction and gasoline production). This strategy is justified by two arguments. On the one hand, more gasoline production will reduce imports of these and thus advance energy security. On the other hand, with the strengthening of PEMEX and CFE, the "Rescue of the energy sector" is sought. One of the sectors seen as a lever for national development is the promotion of economic growth and employment (National Development Plan, 2019–2024).

Climate Policy Mexican politics has embraced questions concerning climate change since the 1990s and shows nearly continuous action until the present day. It took part in the run-up of the 1992 Rio Earth summit, saw the beginnings of policy integrations via an "intersecretarial committee" at the federal level, ratified the Kyoto Protocol in 1998 as a Non-Annex I country, saw a formalization and increasing steadiness culminating in the General Law on Climate Change (GLCC) in 2012 and most recently announced its 2020 Nationally Determined Contributions (NDC's) before the UNFCCC (Pulver, 2009; Gobierno de México, 2020).

As part of the mechanism of the UNFCCC Paris Agreement of 2015, the Mexico presented NDC's in 2016 and 2020 (Gobierno de Mexico, 2020), where in the latter it unconditionally pledges a 22% reduction of GHG emission in 2030 vis-à-vis the business-as-usual (BAU) scenario (conditionally 36%). A short overview of targeted emission levels and a change from the 2016 NDCs to the 2020 NDCs can be seen in Table 6.1. It shows that Mexico has not increased its ambition. On the contrary, based on a more pessimistic BAU scenario from 2020, the pledges of the NDC 2020 would lead to higher GHG emissions in 2030.

Amid moderate ambition levels, Mexico has implemented several climate policy measures, comprising monitoring, mitigation, and adaptation instruments at all levels of government. However, the implementation status, especially at the state level, is slow, see Lopez and Laguna (2020). This text will concentrate on the measures closely related to the energy sector for obvious reasons. Among these, perhaps most prominently, are the steps taken as part of the 2014 fiscal reform. From a climate policy perspective, it mainly consisted of a change of the motor fuel tax and the introduction of a carbon tax.[4] The latter, which taxes different types of fossil fuels except for natural gas, currently imposes an average charge equivalent to 1.56 EUR/tCO_2 on average and covered some 58.1% of national CO_2 emissions (OECD, 2021). The motor fuel tax was transformed from a (fuel) price smoothing instrument into one with fixed rates aiming at excise taxation, thereby contributing to phasing out fossil fuel subsidies.[5] Moreover, it may be interpreted as an implicit carbon tax, which in 2021 exerted a carbon price equivalent to 25 EUR/tCO_2, covering some 31.1% of national emissions (OECD, 2021).

Thus, in Mexico, there currently is a carbon tax with relatively wide coverage and a rate that is comparable to other countries in Latin America, yet low in contrast to the European Union or regulated regions in North America and Europe.[6]

[4] Both taxes, the motor fuel tax and carbon tax part of the Law on Special Taxes on Production and Services (IEPS – Ley del Impuesto sobre Producción y Servicios), see DOF (2021).

[5] A fiscal stimulus, which could be applied ad-hoc and would reduce the tax rate on a % basis, was phased out in 2017, see Arlinghaus and van Dender (2017). However, it was reintroduced in the wake of the pandemic and reinforced during the war in Ukraine in 2022. During March 19–25, 2022, it consisted of a 100% reduction of the fuel tax (IEPS) for gasoline and diesel alike. Moreover, an additional stimulus was granted ranging from 1.30 MXN to 2.10 MXN, depending on the type of fuel. See http://www.dof.gob.mx/nota_detalle.php?codigo=5646110&fecha=18/03/2022 (accessed March 24th, 2022).

[6] Among the growing number of countries that have implemented carbon pricing instruments, Mexico is located at the lower end of the spectrum. While in Latin America, carbon prices are of same order of magnitude as in Mexico (Argentina, Chile, and Colombia have carbon prices of are around 5–6 USD/tCO2), in the United States and Canada, we find a range of 7–36 USD/tCO2 and in Europe of 1 to 137 USD, with the majority of countries having prices of

Table 6.1 Mexican greenhouse gas emission pledges 2016 and 2020

	NDC 2016		NDC 2020	
	Reduction relative to BAU	GHG emissions in $MtCO_2e$	Reduction relative to BAU	GHG emissions in $MtCO_2e$
BAU scenario GHG emissions in 2030	–	973		991
Unconditional pledge for 2030	22%	758	22%	773[a]
Conditional pledge for 2030	40%	538	36%	644

Author's own calculations based on Gobierno de Mexico (2020)
[a]Author's calculations deviate from the report of the Mexican Government (Gobierno de México, 2020), where it states that GHG emissions in 2030 would amount to 781 $MtCO_2e$

The fuel tax, on the other side, has a considerably higher rate but relatively limited coverage, that is, it mainly targets the transport sector. This relatively weak environmental stance in fiscal policy goes back to strong opposition against carbon pricing in Mexico. Industry groups lobbied against the instruments and for reducing policy ambition, see Dibley and Garcia-Moron (2020) and López Pérez and Vence (2021). On the other side, Mexico departed from an even weaker carbon pricing regime, and the tax reform commenced a change of direction in that sense. Arlinghaus and van Dender (2017) show that the total fiscal burden (VAT, motor fuel tax, and later the carbon tax) per tCO_2 increased from 10 EUR in 2012 to almost 150 EUR in 2016.

Next to the federal taxation of carbon, which is concentrated on fuels, some federal states have recently begun to tax GHG emissions directly, that is, from fixed sources. Thus, these subnational carbon pricing initiatives aim at the industrial sector, including electricity generation, and fill a gap left by the national carbon tax. Starting in 2019, to the best of our knowledge, there have been initiatives in 8 of the 32 states, out of which 6 (successfully) enacted their carbon taxation; see Table 6.2, for an overview. What is remarkable is that most states are imposing rates far beyond the national carbon tax. Among these are the heavily industrialized entities of the State of Mexico (Estado de México), Querétaro, and Nuevo León. Baja California's fuel-based carbon tax was ruled unconstitutional.[7] Likely, this is why other states turned to tax emissions rather than the carbon content of fuels.

Lastly, the national level is currently implementing the trial phase of an emissions trading system (ETS). Since the 2018 amendment to the GLCC foresees an emission trading system as mandatory, this was implemented in January 2020, starting with a pilot phase that lasts until December 2022.[8] Currently, the Mexican ETS comprises the energy and industry sectors (Pérez, 2022). There are 300 firms that participate on a mandatory basis – large emitters with 100,000 tCO_2 emissions per year. The emissions cap is determined by historical levels (2016–2019), and permits are allocated freely. After all, the main goal of the pilot phase is to establish a functioning and robust mechanism, thereby laying the groundwork for a mechanism to attain the Paris pledges cost-efficiently. Pérez (2022) comments that among the many challenges connected to fully developing the Mexican ETS are firstly aligning it with existing policies (e.g., the carbon taxes) and achieving coherence with other policy aims, such as the promotion of hydrocarbons in the energy sector by the Ministry for Energy under the administration of President López Obrador (2018–2024).

Elizondo (2022) notes that there has been an extensive consultation process with key actors, such as the national electricity commission that

25 USD or higher (World Bank, 2021).

[7]The supreme court (PODER JUDICIAL DE LA FEDERACIÓN) ruled in 2021 that states have no right to tax crude oil or derivatives, since this is a right exclusive to the federal jurisdiction, see https://www.tlcasociados.com.mx/impuesto-ambiental-por-la-emision-de-gases-a-la-atmosfera-en-baja-california-es-inconstitucional-pjf/ (accessed March 20th of 2022).

[8]See SEMARNAT (2021).

Table 6.2 State carbon taxes

State	Carbon price MXN/tCO2e 2022	Carbon price USD/tCO2e	Comment
Querétaro[a]	539	25.70	Enters into effect in 2022 Inflation-indexed tax rate
Tamaulipas[b]	288	13.70	Enters into effect in 2021 Inflation-indexed tax rate, 25 tCO_2 tax allowance
Nuevo Leon[c]	268	12.80	Enters into effect in 2022 Inflation-indexed tax rate
Yucatan[d]	259	12.40	Enters into effect in 2022 Inflation-indexed tax rate
Zacatecas[e]	250	11.90	Enacted in 2019 Constant tax rate
State of Mexico[f]	43	2.00	Enters into effect in 2022 Constant/indexed
Jalisco[g]	(NA)	–	Legislative initiative in 2020, as of 2022 not implemented
Baja California[h]	(170)	(8.10)	Fuel based Ruled unconstitutional by Mexican Supreme Court

Calculation by authors (Some tax rates depend on official (economic) measurement units (UMA – Unidad de Medida y Actualizacion). These are yearly updated to account for inflation. The rate for 2022 can be found at URL: https://www.gob.mx/fovissste/articulos/comunicado-actualizacion-uma-2022?idiom=es)

[a]Diario de Querétaro (December 21st, 2021), "Cobrarán Impuestos ecológicos, van contra empresas", https://www.diariodequeretaro.com.mx/local/cobraran-impuesto-ecologico-van-contra-empresas-7598569.html (Accessed March 15th, 2022)

[b]Gobierno de Tamaulipas (2020), Periodico Oficial, 29 de julio de 2020, URL: http://po.tamaulipas.gob.mx/wp-content/uploads/2020/07/cxlv-91-290720F-EV.pdf (Accessed March 15th, 2022)

[c]Gobierno de Nuevo León (2021) Periódico Oficial, Monterrey, Nuevo León, Jueves - 23 de Diciembre 2021, pp. 54–58, URL: http://sistec.nl.gob.mx/Transparencia_2015/ (Accessed March 15th, 2022) Archivos/AC_0001_0007_00170072_000001.pdf

[d]Líder Empresarial (January 3rd 2022) Año nuevo: nuevos impuestos y aumentos, URL https://www.liderempresarial.com/ano-nuevo-nuevos-impuestos-y-aumentos/ (Accessed March 15th, 2022)

[e]Diario Oficial del Estado de Zacatecas DOF:20/03/2019, Ley de Hacienda de Zacatecas. Its constitutionality was approved by a ruling of the Mexican Supreme Court, see https://www.mexico2.com.mx/noticia-ma-contenido.php?id=345

[f]El Sol de Toluca (January 29th, 2022) "Empresas contaminantes pagarán por tonelada de gases en el Edomex" URL: https://www.elsoldetoluca.com.mx/local/empresas-contaminantes-pagaran-por-tonelada-de-gases-en-el--edomex-7797046.html (Accessed March 15th, 2022)

[g]Informador.mx (October ninth, 2021) "Archivan nuevo impuesto estatal a empresas emisoras de contaminantes" URL: https://www.informador.mx/jalisco/Archivan-nuevo-impuesto-estatal-a-empresas-emisoras-de-contaminantes-20211009-0090.html (Accessed March 15th, 2022)

[h]Presidencia del Congreso del Estado de Baja California, Comisión de Hacienda y Presupuesto, Dictamen No. 65. URL: https://www.congresobc.gob.mx/Documentos/ProcesoParlamentario/Dictamenes/20200424_65_HACIENDA.pdf; Poder Judicial de la Federación ruled that states have no right to tax crude oil or derivatives, this is a right exclusive to the federal jurisdiction (https://www.tlcasociados.com.mx/impuesto-ambiental-por-la-emision-de-gases-a-la-atmosfera-en-baja-california-es-inconstitucional-pjf/)

runs power stations and grids (CFE), as well as with the hydrocarbon sector, specifically the Ministry of Energy (SENER) and PEMEX, but also the Initiative for Market Readiness (World Bank, 2021) and the German Agency for Development (GIZ) to better design the policy instrument and avoid unintended interference with existing policy measures – a lesson learned from the carbon tax, which was ultimately reduced in scope and effectiveness.

Summing up, we find that climate policy in Mexico has shown little momentum until recently, though politics has shown intentions to leave the path of fossil fuel subsidies. However, in the light of the continuous rise of GHG emissions ever since the commencement of climate policy, Sosa-Rodriguez (2015) deems instruments insufficient. This pessimistic view is supported by the comparative study of Pischke et al. (2019) on the degree of climate policy implementation among large countries in the Americas between 1998 and 2015. While Mexico is in third out of five places, counting the number of laws and regulations, it ranks last regarding policy intensity, though it caught up during the second half of the period studies. And Ortega and Casamadrid (2018) find that actors, who participated in the formulation and enacting of climate policy in Mexico, opine that the debate was centered around economic and fiscal arguments rather than environmental ones. Finally, Octaviano et al. (2016) show that abatement costs for Mexico are substantial and considerably higher than in Brazil since energy production is very carbon intensive for more ambitious GHG reduction targets. This may explain the continued reliance on fossil fuels in the energy sector until the present day.

6.5 Analysis of Energy Policy Mexico

In the following, we present evidence concerning the energy and climate policy instruments currently employed and then use this evidence to assess each instrument's effect on the four categories we proposed. We work our way from instruments directed to the upstream, that is, exploration and extraction activities, to the midstream, that is, the use of fossil fuels for electricity production and in industrial processes, to finally arrive at the downstream, that is, household demand.

Upstream The analysis and relationship between energy policy and environmental policy will be presented for each resource. In the case of oil, the central element in energy policy shows that the policies implemented could help guarantee energy security because new reserves would be added by opening up to the private sector in exploration or by greater participation of the public sector. However, this has not yet materialized. So proven reserves have not increased and production has not reached the goal of 3.0 million barrels per day established in the energy reform in 2013. Therefore, if the investment is reactivated, progress in energy security would be expected (reflected in the (+) in energy independence). However, this again consolidates an energy policy that prioritizes fossil fuels, hence the (−) in energy resilience in Table 6.3 (Torres, 2020). On the other hand, the consolidation of a policy based on fossil fuels will not allow reducing emissions, as shown by the national emissions inventory, therefore a (−) for reduction of emissions in Table 6.3. Regarding the affordability category, the effect of the arrival of new investments and the addition of crude oil reserves on energy costs is still unclear. In this case, it will depend on the determinants of international oil prices. Regarding gas, the behavior in terms of policies is similar to that of the oil market; it only differs because gas is a fossil source that can be used to reduce CO_2 emissions in electricity generation (SENER, 2021). In this case, investment has been directed to exploration, yet here too the reserves have not grown as of now. According to SENER (2020), natural gas production declined over the last few years, going from 6534 million cubic feet per day (MMpcd10) in 2009 to 3842 MMpcd in 2018. The drop in gas production will be reflected, mainly with a (−) sign in the dependence category in Tables 6.3 and 6.4. According to information from the energy information system (SIE, 2022), natural gas imports from the United States represent 94% of total domestic consumption (excluding PEMEX consumption), and by 2019 this proportion increased by 2 percentage points. That is expressed by (−) in the dependency category in Tables 6.3 and 6.4.

Most of the investment has been in pipeline infrastructure to transport and distribute gas imported from the United States, especially from Texas. According to SENER (2020), part of the current administration's strategies consisted in

Table 6.3 Upstream instruments and contribution to energy security and sustainability

Resource	Instruments	Energy resilience	Energy independence	Energy affordability	Reduction of emissions
Oil	Public and private investment in exploration and extraction	(−)	(+)	(?)	(−)
Natural gas	Public and private investment in exploration and extraction	(+)	(−)	(+)	(?)
	Investment in distribution and infrastructure for gas (pipelines)	(+)	(−)	(+)	(?)

Legend: (+) positive effect, (−) negative effect, (0) neutral effect, (?) ambiguous effect(s)

Table 6.4 Midstream and downstream Instruments

Sectors	Instruments	Energy resilience	Energy independence	Affordability of energy/ avoiding CPI increase	Reduction of emissions
Electricity	Combined cycle by gas	(+)	(−)	(+)	(?)
	Long-term auctions	(/)	(/)	(+)	(/)
	Clean energy certificates	(+)	(+)	(?)	(+)
Electricity & Industry	Emission taxes for fixed sources	(+)	(?)	(−)	(+)
	ETS (currently in pilot phase)	(+)	(?)	(−)	(+)
Transport	National carbon tax,	(/)	(/)	(−)	(+ / 0)
	Vehicle fuel tax, and carbon tax	(/)	(/)	(−)	(+)

Legend: (+) positive effect, (−) negative effect, (0) neutral effect, (?) ambiguous effect(s), (/) no evidence found

adding 1224 km of gas pipelines, which translates into a growth of 7.7% in just 1 year. In addition, between 2020 and 2021, three new gas pipelines have started operating, adding 988 km to the network. With this new infrastructure, Mexico will have an import capacity of approximately 13,00015 MMcfd (millions of cubic feet per day). The last idea is represented in table 6.4 with a (−) for dependence and (+) for affordability and resilience. As far as sustainability is concerned, it will be analyzed in the following paragraphs.

Another element to consider in the gas issue is the price difference between Mexico and the United States; according to EIA data, the average gas price in the United States has been below 2.00 US Dollars per thousand cubic feet in the last decade. In Mexico, the average gas price has averaged over 2.50 US Dollars per thousand cubic feet. It is reflected in energy affordability with a (+) (SENER, 2021) in Tables 6.3 and 6.4. Hence, the growing use of gas through combined cycle power generation (see Table 6.4) has had an important advance in terms of affordability (+) and resilience (+), since it helps to diversify the energy matrix.

The impact of fostering natural gas on sustainability is ambiguous, hence a (?) in Tables 6.3 and 6.4. Due to its lower CO_2-content sustainability is improved on the intensive margin. However, in Mexico, 60% of electricity is generated with gas, this proportion has grown in recent decades; for example, in 2014, the share of electricity generation by combined cycle was 22% and by 2015, this proportion rose to 51% (SIE, 2022). In the end, emissions in the electricity generation sector have grown gradually during the period 2000–2015 going from 121,025 to 170,956 tons per year, according to Mexico's national emission inventory (INECC and

SEMARNAT, 2021; Catalán, 2021). So, through the extensive margins, gas contributed negatively to the sustainability category. In the end, however, gas is replacing oil in the energy matrix in general as well as in electricity production. Its true impact should be assessed through a comparison of the counterfactual situation of not replacing oil by gas, for which we haven't found any assessments in the literature. In conclusion, we remain with an overall ambiguous effect on sustainability for gas.

Midstream For electricity generation, since the 2013 energy reform auctions serve to allocate long-term contracts for the supply of electric energy among contenders on competitiveness grounds. The supervising regulatory authority is the Energy Regulation Commission. The contracts awarded will have a duration of 15 years. Between 2015 and 2018, three successful and internationally recognized long-term auctions have been held through which increasingly competitive prices have been obtained (SENER, 2021).

Next to that, there are Clean Energy Certificates CELs. These have been introduced to integrate clean energies in electricity generation at the lowest cost, incentivize the development of new investment projects in clean electricity generation. These may generate and sell CELs participants obliged to acquire CELs, large consumers, and nonrenewable energy producers. The CEL requirement defines the proportion of the total energy supplied to final clients or produced for own consumption during a month to be covered by CELs.[9] The legal requirement has been raised considerably during the past year starting from 5.8% in 2019[10] and getting to 13.9% in 2022.[11]

We find that the measures applied to the electricity market, that is, long-term contracts and CELs, have contributed positively to energy resilience, energy independence, and emission reduction. Each is reflected with a (+) in the table. We find energy affordability affected in an ambiguous way, since much of the technologies for electricity generation through renewable sources are imported.

After having detected the impacts of energy policy instruments, we now turn to climate policy. The literature review conducted by Coste et al. (2018) reveals that the impacts of environmental taxes are moderate, rate short-term, and concentrated on energy-intensive and trade-oriented sectors. These sectors suffer output contractions due to price-induced decreases in demand for their goods and services, which points toward a "(−)" for the affordability of energy. Yet most studies have been carried out for high-income countries in Europe and North America. So, a closer look with respect to Mexico is in order. We will first assess findings with respect to the midstream (electricity and heat production as well as industry) before getting to instruments targeted at final demand, see Table 6.4.

Fixed-Source Carbon Tax (in some States) Barragan-Beaud et al. (2018) present an extensive study assessing and comparing the impact of a carbon tax with that of an ETS on the energy sector in Mexico. Their findings indicate that if carbon tax rates strongly increase over time,[12] initially, there would be low cost-

[9] Entities that must acquire CELs are energy suppliers and installations that have their own electricity generation installation (disconnected from the grid). See Comisión Regulatoria de Energía (2022) "Preguntas Frecuentes sobre los Certificados de Energías Limpias", URL: https://www.gob.mx/cre/articulos/preguntas-frecuentes-sobre-los-certificados-de-energias-limpias (Accessed September 24th, 2022).

[10] https://www.gob.mx/cre/articulos/preguntas-frecuentes-sobre-los-certificados-de-energias-limpias

[11] See Diario Oficial de la Federación, Friday, March 29th 2019, Available at: https://www.cenace.gob.mx/Docs/16_MARCOREGULATORIO/CEL/(DOF%202019-03-29%20SENER)%20Requisito%20de%20CEL%20(2022).pdf (Accessed September 23rd, 2022).

[12] Barragan-Beaud et al. 2018suggest in one scenario a carbon tax that increases from 10 to 50 USD per tCO_2e between 2018 and 2025.

efficiency due to the lag caused by necessary investment. Emissions would not be reduced, but costs would be high to tax-paying firms and might have to be shifted forward to consumers. On the other side, carbon taxes yielding medium run levels of 15–50 USD per tCO_2e would yield abatement levels vis-à-vis the baseline scenario of roughly 40% and 57%, respectively – significantly more than Mexico's conditional NDC. Hence, fixed-source carbon taxes receive a (+) for their effectiveness in emission reduction (Huesca & López, 2016).

On the other hand, electricity prices are projected to increase by some 10% – considerably more than for an ETS, which results in "(−)" for electricity/energy affordability. Finally, Barragan-Beaud et al. (2018) find that the energy mix would evolve toward higher volumes of solar PV and wind plants, while mostly coal would be reduced, which can be neglected given its minor initial share (see Sect. 6.2 of this Chapter). So, the energy mix would diversify, hence a (+). In contrast, the contribution to energy independence is ambiguous, with domestic renewables up and no clear sign of degrowth for the share of natural gas, hence a (?).

The findings of Landa Rivera et al. (2016), who assess carbon taxation in Mexico in a comprehensive numerical model, point in the same direction. They show that a carbon tax reaching emissions of 75% would come at a high cost if tax receipts are not recycled to private households. On the other hand, revenue recycling would lead to a double dividend of increased growth if revenue recycling is implemented. However, with state-level tax revenues and a national electricity market affected, it is hard to see how tax receipts are redistributed to affected households in all of Mexico. Yet, these schemes are just at their starting, and with all states participating eventually, the picture could change.

Bös and Vrolijk (2021) point toward the selectiveness of the Mexican carbon tax of 2014, where natural gas is excluded. They estimate that including natural gas and the heavier taxation of coal – which would convert more into an instrument directed at the midstream – could lead to higher cost-effectiveness (different trade-offs between emissions and output). According to Bös and Vrolijk (2021), taxing coal and gas could particularly be beneficial, since electricity production depends on these sources, offers a relatively low trade-off between output and emission reduction, and represents a large chunk of overall emissions.

Finally, the contribution by Mardones and Mena (2020), showing evidence from Chile, is to be considered due to the similarity of the policies implemented in Chile and Mexico. In both cases, fixed sources are targeted rather than the carbon content of fossil fuels. The Chilean tax consists of a rate equivalent to 5 USD/tCO_2 plus additional tax rate components depending on the emission of local pollutants and the affectedness of a region (the local component of the tax). It thus features a similar rate as in Mexico. Consequently, Chile experiences a low emission reduction effect going back to its carbon tax. Furthermore, indicative for our assessment in the context of the Energy Trilemma is their finding that there is a substantial rise in the price of electricity and a lesser, albeit positive, effect on industrial products and water supply. The authors estimate the overall change of the CPI to be 0.1–0.2% for the prevailing rate of 5 USD/tCO_2 and a 0.2–0.35% increase for a hypothetical carbon tax of 10 USD/tCO_2.

Emission Trading Scheme (ETS) To begin with, there aren't many contributions assessing the impact of an ETS on the Mexican economy. In fact, to the best of our knowledge, the only contribution that does so is the one by Barragan-Beaud et al. (2018) mentioned earlier. They assess a cap that implements Mexico's conditional NDC of 2015, which represents a GHG reduction of roughly 25% in 2030 compared to 2018, and find this would result in permit prices of 2–4 USD/tCO2e by 2024/2025, thus very moderate levels and comparable to today's (selective) carbon tax. This shows that if the cap is chosen based on an (overly) potentially pessimistic scenario, its actual emission reduction effect is low yet still positive – hence a "(+)." In that respect, Barragan-Beaud et al. (2018) explore a more ambitious cap that is better compared to their tax scenarios. It roughly consists of reducing today's emissions in the electricity sector by 50%, resulting in permit prices evolving from 4 USD/tCO2e in 2018 to 15 USD/tCO2e in 2030. So, if the political will is there, the abatement potential of this instrument can be considerable. However, as with the carbon taxes, this would come at a cost estimated to amount to a surge of 3% in electricity prices – hence a "(−)" in the category of energy affordability. Yet, this is much less than the impact caused by a carbon tax while yielding similar abatement levels. The authors' findings with respect to the energy mix and the energy independence mentioned above for the case of carbon taxation basically carry over.

Downstream On the downstream end of the energy value chain, households are subject to direct effects, for example, taxes on motor fuels, and indirect effects shifted down from the midstream. There are several model-based, numerical, and empirical assessments of these direct and indirect effects. The impact of increasing prices on the consumption basket is found in most studies, see Renner (2018). He reports an average price hike of 0.25% going back to the fuel-based (national) carbon tax. Hence, we may put a (−) for "Energy Affordability."

In Mexico's economic inequality context, more important is whether environmental- or energy-related taxes are progressive or regressive. Labeaga et al. (2021) estimate the effects of the 2014 tax reform and find that it led to reduced energy consumption (26%) due to tax-induced price hikes and observe a progressive impact. Assessing a much wider-reaching carbon tax, including natural gas, Renner et al. (2018) find that its effect would be generally progressive, yet it would be regressive for motor fuels. On the other hand, Chapa and Ortega (2017) employ an social accounting matrix (SAM) model and find that the implemented version of a carbon tax would be regressive. And Gonzalez (2012) points out that the scheme of revenue recycling is critical for progression. Using the carbon tax's revenues to reduce an industrial tax would render the carbon tax regressive. Yet, he finds the carbon tax to be progressive in case food subsidies are provided. To the best of our knowledge, revenue recycling has not taken place. Moreover, since several studies report a regressive effect of the national carbon tax, we have another motive to assess the federal carbon tax's impact on energy affordability as negative.

On the other hand, there is evidence that CO_2 emissions might fall as a consequence of households' response to the energy taxes, see Gonzalez (2012), Labeaga et al. (2021), and Renner et al. (2018). A crucial aspect is that some of these results assume a widely applicable carbon tax. Yet, the currently implemented tax, together with the motor fuel tax, mainly hits the transport sector, and while in Mexico, demand for motor fuels is found to be less price-elastic than electricity demand, see Labeaga et al. (2021), Ortega and Medlock (2021) and Renner et al. (2018). Due to the low current carbon tax rate, we put a "(0)" for reducing emissions. This also means that taxing electricity production may improve the trade-off between economic costs for households and climate change mitigation.

On the contrary, the motor fuel tax has a non-marginal tax rate. There is evidence that demand for motor fuels is unit-elastic: for instance, Ortega and Medlock (2021). We, therefore, conjecture that the current motor fuel does have a deterring effect on demand and thus on CO_2 emissions, hence a "(+)" for emission reduction. In the same vein, we may conjecture that the deterred demand occurred due to a rise in fuel prices, see Arlinghaus and van Dender (2017). Thus, there is evidence that the strongest, albeit transport-biased carbon pricing instrument in place caused energy prices to rise. Thus, the assessment is "(−)." As the studies directed at private households are often employing some form of an input-output model, no conclusions can be drawn with respect to the categories of energy resilience and energy independence (hence "(/)" for no evidence).

6.6 Conclusions

Our assessment of impact of policy measures on the four categories representing the Energy Trilemma is summarized in Table 6.3 and Table 6.4. Without exception, the four categories experience impacts from various policy tools and in different directions – positive and negative ones. This even applies to the impact only from energy policy or climate policy. So, from a global perspective, policies do not seem to consider their incoherent impact on (sustainable) energy security. Yet, looking a bit beyond the tables and taking into consideration specific aspects of policies outlined in the text, we come to four main conclusions.

Firstly, we find that policies directed toward the upstream, that is, oil and gas supply policies, predominantly focus on affordability and independence, compromising on emission reduction. Yet, at the same time, climate policy lacks a mechanism that would counteract its negative effects on affordability. Thus, energy and climate policies should be altered to soften existing trade-offs. Energy policy could be amended by stricter regulatory mechanisms to curb emissions on the intensive margins, that is, emission intensity of fossil fuel extraction. In the same vein, the market mechanisms of climate policy, which aim at the extensive margin, could be amended by revenue recycling mechanisms dedicated to vulnerable groups of society or earmarked for transition efforts to soften the instruments' impact on price by means of easing the substitution mechanisms.

Secondly, looking at the energy sector from a macro-perspective, we find that energy policy aims at increasing the supply of energy resources, while climate policy sets price signals to disincentivize consumption of energy. What seems a contradiction at first could be a wise combination of policy tools helping with energy security in the wider sense while decreasing the energy intensity of the Mexican economy.

Thirdly, the policy for natural gas seems to be coherent across both energy and climate policy, at least when buying into the idea of natural gas as a bridge fuel in the process of completing the greening of the economy. Energy policy is dedicated to increasing supply (mainly via imports) and converting it into power helps with the decoupling of end-users from any type of natural resource, while climate policy on the other hand spares natural gas from carbon taxation and thus does not apply a disincentive on its use.

Lastly, the long-term auctions on the electricity wholesale market not only help with energy affordability by being a catalyzer for cost efficiency. Raising efficiency in electricity generation, the auctions also alleviate pressure to provide more (fossil) fuels for growing energy demand.

To conclude, we find that while the largely disconnected policy fields of energy and climate change mitigation, at first sight, seem incoherent, we could identify some areas of (apparent) alignment. Yet, it remains to be said that policy integration is in order to heal shortcomings such as an energy policy agenda largely short of directly and strongly promoting renewable energy sources or timid climate policy shying away from stronger price signals due to a lack of easing the energy transition by positive financial instruments.

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7 Between Oil Dependence and Energy Sovereignty: The Limits of the Energy Transition in Ecuador

Nora Fernández Mora and Andrés Mideros Mora

7.1 Introduction

Since its initiation into the global market at the end of the nineteenth century, the Ecuadorian economy has been characterized by its dependence on income from the export of primary goods, from the cocoa (1895–1922) to the banana (1948–1970) booms, to those of oil extraction (1973–1980 and 2004–2014). It is due to this role as a provider of raw materials that its material base is not in the exploitation of the labor force, but rather in the exploitation of nature (Echeverría, 1994).

With the beginning of the first oil boom Ecuadorian State landownership was established, which, in the 1960s, had guaranteed monopoly ownership of the oil fields that were discovered north of the Amazon (Purcell & Martínez, 2018). Thus, the State began its direct influence in the oil subsector through the design and application of oil and macroeconomic policies that included tax, tariff, exchange, and other monetary policies (Falconí, 2002). This generated a close relationship between the trajectory of oil prices, public investment, and economic growth,[1] which is still today highly vulnerable to oil revenue shocks given Ecuador's role as a price taker in the international oil market (Pieschacón, 2012; García-Albán et al., 2021).

Under the framework of Import Substitution Industrialization (ISI) policies, the first large-scale energy infrastructure projects were financed through receiving extraordinary oil income[2] by the State through oil rent, establishing the link between the energy and productive matrix in force until today. In this context, subsidies were introduced to supply the growing demand for fuel for military, public and private transport, as well as to encourage the replacement of firewood and kerosene by other energy goods (liquefied petroleum gas and electricity) among the population living in poverty, thus increasing their progressive consumption during the modernization process promoted by the State. Through this process, state policies ended up encouraging the concentration of fuel subsidies in thermoelectric produc-

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N. Fernández Mora (✉) · A. Mideros Mora
Pontificia Universidad Católica del Ecuador (PUCE), Quito, Ecuador
e-mail: nefernandez@puce.edu.ec; amideros060@puce.edu.ec

[1] García-Albán et al. (2021) found a coincidence between the trajectory of oil prices and the evolution of real GDP, especially in years of large fluctuations in oil prices such as 1974 (positive), 1986 (negative), 1998 (negative), 2009 (negative), 2011 (positive), and 2016 (negative).

[2] Between 1973 and 1983, six thermoelectric plants and two hydroelectric plants were built, among which the Paute Hydroelectric Plant (500 MW) stands out, on whose natural provision cycle the national electricity supply would depend.

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tion and in the new growing vehicle fleet (Purcell & Martínez, 2018; Gould et al., 2018).

The drop in oil prices in the 1980s, together with the global rise in interest rates and the foreign debt crisis, led to the abandonment of the ISI model and, with it, the large hydroelectric projects,[3] leaving a matrix vulnerable to climatic events such as the El Niño phenomenon or the (dry waters) that periodically affect the hydrographic basin of the Paute power plant; heavily dependent on hydrocarbons through thermoelectric production, and linked to a system of energy consumption dependent on subsidies. Consequently, in the second half of the 1990s, Ecuador faced recurring energy crises that led to periods of supply rationing.

With the arrival of the structural adjustment policies, the public sector was ceding its participation in royalties and oil production to private foreign investment; the country left OPEC, and abolished public electrification institutions to make way for a free energy market model.[4] Tax revenues shrank because of low international oil prices and the state's decreased participation both in production and in the revenues captured by private companies. The prices of electricity, gasoline, and liquefied petroleum gas (LPG) increased as part of the structural adjustment measures to face the fiscal deficit. The effect generated by these policies (the adjustment policies) included the worsening of the living conditions of the population, accompanied by episodes of strong social conflict and political crisis.

Between 1997 and 2000, two presidents of the Republic were overthrown amid popular demonstrations in the face of attempts to eliminate electricity and fuel subsidies (LPG, gasoline, and diesel). As an effect, the prices of LPG and gasoline remained frozen since the beginning of the new century; this has a negative impact on the balance of payments and the fiscal accounts that must allocate more resources to subsidies; thus, for example, in 2006, the fuel subsidy represented 95.8% of the Central Government's oil revenues and 64.3% of its accrued capital expenditures, 28% of the general state budget and was twice as high as the education budget (12%) and four times as high as that allocated to health (7%).

In 2007, after the arrival to the government of Rafael Correa,[5] the country entered a Constituent Assembly process that culminated in the approval of a new Constitution (2008) in which the rights of nature were recognized (Arts. 71–74), Sumak Kawsay[6] (Arts. 14, 275) is defined as a paradigm for development in harmony with nature, and it is established that energy in all its forms is a strategic sector reserved for administration, regulation, and control by the state (Art. 313). At the same time, a series of public policies were implemented to change the productive matrix with the aim of reducing dependence on oil revenues and moving toward a new model of accumulation based on a diversified and sustainable industrial structure, which would paradoxically be financed with the flow of oil revenues generated by the new boom in commodities.[7]

Under this framework, an energy transition process was proposed that included (i) leaving the oil reserves of the Yasuní National Park underground, in exchange for the international community compensating the Ecuadorian state for the loss of income; (ii) implement a strategy for changing the energy matrix that included the construction of large hydroelectric projects that

[3]In 1987 and 1988, the Agoyán (156 MW) and Marcel Laniado Wind (213 MW) hydroelectric plants came into operation; the last ones were part of the country's hydroelectric potential exploitation program.

[4]In 1996, the Electricity Sector Regime Law sought to encourage private investment in both the generation and distribution of electricity. With little success, concessions were granted to companies in thermoelectric generation to face the persistent energy deficit.

[5]Representative candidate of the Citizen Revolution, a political movement that collects the anti-neoliberal demands of social organizations and governs between 2007 and 2017.

[6]The Sumak Kawsay is a multidimensional paradigm that, from a biocentric perspective, proposes new forms of life as the central axis of harmonious development between human beings and nature (Ramírez-Cendrero et al., 2017).

[7]Cycle of high commodity prices (2000–2014), driven by growth in demand from emerging countries, especially China, that benefited commodities net exporters of South American (De la Torre et al., 2016).

generate cheap and clean energy for the national industry, and an incentive policy for the substitution of fossil fuel consumption for electricity, which reduces the fiscal pressure generated by energy subsidies.

The objective of this chapter is to make a critical balance of the results of the energy transition policies in Ecuador, for which it asks: what are the limits and structural contradictions that the development model, that is dependent on oil income, imposes on the energy and production transformation processes in Ecuador? To answer this question, we will review the results of the energy transition linked to the project to change the productive matrix. The relationship between value, State, nature (energy), and society, proposed by Purcell and Martínez (2018) to identify the contradictions of energy policies in countries dependent on natural resources, will be analyzed through energy subsidy and social welfare systems, considered as mechanisms of state-owned land to transfer the oil rent to the process of accumulation of local capital and society. In this way, it will contribute to the study of the structural limits for the energy transition that oil countries face.

This chapter is organized as follows: Sect. 7.1 presents the literature generated around the processes of energy transition and change in the productive matrix, from which the theoretical framework of the research is established. Section 7.2 explains the methodology. Section 7.3 describes the policies of the energy transition, identifies, and discusses the main results. Finally, the conclusions are presented in Sect. 7.4.

7.2 Literature Review

The study of the energy transition is an emerging field of research that has gained ground within the framework of the global transformations generated by an unsustainable energy model that faces the depletion of fossil fuels, a growing energy demand, and the pressure to lower energy prices as well as greenhouse gas (GHG) emissions to combat climate change (Mártil de la Plaza, 2020; Kern & Markard, 2016).

The energy transition can be conceptualized as a set of policies that generate structural changes in the models of energy production, distribution, and consumption (Mártil de la Plaza, 2020), which is not limited to the transition from fossil and nuclear fuels toward renewable sources, but rather implies a multidimensional change that, unlike previous transitions, is driven by political objectives toward sustainability and governed by public policies (Kern & Markard, 2016); therefore, its analysis must include the role of the State (Cherp et al., 2017).

According to the literature, states choose their energy strategies based on their institutional capacity related to their patterns of industry-state interaction (Ikenberry, 1986); material and institutional factors can limit the ability of states to achieve their goals in terms of energy (Cherp et al., 2017). In the case of peripheral economies, they face structural problems such as financial dependence and lack of control over the technologies required for the transition processes (Hansen et al., 2018; Grübler et al., 1999; Raven et al., 2016), caused by their role as providers of energy goods, with economic sectors that are not very intensive in capital and low levels of industrialization, added to the fact that energy innovations are usually generated in countries with a higher GDP per capita and a lower endowment of resources (Burke, 2010).

Because of the link between the energy matrix and the productive structure, from the perspective of energy criticism, theoretical debates and empirical analyzes have been generated to understand the limitations faced by national and regional sustainable development projects of Latin American economies dependent on natural resources, revolving around the relationship between nature, society, state, and capital accumulation. Recent literature has focused on the post-neoliberal[8] period of Latin American governments, whose energy transition projects were

[8]Post-neoliberalism is a trend that, to different degrees, breaks with some aspects of neoliberal politics and includes policies of rent-seeking and taxes, market regulation, social spending, infrastructure construction, and recovery of national sovereignty (Ruckert et al., 2016).

financed with extraordinary income from the commodities boom.

Several political ecology studies have put their focus on the socio-environmental impacts of the construction of hydroelectric infrastructure and the expansion of the frontiers of extraction of energy goods (Viola, 2016; Lyall & Valdivia, 2019), as well as in the social production of the territories in which the analysis of accumulation by dispossession has occupied a central space central (Gudynas, 2010; Veltmeyer & Petras, 2014; Martínez & Castillo, 2016). In general terms, they conclude that these processes have facilitated the control of capital over natural resources, the deepening of inequalities, and the production of new asymmetries, consolidating a neo-extractivist[9] style of development (Schuldt & Acosta, 2006; Svampa, 2013).

The geopolitics of energy and international political economy have examined the role of China as a new pole of capitalist accumulation and its relationship with Latin America through the flows of capital, work, and technology associated with credits for energy infrastructure, guaranteed with resources energy, to which the countries of the region have access (Escribano, 2013; Gallagher et al., 2013a, b). These relations are the result of the international policy agenda focused on energy security for which States, such as China, develop military, diplomatic, and economic strategies to guarantee the supply of oil and gas (Yergin, 2001). This dynamics tends to reaffirm the unequal geographic conditions under which capital accumulation has historically functioned (Viola, 2020; Valdivia & Lyall, 2018).

From the Marxist political economy, it has contributed to the debate of the complex relationship between society, nature (energy), and value through the concepts of land rent[10] and landed state to explain the contradictory results of the national accumulation projects promoted in the region during periods of high commodity prices (Carrera, 2007; Huber, 2009; Echeverría, 2006; Purcell et al., 2016). According to Carrera's (2007) theoretical proposal, the landed state mediates capital's access to nature, capturing the value generated in industrial countries in the form of land rent and controlling its distribution to factions of local capital and society through policies (subsidies, market protection, spending on infrastructure and energy, etc.), constituting capital accumulation processes based on land rent.

Regarding the Ecuadorian energy transition, the empirical literature has focused on the evaluation of scenarios of electrification and decarbonization policies, in which it is shown that, in 2050, sectors such as transport will continue to depend mainly on fossil fuels and that the Economic growth is not necessarily correlated with the growth of renewable energies (Arroyo & Miguel, 2019; Pinzón, 2018), so climate policies and long-term energy planning are necessary to encourage the replacement of nonrenewable energy with clean energy (Villamar et al., 2021; Arroyo & Miguel, 2019; Dafermos et al., 2015).

A part of the literature has been dedicated to characterizing the results of the projects of the post-neoliberal period, having rentier capitalism as the framework of analysis that determines the primary-dependent economies. Within this perspective stands out the work of Purcell and Martínez (2018), which, under the theoretical framework of Carrera (2007), analyzes the contradictions of energy policies concluding that their result was the overproduction of electricity that was unable to be anchored to the national industrial and residential demand and instead was reoriented toward exports and supplied cheaper energy for large-scale mining projects, thus reproducing the dependency on the extractive capital accumulation model that it was intended to overcome with the capture and distri-

[9] Defined as a pattern of accumulation based on the overexploitation of natural resources, largely nonrenewable, as well as on the expansion of borders toward territories previously considered unproductive.

[10] Land rent understood as the part of the social value (extra profits) that capital pays to the land-owning states to access the nonrenewable natural resources over which they have monopoly control. As per Purcell and Martínez (2018), land rent "is not only a redistributive category of the economic surplus but also a material relationship of production (…) that supports specific and unequal processes of capital accumulation" (p. 42).

bution of oil revenue by the State. Because of the global social origin of this differential rent, the global dynamics of capital accumulation limits the power of the landed state over nature (Purcell & Martínez, 2018).

This reading coincides with that made by Wilson and Bayón (2017), who, based on the study of the emblematic projects of the change in the productive matrix, show that being "sustained by the extraordinary flows of income from the land, they have been surpassed by the material base of the Ecuadorian economy" (p. 171), which ties them to the accumulation of transnational capital based on the expansion of extractive borders.

In this research, we start from the theoretical framework proposed by Carrera (2007) to analyze the accumulation of capital through the appropriation of land rent in economies based on natural resources. Through the analysis of the results of energy policies, we explore the structural limits that explain the contradictions of the CME process identified in the research by Purcell and Martínez (2018).

To do this, we put them in dialogue with the role of the landed state and technological rent in the current process of capital appreciation proposed by Echeverría (2006). According to this author, there is a loss of power of national states due to the greater importance of technological rent over land rent for the accumulation of global capital.

7.3 Methodology

This is descriptive research. The strategy used for the research is the study of cases from which the energy transition policies promoted by the Ecuadorian government in the period 2009–2017 are characterized, and sufficient elements are obtained, through a critical analysis based on the knowledge of the literature described in the previous section, to identify the structural limits for the energy transition faced by countries dependent on oil rents such as Ecuador.

In the first phase of the research, information was collected on the context of energy policies. Official documents published by government entities and multilateral organizations were compiled; based on this information, the moments of changes in public policy linked to international oil prices were identified, as well as the analysis variables of the components of the energy transition strategy. In addition, a systematic review of the literature was carried out, including academic articles, technical reports, research reports, and policy evaluations.

In the second phase, for the analysis of results in terms of energy generation, production, supply, and demand, the databases corresponding to the period 2009–2019 of the International Energy Agency (IAE) and the Energy Information System of Latin America and the Caribbean (SIEALC) of the Organización Latinoamerica de Energía (OLADE). To establish energy trends, the Energy Balances of different years prepared by the Geological and Energy Research Institute (IIGE) and the 2018–2027 Electricity Master Plan of the Ministry of Energy and Non-Renewable Natural Resources (MERNNR) were used.

Finally, to analyze the structures of energy consumption, the databases of the Living Conditions Survey-2014, the National Survey of Employment, Unemployment and Underemployment – ENEMDU-Ambiente (2019), and the Business Structural Survey (2019) of the National Institute of Statistics and Censuses were processed. The budget structure linked to fossil fuels was reviewed through the budget execution reports of the Ministry of Economy and Finance and the Petroecuador oil accounts reports.

7.4 Energy Transition Policies: Strategies, Results, and Discussion

The energy transition initiatives studied reflect the tension, present in the Constitution, between the rights of nature and the economic system that incorporates natural resources as a source of financing for public policies. Thus, while the Yasuní Ishpingo, Tiputini and Tambococha (ITT) proposal is being promoted as the banner of an ecological transition process[11], which would leave part of the oil reserves underground in exchange for international compensation for mitigating climate change, the Ecuadorian government incorporates changes to take advantage of high international oil prices and channel oil income toward the project to change the productive matrix based on the development of strategic energy-intensive industries, such as shipyards, petroleum-based products, oil refineries, petrochemicals, aluminum, copper and steel (MCPEC, 2010; SENPLADES, 2013).

For the latter, a greater participation of the State in the oil surplus is guaranteed;[12] the recovery of state control over strategic national sectors such as electricity and water; the increase in investment in infrastructure to accelerate the implementation of renewable energy (hydroelectric) that guarantees energy security, and generates the energy required by the change in the productive matrix and new investments for large-scale mining (MCPEC, 2010; SENPLADES, 2013).

Finally, due to the lack of concrete contributions from the international community, the Yasuní-ITT initiative was abandoned in 2013, and the energy transition process focused on the implementation of the CME strategy.

7.4.1 The Strategy for Changing the Energy Matrix

The energy matrix change strategy is a set of policies proposed as of 2007, with the objective of "providing cheap, clean and efficient electricity for national industrialization and the structural transformation of the country's productive matrix" (Purcell & Martínez, 2018). As shown in Fig. 7.1, this strategy is designed in a comprehensive manner; in addition to intervening in the generation of energy hydroelectricity and incorporating incentives to produce alternative renewable sources such as wind, solar, biomass, and geothermal; it generated incentives for the substitution of fossil fuels for electricity in the consumption of the industrial[13] and residential[14] sectors. A central pillar of this project was the construction of eight new hydroelectric dams: Manduriacu, Sopladora, Coca Codo Sinclair, Toachi Pilatón, Minas San Francisco, Mazar Dudas, Delsitanisagua, and Quijos.

Additionally, investments were promoted in mass transportation services[15] for the largest cities in the country as well as in the repowering of the Esmeraldas refinery and the project of a new Pacific Refinery aimed at the internal production of oil derivatives, which would reduce dependence on the import of these fuels (SENPLADES, 2013; Carrillo et al., 2018).

In general terms, the aim was to produce enough electricity to reduce the consumption of diesel used by the thermoelectric system and replace the use of liquefied petroleum gas (LPG) in homes with induction cookers at the same time as increasing the local production of fuels to meet the demand of the transport sector. Thus, it hoped to gradually reduce State spending on energy subsidies[16] and decrease the balance of payments

[11] The initiative of the government proposed that the international community compensate the Ecuadorian economy with 50% of the profits (USD 350 million per year) that would not be receiving for not exploiting indefinitely the reserves of around 920 million barrels of oil in the Yasuní Park, avoiding the emission of 407 million metric tons of carbon dioxide (Lee, 2021).

[12] Between 2006 and 2014, the average price of Ecuadorian oil was USD 87. Among the reforms carried out, the following stand out: Decree 662 that reformed Law 42 – 2006 to regulate the distribution of extraordinary profits between the State (99%) and private companies (1%), and the Reform to the Hydrocarbons Law (2010) that allowed institutional changes in the sector and the renegotiation of contracts with oil companies (Ruíz & Iturraldes, 2013).

[13] Substitution of diesel use for electricity in the shrimp sector. Articulate the National Interconnected System (SIN) with the Petroleum Electric System.

[14] National Program for efficient cooking and substitution of LPG for electricity in water heating.

[15] Quito Metro and Cuenca Tram.

[16] For example, Coca Codo Sinclair is expected to save 600 million dollars a year in fuel imports.

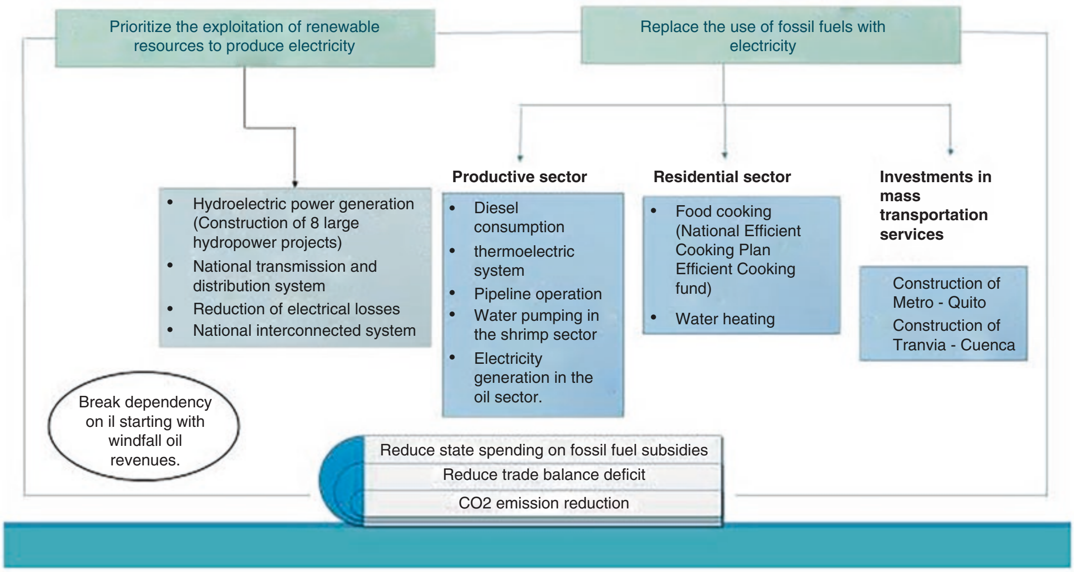

Fig. 7.1 The strategy for changing the energy matrix. (Source: Ministry of Energy and Non-Renewable Natural Resources; Carrillo et al., 2018)

problems faced by the country. In political terms, this strategy sought to create conditions for a future elimination of fuel subsidies without causing social conflict (SENPLADES, 2013; Carrillo et al., 2018).

The capital and technology requirements of this ambitious strategy for the CME were financed by loans granted by the Exim Bank of China and China Development Bank (CDB), tied to the turnkey contracting of companies from that country for the construction of the infrastructure, as well as oil-backed loans. These mechanisms are part of China's strategy to access natural resources (da Rocha & Bielschowsky, 2018; Gallagher et al., 2013a, b), which, as Echeverría (2005), points out, because of China's control over the know-how, technology and capital necessary for the construction of the energy infrastructure, they overcome the Ecuadorian State's control over nature and capture for itself the rent of the land with which the credits will be paid.

This indebtedness dynamics deepened after the drop in oil prices in 2014. Thus, of the 11.3 billion dollars that the Ecuadorian government has received in Chinese loans, 59.5% corresponds to works in the energetic sector. Between 2007 and 2017, investment in the electricity sector reached USD 12 billion, more than ten times the level of investment between 2000 and 2006 (MEER, 2016).

7.4.2 CEM Results and Discussion

As a result of the great investment made by the State, in 2019, the country has an electrical matrix with a greater effective installed capacity (8072.81 MW), in which renewable energy is the most important type of source (64.88%), hydroelectric plants contribute with 62.51% of electricity generation and thermoelectric plants significantly lowered their participation to 20.17% (ARCERNNR, 2020) (see Fig. 7.2). The greater hydroelectric production has contributed to the increase (33%) in the contribution of renewable energies in the energy matrix (MERNNR, 2020). However, hydroelectricity represents only 6.84% of the sources of the country's primary energy matrix, whose structure continues to depend on oil, which provides 86.9% of the primary energy produced.

Although, in the period 2007–2019, the national electricity coverage has increased from 89% to 97.05%, in the year 2019, the electricity that ranks first (26%) in secondary energy production, only it represents 19% of the secondary demand. For their part, fossil fuels together represent 63% of the secondary energy supply and almost 75% of its demand, with diesel oil (31.4%) being the most consumed.

In addition to the fact that since 2016, the country went from being an importer to an exporter of electricity, it can be deduced that the CME strategy generated a surplus of electricity, that as Purcell and Martínez (2018) maintain, since it was not absorbed by the national industrial sector, was reoriented toward export and cheaper energy supply for large-scale mining projects, that is, instead of sustaining the productive transformation of the country, this energy reproduces the dependency of the model of accumulation of extractivist capital that it was originally intended to overcome (Purcell & Martínez, 2018). This contradiction can be explained by the following two factors:

(a) The failure of the CMP policies to transform the productive structure of the country, expressed in the drop in the participation of the industrial sector in the GDP, from 12.2% in 2009 to 11.8% in 2019, which shows the inability to state policies to determine "the course of accumulation in each valorization space" (Grinberg & Starosta, 2015, pág. 240). Thus, the large projects of strategic industries have not been carried out due to a lack of foreign direct investment, nor has the local productive sector made the leap toward industrialization by substitution of exports (Purcell & Martínez, 2018). Instead, the extraordinary flow of rent from natural resources works as "an obstacle to generating industrial development in the region" (Wilson & Bayón, 2017, pág. 171) because, given the structural conditions, Ecuadorian capital continues to find it more profitable to value itself based on the appropriation of land rent (Grinberg & Starosta, 2009).
(b) Renewable energy (hydroelectricity) is absorbing only part of the increase in energy demand, but without substantially modifying the fossil fuel base on which the economic system depends for the production, distribution, and mobility of people and goods.

As of 2016, the year in which the largest hydroelectric plant in the country (Coca Codo Sinclair) came into operation and the industrial diesel sub-

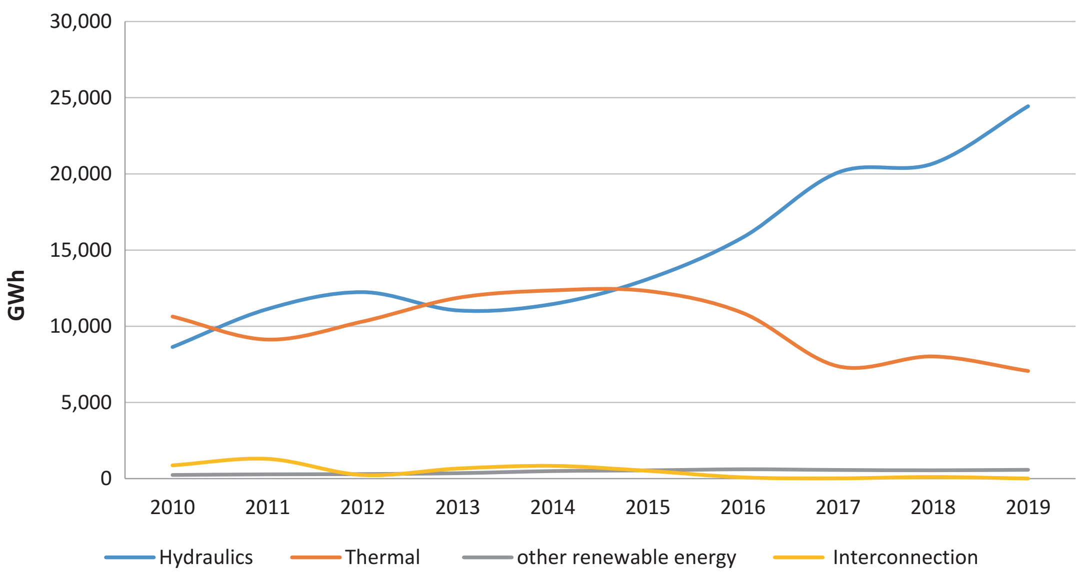

Fig. 7.2 Electric power generation GWh. (Source: Ministry of Energy and Non-Renewable Natural Resources, Energy Balances)

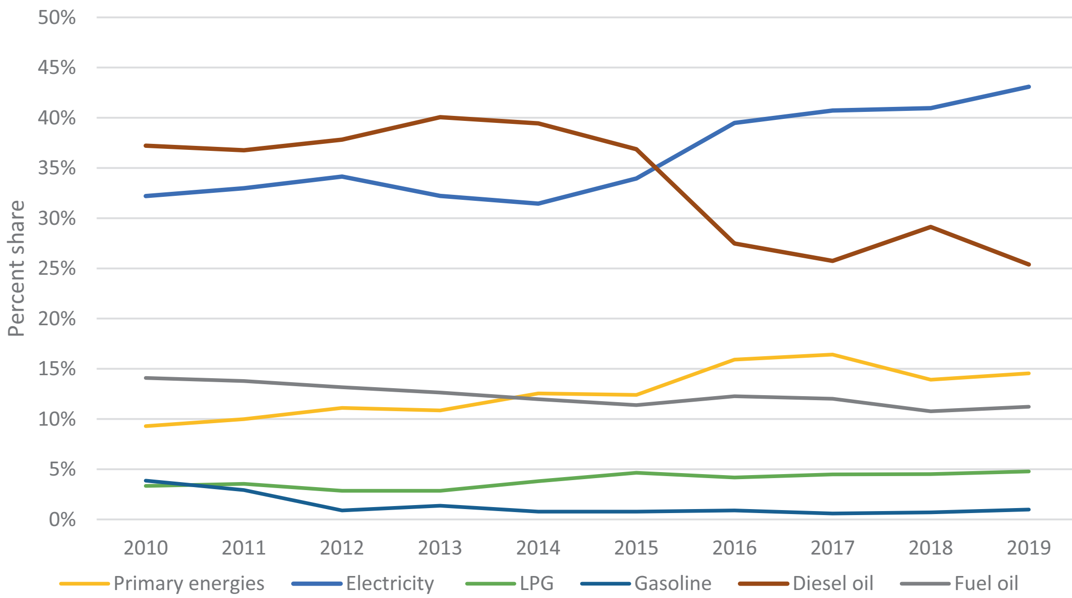

Fig. 7.3 Consumption structure of the industrial sector – percent. (Source: National Energy Balance, 2019; MERNNR, 2020)

sidy was partially withdrawn, the industrial sector changed its majority consumption of diesel for electricity (Fig. 7.3). In addition to this structural change, the industry increased the weight of LPG consumption (+1.45 pp), and reduced those of fuel oil (−2.87 pp) and gasoline (−2.88 pp); that is, the energy matrix of the industrial sector became more sustainable. However, after increasing its energy consumption steadily between 2010 and 2014, the industrial sector reduced its share of total energy consumption, accounting for only 15.8% in 2019,[17] a percentage three times less than the 49% represented by the transportation sector, whose share of energy demand increased by 7.4 pp. between 2010 and 2019 (MERNNR, 2020).

The weak impact that the changes produced in the energy consumption of the industrial sector have on the energy matrix of the country, are related to the limits that the role of supplier of raw materials imposes on the productive transformation project. In this sense, the redirection of excess electricity toward extractive activities is consistent with the information provided by the Business Structural Survey (2019), in which it is observed that the exploitation of mines and quarries (CIIU B) has the most important participation in the amount of electrical energy produced and consumed (kwh) compared to that purchased by the public network, for which the offer from the State of providing electricity through the public network at competitive costs constitutes a very attractive advantage for new investments in mining and oil.

The structural dependence of the economic system on fossil fuels can also be visualized through energy demand. In the period 2009–2019, the GDP registered an accumulated growth of 31.8%,[18] with fluctuations in its variation rates, while the country's total energy and fossil energy consumption did not stop growing. In this period, energy demand increased by 36.2%, going from 69 million BEP in 2009 to 94 million BEP in 2019 (MERNNR, 2020); energy consumption per inhabitant grew by 10.7%, going from 4.94 BEP/inhab. in 2009 to 5.47 BEP/inhab. in 2019.

[17] −1.7 pp than in 2010.

[18] In constant 2007 dollars.

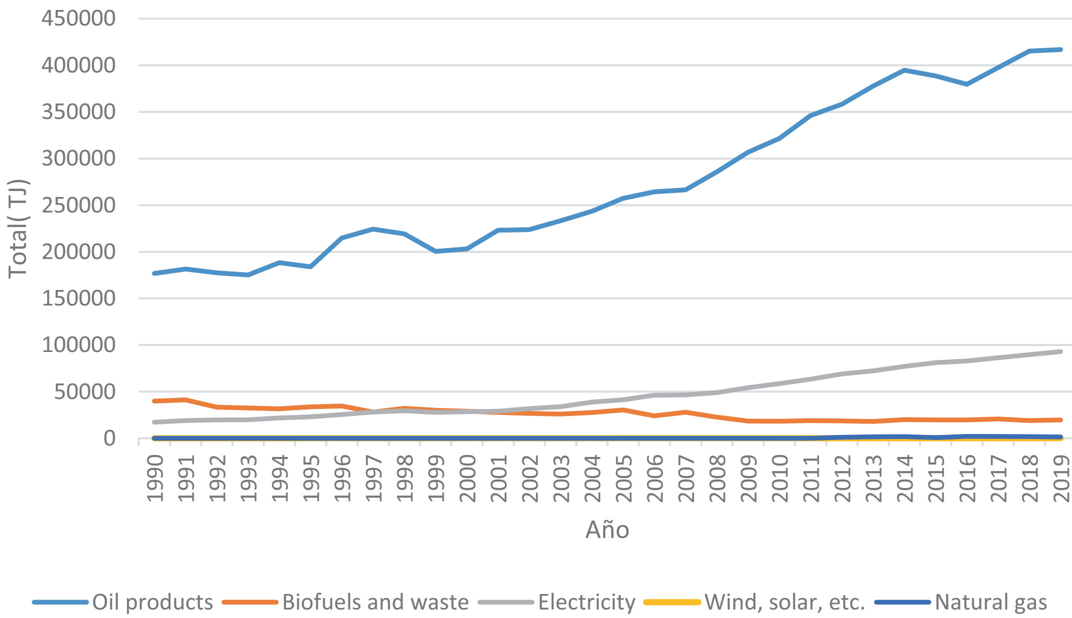

Fig. 7.4 Final consumption by source. (Source: IEA World Energy Balances)

Except for the years 2015 and 2019, the country's energy demand has maintained a low elasticity[19] with respect to the variation in GDP (MERNNR, 2020).

The evolution of energy demand by source (Fig. 7.4) shows us that, with an average share of 81%, fossil fuels remain the most consumed energy goods in the country. Diesel and gasoline are the sources with the highest demand for energy, with growth within the period of 33.5% and 58.4%, respectively. For its part, the demand for liquefied petroleum gas (LPG), the main fuel used for cooking food, grew by 29.5%. At the end of the period, diesel represented 32.2% of the total energy consumed in the country, while gasoline accounted for 29.6%, electricity 17.2%, and LPG 10% (MERNNR, 2020).

By the destination sector, in 2019, 82.7% of diesel was consumed by transportation. This sector also consumed 76.1% of total gasoline, while the largest demander (70.8%) of LPG was the residential sector (MERNNR, 2020). In 2019, 52.7% of the energy consumed by the transport sector came from diesel and 45.6% from gasoline. When disaggregating the consumption of the transport sector by type of vehicle, land transport registered a demand equivalent to 94.4% of the total. Heavy cargo transport has the highest participation, with 46.8%. By type of vehicle, passenger vehicles were the largest gasoline consumers, with 47%; the largest diesel demanders were heavy-duty vehicles, with a 74.1% share (MERNNR, 2020).

If we add to this that, according to the Business Structural Survey (Figs. 7.5 and 7.6), diesel and extra gasoline are the fuels most consumed by companies nationwide (INEC, 2019), and that the Intensity of energy use by value added[20] is higher in the activities of Transportation and storage (CIIU H) and Manufacturing industry (CIIU C), it is indisputable that after the implementation of the CME, fossil fuels continue to be the material basis for the production and distribution of goods.

[19] The elasticity of energy demand allows identifying the degree of stability that the energy sector has with respect to variations in the country's economic conditions. A low elasticity index indicates that energy demand hardly changes in the face of variations in national income (MERNNR, 2020).

[20] Values in mega Joules per dollar.

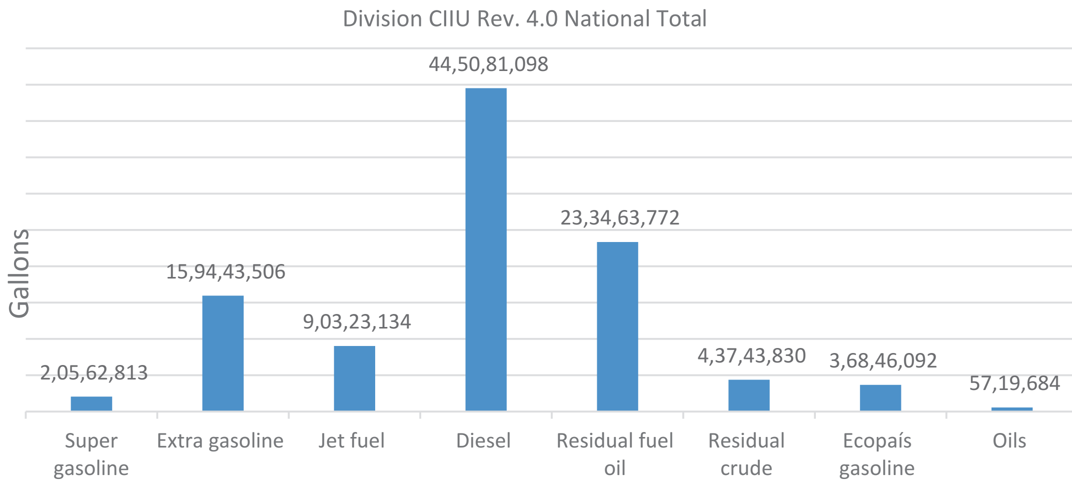

Fig. 7.5 Quantity of fuels and lubricants consumed, national total. (Source: Instituto Nacional de Estadística y Censos (INEC) – Business Structural Survey, 2019)

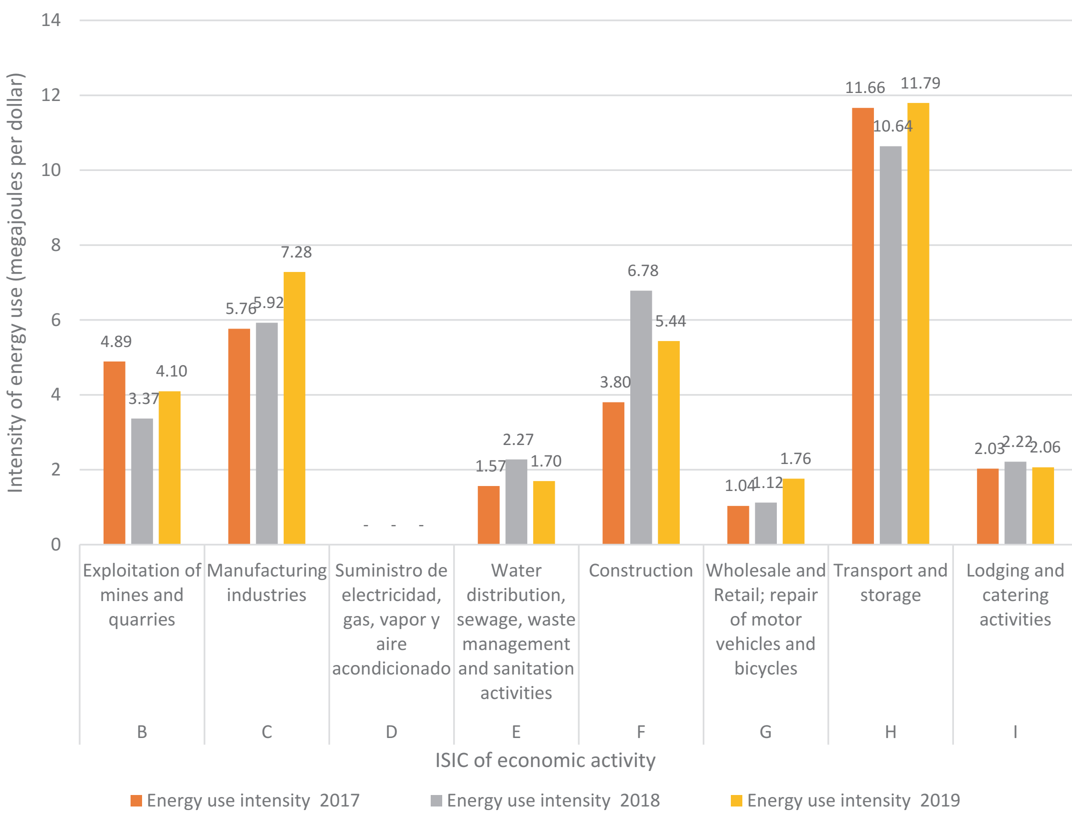

Fig. 7.6 Intensity of energy use by added value according to ISIC of economic activity values in megajoules per dollar. (Source: INEC – Business Structural Survey, 2019)

The demand for fuels is greater than the secondary production of derivatives, which is also reflected in the increase in imports of these energy goods, which, during the analyzed decade, registered an increase of 63.9%; these imports are mainly composed of gasoline and diesel, both with a significant weight in fuel subsidies.

7.4.3 Effects on the System of Subsidies and Energy Consumption

Ecuador's energy subsidy system is materially linked to imports of fossil fuels, which are mainly destined for the transportation sector, and linked politically to the social outbursts, that have been generated in response to the State's attempts to eliminate subsidies, which are an expression of the dispute over the flow of oil income that arises from social organizations before the State in its role as distributor of funds.

The evolution of the magnitude of these subsidies is influenced by internal factors (increase in energy demand) and external factors (international prices of oil and derivatives) (Carrillo et al., 2018; MEF, 2019), so that in the period 2009–2013, the participation of fuel subsidies in the PGE increased by 8.5 pp, then began to decrease together with the fall in international oil prices and the introduction of the first measures of partial elimination of subsidies implemented as of 2015 to face the economic recession[21] (see Fig. 7.7).

Since 2008, energy subsidies were included in the General State Budget through the Financing Account for Deficit Derivatives (CFDD),[22] in this way the use of public resources to cover the cost of importing fossil fuels became transparent. as well as its financing with flows of gross oil income generated by the exploitation of the country's oil. In the 2010–2015 period, the amount accrued by this account remained above 4% of GDP, reaching its maximum in 2013 and 2014 (Carrillo et al., 2018; Puig et al., 2018).

In 2019, CFDD expenditures reached USD 4439.51 million, which represented 4% of GDP, 12% of PGE, and 57% of oil revenues, while the income accrued was USD 3991.9 million, 44% financed with current shares in oil revenues. These figures are close to the budget allocated to the education sector (13.6%), and higher than those allocated to the health (7.8%) and social welfare (3%) sectors, which shows one of the contradictions of the social claim on fuel subsidies within an economy dependent on natural resources, characterized by high levels of inequality.

Of the total public resources allocated to fuel subsidies in the 2007–2016 period, the transportation sector absorbed 46%, followed by the electricity generation and residential sectors, which each received 14% % (Carrillo et al., 2018). Specifically, by type of fuel, half of the subsidies went to diesel (50%), while 21% was assigned to gasoline, consumed mostly by medium- and high-income households, and LPG for cooking, which is evenly distributed among all income quintiles, absorbed around 14% of the subsidies (Carrillo et al., 2018; MIPRO, 2010).

Several studies have shown the inefficient and regressive nature of fuel subsidies in Ecuador, as being a very costly mechanism for transferring income to poor households that benefits the highest income quintiles more[23] (MIPRO, 2010; Feng et al., 2018; Schaffitzel et al. 2019). This is another contradiction that is generated in the process of capturing and redistributing the oil income carried out by the State through energy subsidies. However, the elimination of subsidies for diesel and LPG would affect the quintile with the lowest income through the generation of additional

[21] Subsidies for aviation fuel (Decree 1283) and industrial diesel (Decree 799) were partially withdrawn, and the price of premium gasoline was increased.

[22] This account was born with the name of Derivative Import Financing Account (CFDID), which was changed in 2010. Before that, these costs were considered part of the budget of the public company Petroecuador. Since 2009, Petroecuador transfers to the CFDD the income it obtains from the internal sale of oil derivatives.

[23] According to Feng et al. 2018 "it costs US$13 to transfer US$1 to households in the bottom quintile using gasoline and diesel subsidies; US$ 10 with electricity subsidies, and US$ 7 with LPG subsidies."

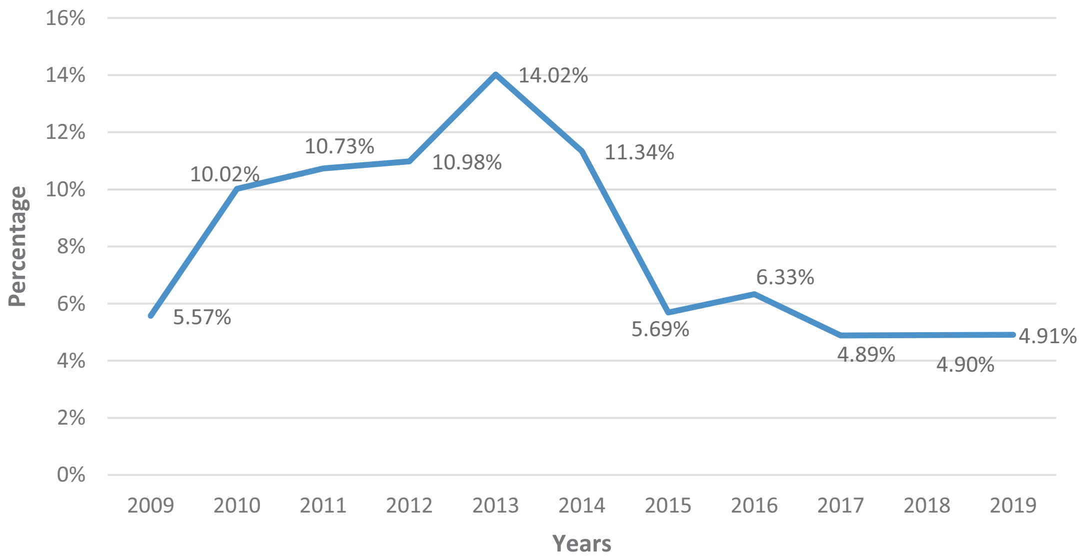

Fig. 7.7 Weight of fuel subsidies in the PGE. (Source: MEF, 2019)

expenses, in the case of diesel, the majority (95%) coming from the indirect effect produced by additional electricity costs, food, transportation, and of direct increases in spending in the case of the elimination of LPG subsidies (Schaffitzel et al., 2019).

The regression of the benefits of fuel subsidies and the effects of their elimination are related both to the structure of consumption of energy goods by income levels and to the structure of household spending. Thus, according to the data from the Living Conditions Survey (ECV-2014), 95% of households use LPG for cooking, almost evenly distributed among the deciles, while only 26.5% report spending on fuel for automobiles, going from 10% in the first decile to 40.55% in the last decile.

Figure 7.8 presents the percentage of income allocated to spending on fuels[24] by decile of monthly family per capita income registered in the ECV-2014. The percentage of income allocated to spending on fuel decreases when going from decile 1 (22%) to decile 10 (2.1%), registering the greatest difference between deciles 1 and 2. According to this description, a greater impact can be inferred in households with lower incomes.

Information from the National Employment, Unemployment, and Underemployment Survey, ENEMDU-Ambiente, show that in 2019, 30.4% of households had vehicles, of these only 7.3% use diesel, so its impact on households would be more linked to the estimated weight of 36.6% that it has as a productive input on the transport sector's total costs (MCPEC, 2010). These estimates are like the population's perceptions of the effects that the elimination of the fuel subsidy would have on the price of public transport and food, via an increase in distribution costs, and therefore on their well-being.

Under these circumstances and the worsening of the population's living conditions[25] given in the framework of a structural adjustment process, in October 2019, after the announcement of the

[24] Includes fuel for vehicles and other uses, coal, LPG, kerek, diesel.

[25] To December 2019, multidimensional poverty and extreme poverty increased, reaching 71% and 42%, respectively. In addition, there was an increase in unemployment, underemployment, informal employment, and unpaid work, purchasing power reduced and the loss of access to public services that guarantee rights, the possibilities of social advancement and improvements in well-being (Herrera & Macaroff, 2020).

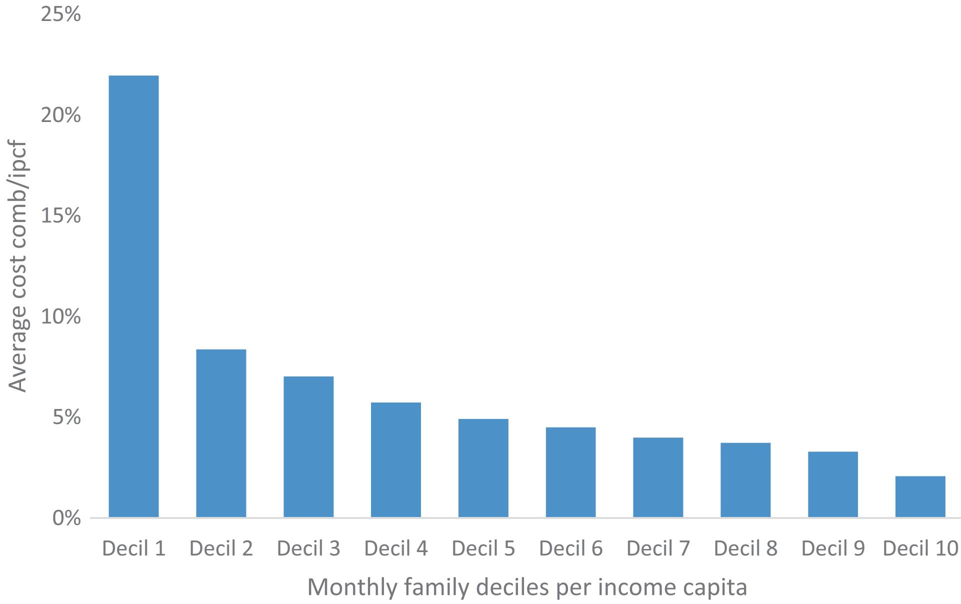

Fig. 7.8 Percentage of income spending on fuel, by decile. (Source: Instituto Nacional de Estadística y Censos (INEC) – Living Conditions Survey (ECV), 2013–2014)

elimination of the gasoline and diesel subsidy[26] (Decree 833) by the central government, the largest social uprising recorded since the presidential overthrow of the year 2000 was unleashed. In this process of social dispute to maintain access to part of the oil revenue through energy subsidies, the organizations of carriers – the largest consumer of diesel and gasoline – students, workers, and the indigenous movement participated. This culminated in the repeal of Decree 833.

7.5 Conclusions

The study of energy transition initiatives in a country dependent on oil requires the analysis of the value-State-nature-society relationship that occurs through land rent. Starting in 2007, the Ecuadorian State, in its role as owner of natural resources and collector of oil revenue, entered into the dispute over the redistribution of surplus value at a global level through a series of institutional reforms that allowed it to redirect the oil rent toward a local accumulation project. The flows of this income at the national level demonstrate a social relationship that accounts for the tensions between the different social classes (Purcell & Martínez, 2018).

The Ecuadorian State's capital accumulation strategy, based on the appropriation of land rent, materializes through the policies for the change of the productive matrix articulated to its strategy of change of the energy matrix; however, these ignore "the global dynamics of uneven geographical development in which the Ecuadorian economy is trapped" (Wilson & Bayón, 2017, pág. 21), underestimating both the structural limits imposed by the marginal participation of the Ecuadorian State within global energy circuits and "the capacity of rentier capitalism to reproduce the subordination of the region within global capital circuits" (Wilson & Bayón, 2017, pág. 22).

Thus, the international drop in oil prices in 2014 marked the end of the material conditions that supported the project of exiting extractivism

[26] In August 2018, in the adjustment scenario prior an agreement with the International Monetary Fund, the government liberalized the price of super gasoline (Decree 619) and reduced the subsidy for extra gasoline and Ecopaís (Decree 490), increasing its price from USD 1.48 per gallon to USD 1.85.

with the income generated by extractivism (Wilson & Bayón, 2017; Coronil, 1997). For its part, the energy transition process, whose possibility of being maintained over time depends on the generation of extraordinary oil revenues and external financing, was maintained with the construction of large infrastructure works financed with Chinese capital, which, in the form of debt interest, generated a counterflow of oil income from the State toward the global processes of accumulation by dispossession (Harvey, 2004). In this way, the dynamics of the global reproduction of capital limits the power of the Ecuadorian State's landownership over nature "while integrating the rent of the land to concretize its historical existence" (Echeverría, 2005, pág. 18), thus, reappropriating overall social gain.

This process shows us the dynamics that occurs between land rent and technological rent in which the latter, according to Echeverría (2005), increases its weight in the process of capital reproduction at the expense of land rent. The technological rent captured by companies and countries that have control over cutting-edge technology allows them to "establish a monopoly over certain dimensions of nature," overcoming the monopoly over natural resources of peripheral countries such as Ecuador, which is essential to understand the permanent loop of dependency and underdevelopment that this country maintains, despite the processes of local accumulation that, through public policies financed with oil revenue, are undertaken in the cycles of booms based on the high oil prices.

In other words, it is precisely this organization of national accumulation based on land rent that condemns nation-states like Ecuador to "systematically lose in competition with national capital conglomerates (such as China) that organize their accumulation around a base governed by technological income" (Echeverría, 2005, pág. 19). We consider that this perspective complements the interpretation of the limits of capital accumulation processes through the appropriation of land rent proposed by Carrera (2007), for whom "capital accumulation is a global process by the unit of its content that is realized taking the fragmentary form of national processes of capital accumulation, which confront each other antagonistically in the world market" (Carrera, 2007, págs. 13–14).

The results of the CME strategy show us that, although, between 2008 and 2018, energy production from renewable sources (mainly hydroelectric) increased by 33%, oil remains the most important primary energy source. In terms of energy consumption, far from generating a substitution of fossil fuels for electricity, there was an increase in the demand and production of energy from fossil fuel sources in all sectors of the economy (MERNNR, 2020), and with it an increase of spending on their subsidy in the public budget.

These results show the limits of investment in hydroelectric energy as the axis in the energy transition process, because although the increased production of electricity has met the increases in its demand, fossil fuels are the material base on which rests the development of Ecuadorian capitalism. This is how the transport sector, and in particular cargo and passenger transport, is the largest consumer of diesel and extra gasoline, and therefore the largest beneficiary of its subsidies.

Generating a change in this structure of energy consumption implies not only replacing the supply of electricity generated by fossil fuels, but also requires long-term policies such as the electrification of transport, industry, and energy consumption already proposed in the CME strategy and truncated by the fall in international oil prices in 2014. This temporary difference between the cycles of structural transformation linked to the development of new productive forces (long term) and the commodity booms that make the capture and distribution of oil revenue viable (short term) affects the real possibilities of the energy transition.

The impulse of new productive forces financed with oil income brings along the development of the specific contradictions of an oil-dependent country, which are expressed "in the set of inequalities present at all levels of the social structure" (Cueva, 2004, pág. 99). Thus, the system of energy subsidies, historically aimed at the consumption of fossil fuels, has a regressive character that mainly benefits the highest income quintiles, a characteristic that did not change with the application of comprehensive policies for changing the energy matrix. However, the attempt to withdraw subsidies in 2019, which affects the lowest income quintile, once again repositioned the conflict around fuel subsidies as a conflict over the distribution of land rent between social organizations and the government.

The welfare system (social services and protection) also depends on the amount of oil revenue that is channeled directly through public investment or indirectly through the increased collection generated by growth conditions driven by rising petroleum prices. Both systems, subsidies and welfare, are intertwined, since they constitute containment mechanisms for family budgets in periods of crisis, which are opposed in scenarios of deficit and fiscal austerity. After the drop in oil prices in 2014, maintaining energy subsidies has meant a smaller budget for the State for education, health, and subsidies linked to social welfare. These contradictions are nothing more than the expression of what (1997, pág. 18) points out as "the distributive relations that make the capture of rents the organizing principle of the economic activities of the landowning states."

Overcoming all the contradictions that the link between the Ecuadorian economy and the global economic system imposes on energy transition processes requires long-term economic and energy transformation projects that recognize the productive, technological, fiscal, and social limitations of the country; because of this, it is necessary to advance in a research agenda that rigorously evaluates the impacts of policies for changing the energy matrix on fiscal, subsidy, and welfare systems. It is also necessary to build scenarios that allow projections of energy policies that articulate local, national, and regional projects.

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8 Energy Transition and Consumption Subsidies in Oil-Exporting Countries: Venezuela and Ecuador Between a Rock and a Hard Place

José Luis Fuentes and Guillaume Fontaine

8.1 Introduction

Oil-exporting countries have a hard time engaging in decarbonization, because it implies a double opportunity cost to their governments. On the one hand, they have to face the immediate costs of the energy transition while expecting differed utilities like any country; on the other hand, they have to anticipate profit loss from the expected decrease of their oil rents if the transition is successful. A good compromise would be to finance the transition with oil rents, sound stabilization funds, and the progressive elimination of consumption subsidies (Di Bella et al., 2015). Yet, in practice, this might be an impossible challenge, considering the political costs of subsidies elimination and the inflation thereof.

This chapter provides an explanation to the implementation gap in energy transition in two Latin American oil-exporting countries: Venezuela and Ecuador. Our argument is that this gap is caused by the persisting subsidies on oil and gas energy consumption. In both cases, the mobilization and manipulation of the policy mix reveals contradictory aims and means in agenda-setting and strategic planning, which prevent the institutional change required by decarbonization. Therefore, the institutional system's resilience and the countries' oil dependence hinder the implementation of the energy transition in both cross-sectorial coordination and political interplays activities.

In the rest of this chapter, we present the evolution of the energy mix along the past two decades in order to estimate the scope of oil dependence and the marginal importance of renewable energy sources, both for supply and demand (Sect. 8.1). Then we analyze the public policies of consumption subsidies on oil and gas products and on renewable sources in both countries, based on the policy design framework's fourfold model of causation, evaluation, instrumentation, and intervention (Sect. 8.2).

8.2 Research Problem and Hypothesis

8.2.1 Oil Dependence

Oil production became a major source of incomes in the 1930s in Venezuela and in the 1970s in Ecuador. Venezuela is the biggest oil exporter in

J. L. Fuentes
The Comparative Policy Lab at FLACSO, University of the Americas (UDLA), Quito, Ecuador
e-mail: jfuentes@flacso.edu.ec

G. Fontaine (✉)
Latin American Faculty for Social Sciences (FLACSO), The Comparative Policy Lab at FLACSO, Quito, Ecuador
e-mail: gfontaine@flacso.edu.ec

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Latin America and the Caribbean, while Ecuador is a medium-range producer and exporter in the region. Although they weigh differently on international markets, they share many features regarding the incidence of oil rents on their economies and societies. In both countries, the energy mix is dominated by oil consumption and production.

In Venezuela, the average oil production was around 3.1 million barrels per day (b/d) since 2000, at a time when oil production represented 73% of the overall primary energy. However, since 2019, it has fallen by 49% due to the economic crisis and economic sanctions imposed by the US government against any corporation operating in Venezuela (See appendix 1; OLADE, 2021b). In Ecuador, the average production reaches 0.5 million b/d. Oil has been representing around 90% of the total primary energy, in spite of a slight reduction in 2016. It increased by 33% after 2000, after the construction of the heavy crude oil pipeline (a.k.a. the OCP) (See appendix 4; OLADE, 2021a).

Carbon fossil fuels are the main energy source for consumption in both countries. In Venezuela, the demand for carbon fossil fuel increased by 53% in 2004–2013, but it decreased by 58% afterward, as a result of a severe economic recession. In the transportation sector, it increased by 23% in 2000–2006, then by 5% in 2007–2013, but it decreased by 50% in 2014–2019 (Appendix 2; OLADE, 2021b). Likewise, in the industrial sector, it increased significantly in 2000–2006 (+96%) and in 2007–2013 (+563%) but it decreased by 70% afterward, which coincides with the power generation crisis (Appendix 3; OLADE, 2021b).

In Ecuador, the demand for carbon fossil fuel increased by 60% in 2000–2013, and by 9% afterward. Transportation is the sector that most contributed to this trend. It increased by 62% of the total demand in 2000–2013 and by 32% in 2014–2020 (Appendix 4; OLADE, 2021a). The demand by the industrial sector is more erratic, as it decreased by 37% in 2000–2007, and then it increased by 67% in 2007–2013, and eventually decreased by 45% in 2014–2019 (Arroyo & Miguel, 2020, 3883; Appendix 6; OLADE, 2021a).

In both countries, the energy mix diversification was essentially related to the development of hydropower infrastructures. In Venezuela, hydropower supply increased by 50% in 2000–2013, as a result of huge investments to address the recurring problem of electricity shortages. Yet, it has decreased by 38% afterward, once again because of the economic crisis and for a lack of investments (Vidoza & Gallo, 2016, 237). Meanwhile, the demand of electricity has been increasing significantly until 2014 (+28% in 2000–2006; +8% in 2007–2013), but it decreased by −15% in 2014–2019. The reduction of electricity demand in the industrial sector was caused by a shift toward thermopower (See appendix 1; OLADE, 2021b).

In Ecuador, hydropower supply increased by 35% in 2007–2013, and then by 115% in 2014–2019. This resulted from the execution of mega projects such as the Coca Codo Sinclair dam, which is currently the biggest one in the country. Consequently, the demand for electricity also increased consistently (+62% in 2000–2006; +55% in 2007–2013; and +21% in 2014–2019) (See appendix 4; OLADE, 2021a).

The relatively marginal incidence of hydropower in the total energy supply and the continuity in demand trends indicate that energy transition policies have had limited effects in both countries. These trends in energy demand coincide with the 2000–2013 oil prices windfall. Therefore, the dependence on oil – whether for rent seeking or to attend the increasing domestic energy demand – has actually increased. In both cases, the dependence of economic and social policies to oil rents has a negative effect on the energy transition policies. Although the hydropower supply capacity has been improving, this had no significant transition effect on the energy mix, since it did not stop the growing energy consumption of carbon fossil fuels, in spite of what governments announced in 2007 when formulating this policy. This is the implementation gap in the energy transition policy (Fontaine et al., 2019, 64).

8.2.2 Energy Subsidies and Resource Nationalism

For decades, energy subsidies have been related to the increasing energy demand implied by the modernization of the economy and welfare policies in Venezuela and Ecuador. Conversely, the elimination of these subsidies, especially for individual consumption in transportation and households, has always been a highly politicized issue. Consequently, as of today, oil and gas products remain heavily subsidized in both countries (Espinoza & Guayanlema, 2017, 15).

In the 1980s, during a longstanding economic and financial crisis, they were part of social demands for more wealth equity. Therefore, their elimination or even their reduction through targeting policies was a cause of political contention with several governments, for their effect on the economy and the overall society (Escribano, 2019, 16). For instance, the attempt to eliminate subsidies on oil products and the raise of transportation costs triggered the 1989 social outbreak in Caracas, the capital city of Venezuela. Likewise, the attempt to reduce gasoline and gas subsidies, in Ecuador, was key in President Bucaram's 1997 overthrow, as it would provoke President Mahuad's overthrow, 2 years later. Eventually, it was the starting point of massive protests in October 2019 and June 2021, for which the governments of President Moreno and President Lasso successively retreated on the very same measures.

During the 2000s, several political and social movements resented the Washington Consensus and rejected the economic development model based on the liberalization and deregulation of the energy sector (Fontaine, 2010). They also called for more domestic autonomy from an international system deemed unfair, in the design of social and economic policies. In the wake of the so-called pink tide (Chodor, 2015) that brought in several left-wing governments around Latin America, the election of Hugo Chávez (in 1998) and Rafael Correa (in 2007) crystallized these demands and announced the return of resource nationalism.

Since 1999 in Venezuela and between 2007 and 2021 in Ecuador, energy policies have been driven by "resource nationalism" (Mares, 2011) featuring government's claim for sovereignty in natural resources governance, claims to increase the government-take in mineral rents, and the recovery of state control over the extractive industries, thus imposing new state-driven oil policies. Recent research has shown how this resource nationalism hindered public accountability and citizens´ control over the public service, which diminished the state's capacity to manage oil rents and created persisting dependence patterns by economic and political actors in both countries (Fontaine et al., 2020). Moreover, resource nationalism facilitated the discretional management of oil rents by the executive power in Venezuela (Fontaine & Medrano Caviedes, 2016) and covered for the inconsistency of the policy mix in Ecuador (Fontaine et al., 2019). Hence there was an implementation gap in energy transition policies.

8.2.3 Analytical Framework

The process of this implementation gap can be traced within the policy design framework, based on a realist approach of causality (Fontaine, 2020; Fontaine et al., 2020). Realism means we are interested in testing a causal mechanism linking agenda-setting and policy outcomes. In the present case study, the process leading to implementation gap went through three sets of activities: strategic planning, cross-sectorial coordination, and political interplays. The empirical evidence comes from the policy mix combining four categories of policy instruments, namely, information, regulation, finances, and administrative organization. These instruments provide the expected empirical observations of our hypothesis, which are treated as individually necessary but insufficient conditions, or "hoop tests" (Van Evera, 1997).

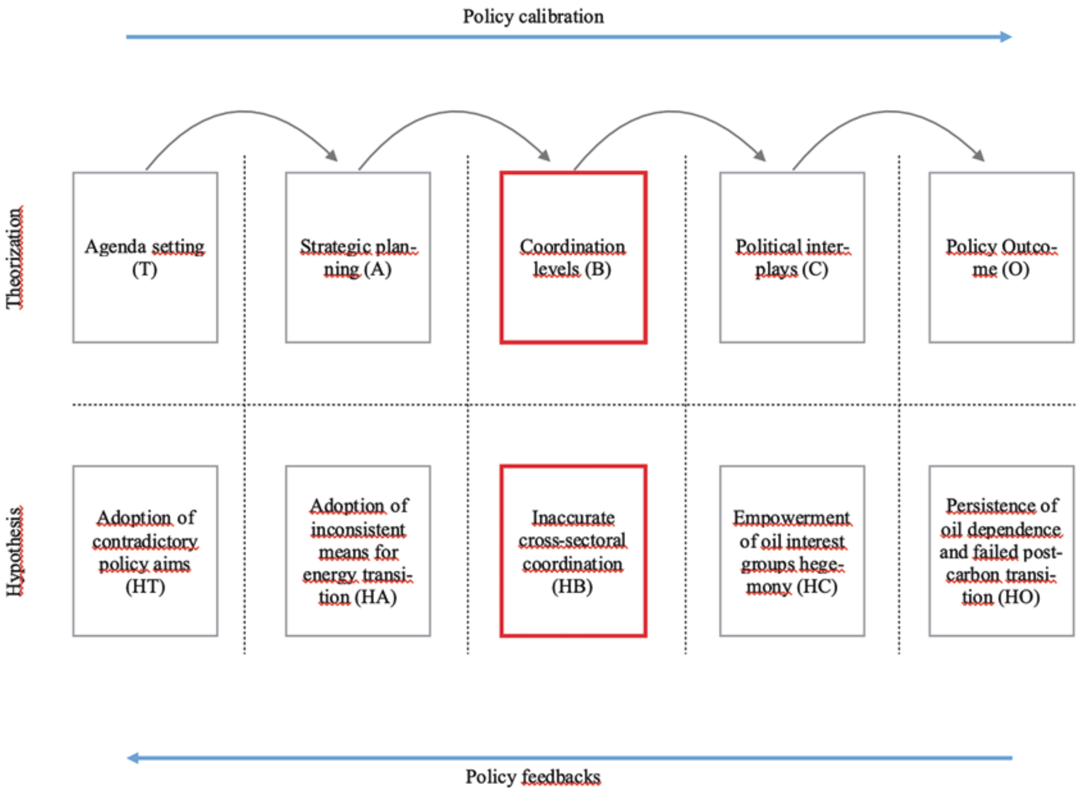

Fig. 8.1 A causal mechanism of policy design

Figure 8.1 presents a model based on the causal process linking agenda-setting to policy outcomes, throughout three sets of activities: strategic planning, cross-sectorial coordination, and political interplays. The causal process displays as follows: contradictory policy aims are adopted (HT), which leads to adopt inconsistent means for the transition policy (HA); consequently, the government cannot accurately coordinate the energy transition with other policy areas (HB), which reinforces oil interest groups hegemony (HC); eventually, this leads to the persistence of oil dependence and failed post-carbon transition (HO).

In this model, each set of activities consists in mobilizing state's resources of information, regulation, finances, and administrative organization (Fig. 8.2). Taken together, these resources constitute the instruments mix elaborated by the government in a policy design. Therefore, they provide the expected empirical observations necessary to confirm or disconfirm our hypothesis. The causal mechanism displays as follows: in order to turn their ideas into actual policy measures, the government combines instruments of information, regulation, finances, and administrative organization throughout three sets of activities linking the agenda-setting to the policy outcome (described in Fig. 8.1), which explains the implementation gap of decarbonization.

The following section presents the empirical findings of our research. We examine the collected evidence of each expected empirical

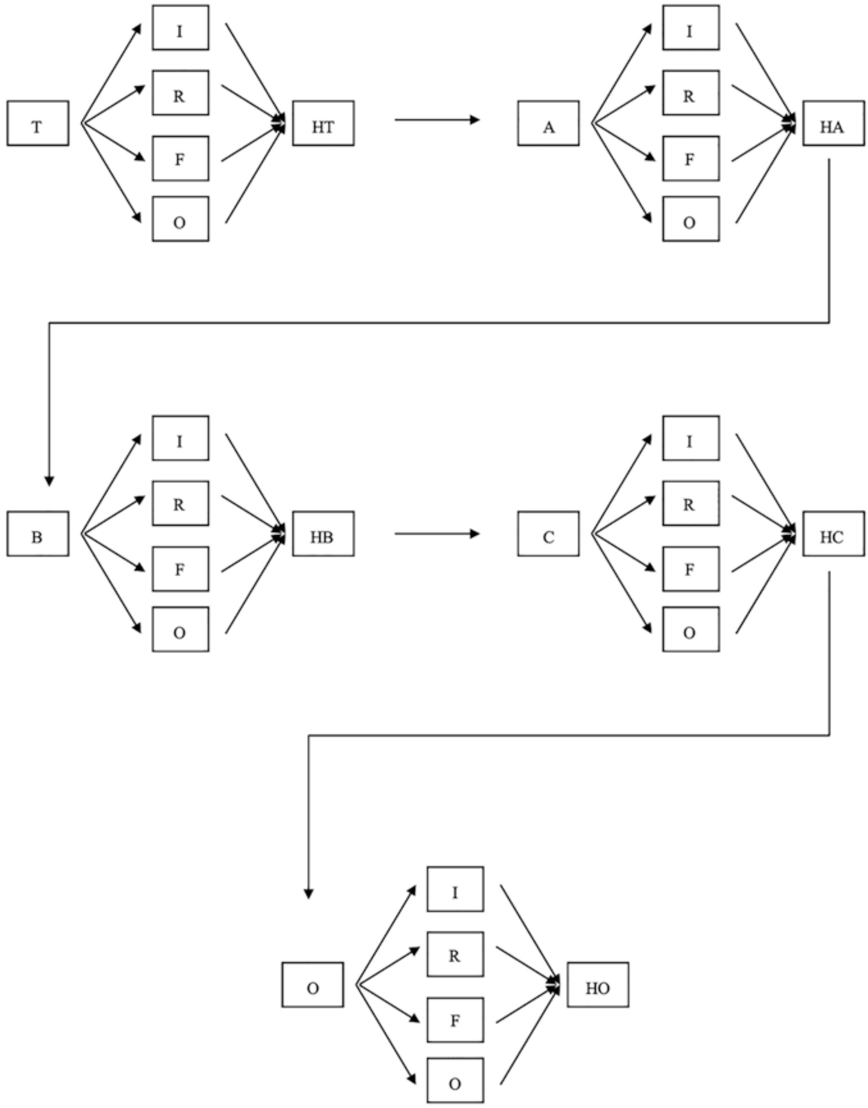

Fig. 8.2 Expected empirical observations

observation from the policy mix; therefore, we review successively the information brought in by instruments of information, regulation, finances, and organization.

8.3 Empirical Evidences and Discussion

8.3.1 Evidence from Information Instruments

Once elected, presidents Chávez and Correa advocated for similar changes in the energy sector, even though they adopted slightly different policy aims and means. In Venezuela, the Chavez administration engaged in redistributive policies, through a series of programs known as “missions,” financed by the exceptional rents generated simultaneously by the prices windfall and the increased government-take in oil contracts. In Ecuador, the Correa administration pretended to enter the post-carbon energy transition, but at the same time they praised an economic development model similar to the 1970s strategy of industrialization by imports substitution. The existence of these contradictory aims corresponds to the encompassing goal of a post-liberal (nationalist) economic transformation (called “the productive matrix shift”).

In both countries the government would not question the existence of energy demand subsidies, especially in the worldwide context of high oil prices. Development plans for the energy sector and official declarations by both administrations provide a source of information that shows how these policy changes played out.

In Venezuela, during his first government year, President Chávez presented the Nation’s Economic and Social Development Plan. He questioned the policies designed during the 1990s, in an era of calls for foreign direct investments (FDI) and private corporations. He also claimed his intention to restore the role of Venezuela as a major international actor, beyond the energy market. The plan aimed at designing an alternative development model that would reduce the country’s dependence on oil production and exports, which meant increasing considerably renewable energy supply (MPPP, 2001, 15).

The paradox is that achieving this aim lead the government to design a new economic system allowing better oil rents distribution (MPPP, 2001, 26), for which it was necessary to sustain and even increase the production of carbon fossil fuels. Therefore one of the objectives of the 2006 “Oil Harvest Plan” was to strengthen Venezuela’s position on international oil markets, by increasing production and certifying new proven reserves. Later on, in the 2007 “Homeland Plan,” the development of renewable energies remained limited to a complementary energy supply source, in places hardly accessible to conventional energy infrastructures. These plans also underline the country’s capacity to develop the production of renewable and nonrenewable resources.

In Ecuador, the 2007 Energy Agenda provided an assessment of the energy sector. Accordingly, since the economic dependence on oil rents and oil consumption was the main sectorial problem (MEM, 2007, 89), the new energy policy aimed at accelerating the transition to a sustainable model, through the program called “The Yasuni-ITT Initiative.” This program would commit the country to stop exploiting its biggest oil reserves, located underneath the Yasuni national park in the Amazon. They would do so in exchange for an international billionaire contribution (MEM, 2007, 80; SENPLADES, 2009, 358). Yet, while aiming at this objective, the government decided to give way to the construction of a petrochemical complex on the Pacific shore that would increase the refining capacities and cover for the oil products deficit. This meant continuing with the former policy of highly subsidized energy consumption, especially for liquefied gas and gasoline.

The combination of transition and development objectives was consistent with the difficulties faced by these governments to eliminate the subsidies from their financial instruments tool box for social policies. In Venezuela, this intention was postponed twice by the Chávez administration: in 2004, when the government faced a short supply crisis after a huge national strike in the oil sector leading to the sack of thousands of the national company’s employees and executives; and in 2008, after the sharp drop of oil prices dried out half the state budget. Eventually, the progressive reduction of energy subsidies was put on the government’s agenda in 2013 (to become effective in 2018), in the middle of the worst crisis ever experienced by this country.

In Ecuador, President Correa was openly reluctant to eliminate these subsidies, which were deemed to guarantee social peace (El Universo, 2007). Moreover, he was cognizant that even reducing them in the slightest proportion could hinder productive sectors more than they would benefit the state budget. He saw them as harmless instruments (La Hora, 2008), so that they remained untouched in the 2007 Energy Agenda and in the National Development Plan.

8.3.2 Evidence from Regulation Instruments

The implementation of the new energy policy in Ecuador and Venezuela required a major transformation in regulation systems, which initiated at the very beginning of both the Chávez and the Correa administrations. They started with using every resource from the Constitution and laws, to reform the development model and promote alternative and self-sufficiency policies – called "endogenous sustainable development" in Venezuela or "Good living" in Ecuador. To achieve the policy aims of resource nationalism, they imposed stricter public control over the energy sector ownership and management, which is traditionally the main source of income and employment at a national level. These reforms also defined new rules for oil rents distribution; in a context of sustained oil prices increase (Fontaine, 2011, 2893).

In 1999, President Chávez called for a national assembly to reform the 1958 Constitution, which had been the pillar of democracy for four decades. In the new Magna Carta, the state was responsible to establish a sustainable social and economic system (Art. 127). A call was also made for a major change in development policies (Art. 128), to reverse 80 years of oil rent's dependence. A likely story, since at the same time, the energy sector remained strategic and the national oil company's ownership became an untransferable state prerogative (Art. 29 and 31), which indicated a return to (and a radicalization of) the resource nationalism from the 1970s. Yet this amendment deeply altered the relationships between the state and the private sector engaged in the Venezuelan oil production, transportation, transformation, and distribution, while granting PDVSA overwhelming powers on any kind of operation around the country.

In a similar fashion, the 2008 Ecuadorian Constitution was tailor-made for the government's resource nationalism, as it referred to a new development model based on national sovereignty that would progressively free the country from oil dependence. It also proclaimed new environmental rights and the necessity to apply a model of sustainable development planning. However, the nationalist spirit of the national assembly had the Magna Carta declare energy and natural resources as a strategic sector, which meant these resources were considered essential to the state's survival (Fontaine et al., 2019). Hence, strategic sectors become the sole state's ownership and responsibility, guaranteed by national companies (Art. 256).

The existence of these regulation norms is hard evidence of the inherent contradictions of both government's energy policies. On the one hand, they pretended to build up a new (decarbonized) economic system, but on the other hand, they were willing to upgrade old nationalist policies from the 1970s oil boom, by granting national oil companies a special status and by increasing state control over upstream and downstream activities. In that context, the new rules of oil rents assignment neither actually considered eliminating nor reducing energy subsidies, which indirectly affected the policy design of the energy transition.

To achieve the policy aims claimed in planning and regulation, the Chávez and Correa administrations focused on the reform of the oil and electricity sectors. In Venezuela, the 2001 law on electricity and the 2001 law on carbon fossil fuels were granted the highest level of hierarchy (that of organic laws). The former established a unified system of power generation, transportation, distribution, and commercialization controlled by the public service. In 2008, this law was reformed to transfer the ownership of the electric sector to public companies. The latter granted the national oil company a status of majority stakeholder, while securing the state's supremacy over private interests. Afterward, the law commanded ordering the migration of most existing contracts to new public-private partnerships and joint ventures (except for extra heavy crude exploration and exploitation).

In the Venezuelan case, when referring to the use of regulation instruments for the energy policy, the transition was pushed into the background, since the government favored the development of conventional energy sources (i.e., oil) at skyrocketing prices. In the meantime, the executive power was entitled to define the prices of oil products on the domestic market, and PDVSA became the exclusive gasoline retailer, which eventually guaranteed continuity in the distribution of oil subsidies. Only in 2011 did the law on the rational and efficient use of energy foster the development of renewable sources of energy and energy efficiency.

In Ecuador, the government initially failed to set new rules for oil rents distribution in October 2007 through the Executive Decree 662, aimed at confiscating the extraordinary utilities made by private corporations since 2003. Later on, however, they succeeded in renegotiating every contract with those remaining in operations, through the 2010 law on carbon fossil fuels and the creation of a new type of service contact. This regulation attempted to revise and increase the government-take in oil rents (Fontaine, 2011, 2892).

Since the 1970s, the regulation granted the executive authority to establish the prices of oil products on the domestic market. It remained unaltered between 2003 and 2013, after the elimination of the subsidies to the industrial sector and air transportation. This longevity was a key factor in the energy transition process, which was limited to building big hydropower facilities, according to the "energy mix transformation" policy (Fontaine et al., 2019). The reform of electricity regulation and the law on water resources aimed at facilitating public investments and state assertion in the development of these projects (Ponce-Jara et al., 2018, 256). Eventually, Ecuador adopted a specific regulation on energy efficiency, in 2016.

Last but not least, in both countries, the need for a new energy policy design and the persistence of diverging or even contradictory policy aims of continuity and transition went through a process of constitutional reform, followed by the adoption of new sectoral laws. In Venezuela, the regulation on energy and subsidies was created and promoted by the executive power within the frame of "habilitating" laws, which entitled the President to govern by executive decrees. In Ecuador, the regulation was adopted by the President with the support of the legislative power. But it was hardly discussed or debated among political stakeholders, which contributed to establish a hierarchical governance mode in the energy sector, similar to the Venezuelan model. This contributed to the persistence of subsidies to energy consumption in household and transportation sectors. Eventually, this hindered the energy transition, as did the mobilization of financial instruments analyzed below.

8.3.3 Evidence from Financial Instruments

The existence of contradictory policy aims held by resource nationalism led to the state financing two different kinds of programs that were implemented independently, which prevented the design of an effective energy transition. In Ecuador and Venezuela, huge public resources were spent to maintain energy subsidies, while investing massively in hydropower facilities. The persistence of these subsidies had a negative effect on the overall energy demand, which increased instead of engaging in a substitution process of nonrenewable energy sources (oil, for that matter) by renewable ones (like hydropower). This policy also had a negative effect on the level of public spending in times of exceptionally high oil prices, hence creating structural deficits when these when down after 2015–2016 (Schaffitzel et al., 2020, 2).

Oil subsidies directly affect transportation costs for people and merchandises, and indirectly the prices of goods and services on the domestic market. In Venezuela, they have been prevailing since the 1950s, when the country managed to develop a high capacity of refinery that would allow them to export oil products (additional to traditional crude oil exports). In Ecuador, the refinery capacity allows the country to supply the domestic market, but it remains insufficient to export anything else than crude oil. Moreover, since 2000, the domestic market has been relying on imports for certain products (like gasoline) necessary to refine the crude oil on site (Espinoza & Guayanlema, 2017, 15).

The limited production capacities of oil products and liquid natural gas (LNG) have not improved since 2001 in Ecuador, which means the country keeps importing them. Eventually, they are subsidized by the state, which is particularly costly in a context of oil prices windfall. As of 2019, oil products were still financed up to 32.6% by the Ecuadorian state (to be compared with 66.5% in 2011). The amount in constant USD increased from 1.07 to 3.9 billion (between 2006 and 2014), and then fell back to 1.2 billion in 2019. Subsidies currently amount to 7% of the state budget (Schaffitzel et al., 2020, 1). However, there is no reliable available information about subsidies for the domestic supply to the national oil company, Petroecuador (Schaffitzel et al., 2020, 2).

In Venezuela, the price of oil products has not changed between 1996 (when it was established at 7 bolivars per gallon) and 2020, in spite of the hyperinflation that sparked in the early twenty-first century and led to three devaluations of the national currency. According to official data reported by PDVSA, oil subsidies in current USD may vary from 1.5 billion (in 2012) to 10.0 billion (in 2014) and 7.1 billion in 2016 (afterward the company stopped publishing them). This is a significant share of the company's financial operations (between 2.1% and 14.3% of their assets, which were estimated around USD 70 billion in the mid-2010s).

Moreover, since 2003, PDVSA has taken responsibility for funding multiple social programs (the so-called missions), based on the criteria that, as a national company owned by the state and the Venezuelan people, it was compelled to contribute to the country's economic and social development, which it had failed to do since its creation in 1976. These programs expanded up to 34 between 2003 and 2016, in health, education, food supply, household, energy efficiency, and so forth. As of 2016, five of them remained active, according to the last available report by PDVSA's department of social corporate responsibility. The company invested around USD 28 billion in these programs between 2009 and 2013, and in 2016, they still assigned them USD 9 billion, when the WTI (West Texas Intermediate) was plummeting, back to its 2003 level.

Under the Chavez and Maduro administrations, PDVSA has multiplied local and regional development funds (like FONDEN and FONDESPA, Miranda, etc.) on behalf of the Bolivarian revolution. According to the 2016 report on corporate social responsibility, the contribution to these social funds by PDVSA reached USD 12 billion in 2006, and 30 billion in 2012, before decreasing as a consequence of oil rents shortfall. For the government, the use of such financial instruments through the national oil company was a way to manage directly state resources without being accountable for their efficiency or their final destination, which was a very opaque procedure escaping regular state budget planning (Fontaine & Medrano Caviedes, 2016).

As a result of the nationalist resources policies, progress in the post-carbon transition remained marginal. The energy transition was limited to increase hydropower supply, but the investments in alternative renewable sources were limited. Two wind plants were built in Ecuador: San Cristobal in Galapagos Islands (16 million dollars of investment) and Villonaco in Loja province (32 million dollars investment), which hardly reach 0.03% of the total electricity supply. Likewise, two wind plants were built in Venezuela: Paraguaná and La Guajira. But none of them is currently operating.

The Ecuadorian government pretended to replace domestic gas consumption by electricity through the program of energy efficiency and induction stoves. This program started in 2013 with the aim to address 60% of the national households. But the logistics failed and by 2015, it was hardly implemented by 20%, while legal claims by unhappy users were spreading out. It was eventually terminated by the Moreno administration, after less than 50% implementation.

In a nutshell, the development of financial instruments brings in hard evidence of the overwhelming importance of oil rents in financing social policies in both countries, not only through subsidies but also through the direct funding of government programs. This explains why the energy transition put on the agenda by the administrations Chávez and Correa during the 2000s was actually doomed to fail – with public spendings driven by increasing oil prices – and eventually pushed into the background, when the state budget deficit became unbearable.

8.3.4 Evidence from Organization Instruments

The new energy policy designed in the early 2000s in Ecuador and Venezuela was based on administrative agencies specialized in two distinct sectors, which ended up working with great autonomy from one another. Hence, there was a complete lack of coordination between the renewable energy administration and the traditional agencies in charge of the oil sector.

In Ecuador, the government created a Ministry of electricity and natural renewable resources, responsible for the energy transition and independent from the Ministry of nonrenewable natural resources, which were responsible for the oil policy at all levels (Ponce-Jara et al., 2018, 516). The new ministry was initially in charge of reforming the energy mix, which consisted essentially in building huge hydropower plants across the country and, to a far lesser extent, implementing energy = saving programs (e.g., by replacing traditional light-bulbs by LED and other energy-efficient bulbs, or by replacing traditional liquefied petroleum gas (LPG) stoves by induction cookers) (Ponce-Jara et al., 2018, 520).

In 2011, the Ministry of nonrenewable natural resources was turned into a State Ministry of strategic resources, therefore becoming back the agency in charge of the overall energy policy and supervising the construction of hydropower plants to increase the total energy supply. Meanwhile, after the adoption of the organic law of the electricity service, the system of generation, distribution, and trade, as well as the agencies in charge of controlling the sector since 2007 were placed under the authority of this ministry, which reported directly to Presidency of the Republic. The Moreno administration put an end to this in 2017, but in 2019, the electricity, oil, and mining sectors merged back within a single agency. All in all, the institutional instability and the turn over thereof did not contribute to advance the energy transition.

In Venezuela, the 2001 organic law on electricity had created a centralized system, similar to the Ecuadorian, to manage the public service of electricity administration, distribution, and trade. This system was fully operational in 2007, but PDVSA always remained the agency providing for the financial resources to support development projects in the electricity sector, apart from being in charge of their administration. In 2007, the government created the public corporation CORPOELEC, to control every generation company (either public, private, or managed by local governments). In 2009, this agency was placed under the supervision by the Ministry of power energy, as well as the whole system of electricity generation and distribution, including the management of every project of power generation and renewable energy (Bautista, 2012, 332). As we can see, the emerging renewable energy sector remained submitted to the investment and management capacities of the nonrenewable energy sector. Hence, there was persisting hegemony of the oil sector in the energy policy, and the consequent implementation gap in the post-carbon policy.

8.4 Conclusion

One of the major challenges for the energy policies, in oil-producing countries like Ecuador and Venezuela, consists in tackling oil dependence, both to finance the domestic economy with rents and exports, and to satisfy the growing energy demand by the industrial, the transportation, and the household sectors. During the 1990s liberal era and, afterward, during the 2000s resource nationalism era, governments have claimed to attempt to reduce this dependence. Yet their efforts have been frustrated by the resilient rentier state and the path dependence of natural resources overload in the development model.

Since the early twenty-first century, resource nationalist governments from Ecuador and Venezuela have claimed to adopt decarbonization aims, which were supposed to be achieved through massive investments in building hydropower capacities. However, simultaneously they have been using oil rents to support state-driven policies and to finance energy subsidies, in order to secure political agreements and to resolve social disputes. The analysis of the energy balance indicates that, so far, this contradiction has led to an implementation gap and a failed energy transition. As of today, even though the electricity supply has been notably increasing (again, almost exclusively because of massive investments in hydropower), in both countries, the energy mix diversification remains a myth printed on blue-sky laws, instead of a real policy.

The main cause of these suboptimal results lies in ill-designed policies, based on contradictory aims and persistent instrument mixes betraying governments´ preferences for distributive programs rather than efficient public spendings and economy diversification. Among these instruments, resilient energy subsidies hinder any possibility, both to reach decarbonization through the energy transition and to get rid of the opacity typical to resource nationalism, eventually preventing nonstate actors from getting involved in the policy design that will determine their fate for the forthcoming decades.

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Legal Documents

Ecuador

Constitución de la República del Ecuador.
Decreto Ejecutivo 662 del 4 de octubre de 2007 que aplica la ley 42-2006 reformatoria de la ley de hidrocarburos publicada en el Suplemento del Registro Oficial No. 257 del 25 de abril del 2006.
Ley de hidrocarburos.
Ley Orgánica de Eficiencia Energética.
Ley Orgánica de Servicio Eléctrico.

Venezuela

Constitución de la República Bolivariana de Venezuela.
Ley de uso racional y eficiente de la energía.
Ley Orgánica de Electricidad.
Ley Orgánica de reordenamiento del mercado interno de los combustibles líquidos.
Ley Orgánica de Reorganización del Sector Eléctrico.

9 The Brazilian Hydrocarbon Dilemma: Did Brazil Hit the Big Ticket Too Late?

Rafael Almeida Ferreira Abrão, Giorgio Romano Schutte, and Igor Fuser

9.1 Introduction

The global energy transition is more complex and uncertain than usually described in the literature. Existing natural resources, the technologies available, the institutional structures, the political scenario, and the historical path in energy use will shape the way for several types of energy transition in each country and region. This transition suggests a nonlinear path to a zero-carbon emissions economy. In this chapter, we explore the case of the energy transition in Brazil, a country with significant recently discovered and undeveloped oil and gas reserves.

Some scholars such as O'Sullivan et al. (2017) and Van de Graaf (2018) suggested that countries in this position would face serious challenges as the need for the energy transition progresses. In this view, with less oil demand, regions with higher extraction costs would become less attractive or even commercially unviable. The remaining demand would be supplied with cheap oil, benefiting the producing countries of the Middle East by making it impossible to develop new regions with higher extraction costs.

Hydrocarbon producers are often portrayed as the "losers" of a transition to renewable sources. The losers remain trapped in the supply of oil and gas, while those that are currently net energy importers may occupy a more comfortable position in a clean energy future. However, can the case of a country with a clean energy matrix that has recently found large deposits of hydrocarbon resources be labeled as a loser in the energy transition game?

Brazil ranked third in renewable energy generation capacity in 2020, with 515,449 gigawatt-hours (GWh), behind only China and the United States (IRENA, 2021, p. 7). According to the Energy Research Office (EPE in its Portuguese acronym), the share of renewables in Brazil's energy matrix accounts for 48.4% of the internal energy supply in 2020. Worldwide, this share is equivalent to 13.8%. But among the Organization for Economic Co-operation and Development (OECD) countries, this share represents only 11% (EPE, 2021a, b, p. 12). In Brazil, however, the share of renewables is even larger if only electricity is considered, representing 84.9% (compared to 22% in the world average), of which 65.2% correspond to hydraulic (isn't "hydroelectric power" the more common term?) energy, followed by biomass (9.1%), wind (8.8%), and natural gas (8.3%) (EPE, 2021a, b, pp. 16–17).

After decades of efforts to develop its oil industry, Brazil is becoming an oil-exporting country due to the discovery of huge offshore resources on its southeast coast known as Pré-sal (and to the development of technologies that

R. A. F. Abrão (✉) · G. R. Schutte · I. Fuser
Universidade Federal do ABC, São Bernardo do Campo, Brazil

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makes them accessible). That is the winning ticket. The challenge for Brazil is to balance the economic gains of the presalt with policies to support national development and, at the same time, encourage the use of other energy sources.

This idea finds support in Fattouh et al. (2018). They argue that, "there is no conflict between renewable investment and hydrocarbon business in these countries" (Fattouh et al., 2018). The authors discussed the dilemmas posed for the global oil industry in the context of the energy transition, concluding that "for oil-exporting countries, there is no trade-off involved in renewable deployment as such investments can liberate oil and gas for export markets, improving the economics of domestic renewables projects" (Fattouh et al., 2018).

We argue here that depending on the national policies implemented, presalt might not necessarily conflict with the goals of an energy transition. In the Brazilian case, the increasing consumption of natural gas from presalt in thermal power plants enables the replacement of other more polluting fossil fuels, such as fuel oil. At the same time, it reduces the pressure for the construction of new hydroelectric plants that could only be installed in the Amazon, bringing serious environmental and social impacts. As for presalt oil, increasing production by itself will not cause an increase in the consumption of gasoline and diesel oil, according to those responsible for Brazilian energy planning. One has to consider also the expansion of biofuels – ethanol and biodiesel – in the transportation and power generation sectors.

An extensive bibliographical review was carried out for this chapter. We focused on works related to geopolitics and the political economy of energy. Our investigation was based on three types of bibliographic sources: books, articles, and datasets made available by institutions such as the International Energy Agency (IEA), the Organization of Petroleum Exporting Countries (OPEC), the International Renewable Energy Agency (IRENA), Brazil's Energy Research Office (EPE), the BP Statistical Review of World Energy, and the U.S. Energy Information Administration (EIA).

The EPE (2020) predicts a moderate fall in the share of oil in the Brazilian energy matrix in the next 10 years. Presalt production is expected to replace oil extracted from conventional and more mature fields, with surpluses being exported in ever larger volumes. The income generated by these exports could possibly favor economic and social development and investments in renewable energy and environmental protection – if policymakers create instruments to allocate oil revenue for this purpose – contributing to a reduction of CO_2 emissions.

However, if a clear strategy is not implemented to take advantage of these resources, private domestic and international interests might appropriate the oil revenues. We believe that the role of the State in supporting the growth of renewable sources is fundamental to securing the necessary investments and technological development related to the multiple tasks of the energy transition.

We will analyze the challenges imposed on Brazil by the global energy transition scenario. A qualitative methodology is used, which includes a bibliographic review, collection of statistical data, and systematic analysis of the characteristics of the Brazilian energy sector. This chapter was organized into six sections, including this introduction. In the second section, we discuss the characteristics of the Brazilian energy matrix. In the third section, we analyze the changes that occurred after the discovery of the presalt. In the fourth section, we seek to answer if Brazil was awarded a winning ticket too late. In the next section, we make an overview of the energy transition process with Brazilian characteristics. Finally, we briefly outline some final considerations.

9.2 A "Clean" Energy Matrix

Two particularities of the Brazilian energy system explain the strong presence of renewable sources in the energy matrix. First, the decisive role of hydroelectric plants, which throughout the twentieth century became the main source of electricity in the country. With 12% of all surface freshwater on the planet, Brazil has hundreds of dams spread over 17 watersheds and an electricity grid that integrates the supply of electricity in almost all of its territory. The National Interconnected System (SIN) brings together 152 hydroelectric plants, from huge ones such as the Itaipu Hydroelectric Dam to the hundreds spread out across the country.

An energy matrix represents the set of energy sources available for transportation, combustion, and electricity generation. The electric matrix is made of the energy sources available for electricity generation. Figure 9.1 shows the large share of renewable sources in Brazil compared to the rest of the world and the set of countries from the OECD.

The expansion of hydroelectric power in Brazil was consolidated in the 1970s. The construction of the Itaipu binational power plant was a milestone. Brazil was interested in increasing electricity generation to meet the rise in energy demand amid the country's industrialization process (FUSER, 2015). In April 2022, 76% of all Brazilian electricity was distributed in the SIN (Agência Nacional de Águas, 2022).

The construction of Itaipu reinforced Brazil's choice for an electric matrix to take advantage of the rich endowment of water sources. This put Brazil in an advanced position in two key sectors of the global energy transition: the decarbonization of the electricity matrix and the replacement of fossil fuels with renewable sources in the transport sector. The following figures demonstrate the strong presence of hydroelectric and other renewable energy in the Brazilian electric matrix.

Figures 9.2 and 9.3 show the result of this process of expansion of hydroelectric power generation. Hydropower accounts for 65.2% of electricity supply, which added to other renewables, accounts for 84.8% of the Brazilian electric matrix. In comparison, the world average share of renewables in the electric matrix is only 23%. In the OECD, it is only 27%.

Another Brazilian singularity is its prominent position as a major producer of two important biofuels: ethanol and biodiesel. Brazil is the world's second-largest producer of ethanol (only behind the United States) and the only country to offer consumers the option to fuel their car with biofuels only. Ordinary ethanol emits up to 80% fewer greenhouse gases – such as carbon dioxide (CO_2), methane gas (CH_4), and nitrous oxide (NO_2) – when compared to gasoline. There is also the second generation of ethanol, which emits up to 93% fewer greenhouse gases when compared to gasoline.

The wide use of sugarcane ethanol and even biodiesel allowed Brazil to control CO_2 emissions in the transportation sector, although the strong expansion of consumption demands alternative solutions. Since 2003, the use of ethanol (both anhydrous and hydrated) reduced the emission of more than 556 million tons of CO_2 into the atmosphere until April 2021, according to Brazil's Sugarcane Industry association (ÚNICA, 2021). This is equivalent to the annual emissions added up from Argentina, Venezuela, Chile, Colombia, and Uruguay combined.

Table 9.1 shows Brazil's reduced level of emissions. On average, a Brazilian citizen emits one-seventh of what an American citizen emits

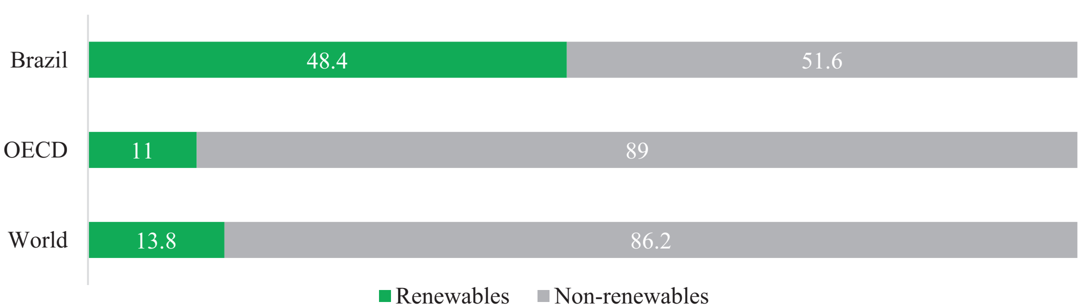

Fig. 9.1 Share of renewable energy resources in the energy matrix (%, 2020). (Source: EPE, 2021a, b, p. 11)

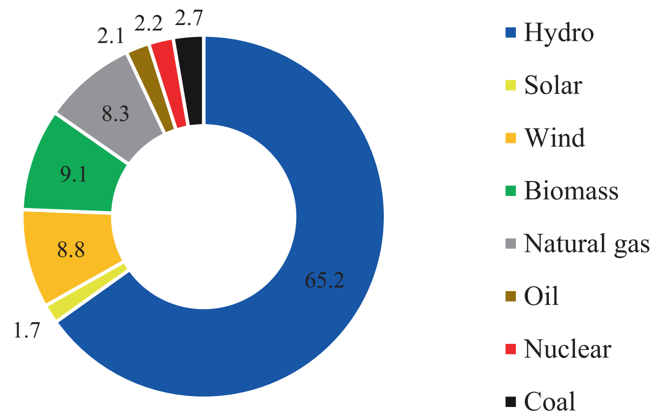

Fig. 9.2 Structure of the Brazilian electric matrix (Brazil, %, 2020). (Source: EPE, 2021a, b, p. 38)

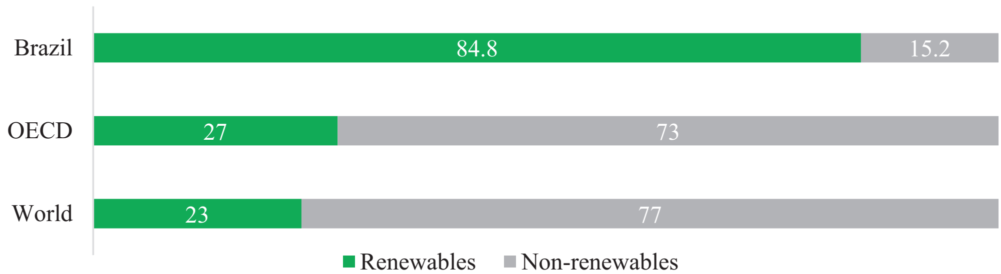

Fig. 9.3 Share of renewables in the electric matrix (%, 2020). (Fonte: EPE, 2021a, b, p. 39)

and one-third of what a European or Chinese citizen emits in energy production and consumption.

Biofuels have great economic importance in Brazil and the United States, where they are mixed with traditional oil products, increasing gasoline performance and reducing emissions (Ackrill & Kay, 2014). Brazil's position among the largest biofuel producers is shown in Table 9.2.

Brazil is the second largest producer of biofuels in the world, accounting for 20.3% of the world's production, second only to the United States.

The Brazilian sugarcane industry also contributes to the country's energy security – and the reduction of greenhouse gas emissions. The use of residual biomass resulting from sugarcane processing generates electricity, which is offered commercially in the national electricity network through the SIN. About 200 of the 369 sugar-alcohol plants in operation commercialize the energy obtained by burning sugarcane bagasse, which provides 9.1% of the electricity consumed in the country (Losekann & Tavares, 2021).

Wind energy accounts for more than 40% of new energy generation ventures, with a total generation potential estimated at 500 GW (Vasconcelos, 2021). This amount meets three times the current energy demand in Brazil. Figure 9.4 shows the advance of wind energy production in Brazil, which has been growing at an accelerated pace since 2007.

The rapid growth of wind and solar energy generation in the 2010s reinforces the potential for a transition to a zero net carbon energy model without jeopardizing the perspectives of national economic development, which demands increasing volumes of energy. The contribution of so-called new renewable sources provides additional energy to respond to the demographic growth, industrial and urban development, and access to

Table 9.1 CO_2 emissions per capita (2018, tons of CO_2 per inhabitant)

Country	CO_2 emissions
USA	15
China	6.8
European Union	6.1
Brazil	1.9

Source: EPE (2021a, b)

Table 9.2 World's largest biofuel producers by country or region (2021)

Biofuels	Billions of liters per year	Share of world biofuel production (%)
Ethanol	**114.2**	**65.3**
USA	57.5	32.9
Brazil	35.6	20.3
India	3.1	1.7
Rest of the world	18	10.3
Biodiesel	**60.7**	**34.7**
Europe	17.7	10.2
USA	14.5	8.3
Indonesia	9.3	5.3
Rest of the world	19.2	11
Total worldwide	**174.9**	**100**

Fonte: International Energy Agency (2021)

higher standards of living for the unprivileged part of the Brazilian population.

9.3 The Presalt Revolution

It is noteworthy that neither the consumption of ethanol nor the electrical generation from sugarcane biomass suffered any shock with the new reality that emerged in the Brazilian oil industry in November 2007. After the announcement of a huge amount of oil and gas reserves in deep waters off the Brazilian coast, the country's position in the world market changed significantly. International oil companies started to consider Brazil as a new investment opportunity. The announcements of proven reserves could reach 100 billion barrels of oil (Sauer & Estrella, 2019, p. 3). This would make Brazil expected to be not only self-sufficient but to put the country among the list of the world's top oil-exporting countries. By 2020, Brazil was already among the top ten producing countries in the world, ahead of traditional producers such as Iran and Kuwait, as shown in Table 9.3.

In the energy transition, regions with higher extraction costs could become less attractive or even commercially unviable, and the remaining demand will be supplied with oil with competitive production costs (O'Sullivan et al., 2017). However, oil still plays a significant role in enabling the change in the existing production and consumption paradigm and the energy transition itself. Oil tends to maintain its high value for a long time, at least three decades (Sauer, 2016, pp. 316–7). And even if oil loses its leading role, it will continue to be an essential energy source, just as the decline in coal in the twentieth century did not eliminate it from the world energy matrix. Fossil fuels will likely remain a relevant part of the global energy matrix, coexisting with renewables far beyond the peak in demand oil (Paltsev, 2016; Scholten, 2018).

Thanks to its rich presalt reserves, Brazil achieved an average production of 2.8 million barrels of oil per day in 2019. The EPE (2020) predicts that this volume should double within 10 years, reaching 5.3 mbd, of which approximately two-third will be exported. With an oil industry of these dimensions, Brazil is currently in a firm position among the world's major oil exporters.

From a country that previously lacked oil reserves and had to look for alternative sources of supply even before the world began to talk about energy transition, Brazil has become not only a major producer but an oil exporter, as shown in Fig. 9.5.

As Fattouh et al. have said (2018), in countries in this position "there is no trade-off involved in renewable deployment as such investments can liberate oil and gas for export markets, improving the economics of domestic renewables projects." The main challenge in the long run, for oil-exporting countries, will be the economic diversification of their source of income as "the ultimate safeguard" against the risks associated with the energy transition. According to the authors:

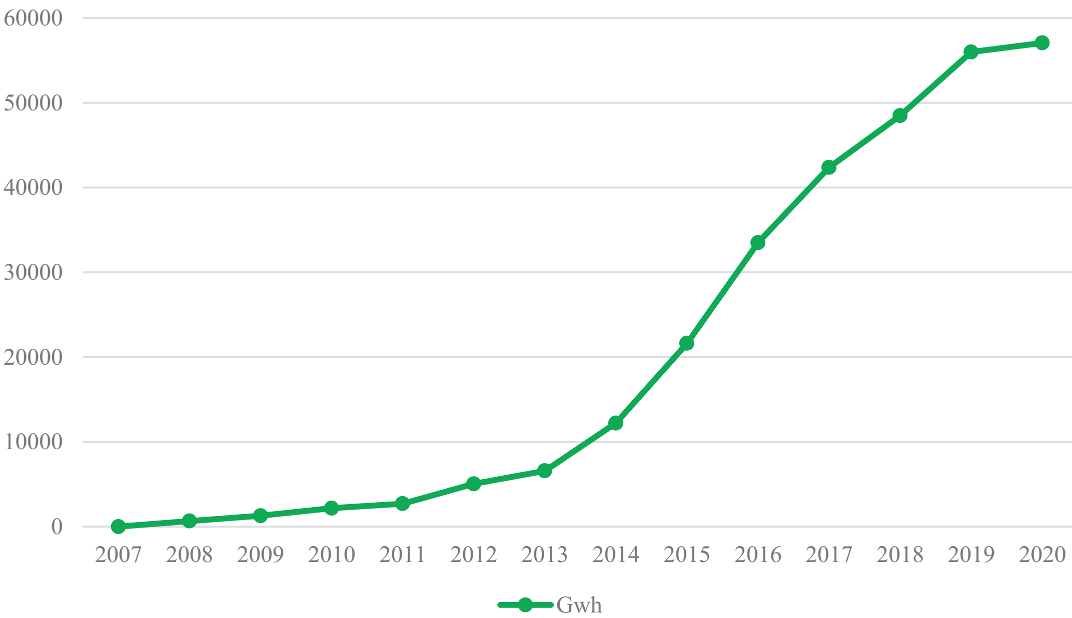

Fig. 9.4 Wind power generation in Brazil in Gigawatts/hour (GWh). (Source: EPE, 2021a, b)

Table 9.3 World's largest producers of oil, oil products, and biofuels (2020)

Country	Million barrels of oil equivalent per day	Share of world production (%)
USA	18.61	20
Saudi Arabia	10.81	12
Russia	10.50	11
Canada	5.23	6
China	4.86	5
Iraq	4.16	4
United Arab Emirates	3.78	4
Brazil	3.77	4
Iran	3.01	3
Kuwait	2.75	3
World total	**93.86**	–

Source: U.S. Energy Information Administration (2022)

> Indeed, investment in renewables could help further boost their short-term revenues as it frees up their hydrocarbon resources for export (as long as international prices are above the break-even price). Oil-exporting countries have unique characteristics that make the rationale for investment in renewables for them quite compelling. These countries have rising energy demand and are at a stage of development where economic growth is tied up with energy consumption. (Fattouh et al., 2018)

9.4 Did the Winning Ticket Come Too Late?

Regarding peak demand, one can differentiate between international and domestic demand. The global analysis of oil consumption data shows that there was a cyclical drop in the level of demand from the previous year. This happened in five historical moments: in 1930, during the Great Depression (−5%); in 1942, during the Second World War (−5.7%), and in 1975, related to the impact of the boycott of Arab producers and the price shock (−5.5%); in 1981, related to the second oil shock and the Iran-Iraq War (−6.4%); and, in 2020, related to Covid-19 pandemic (−9.3%). In the latter case, global demand reached its lowest level since 2012 (BP, 2021).

Global demand in absolute terms increased by 67.43 million barrels per day since 1992. That year the United Nations Conference on Environment and Development, also known as the Rio de Janeiro Earth Summit, was held. The world demand was 97.6 million barrels per day in 2019. In 2020, there was no lack of speculation that the pandemic would accelerate the peak of demand, while the fall in prices generated

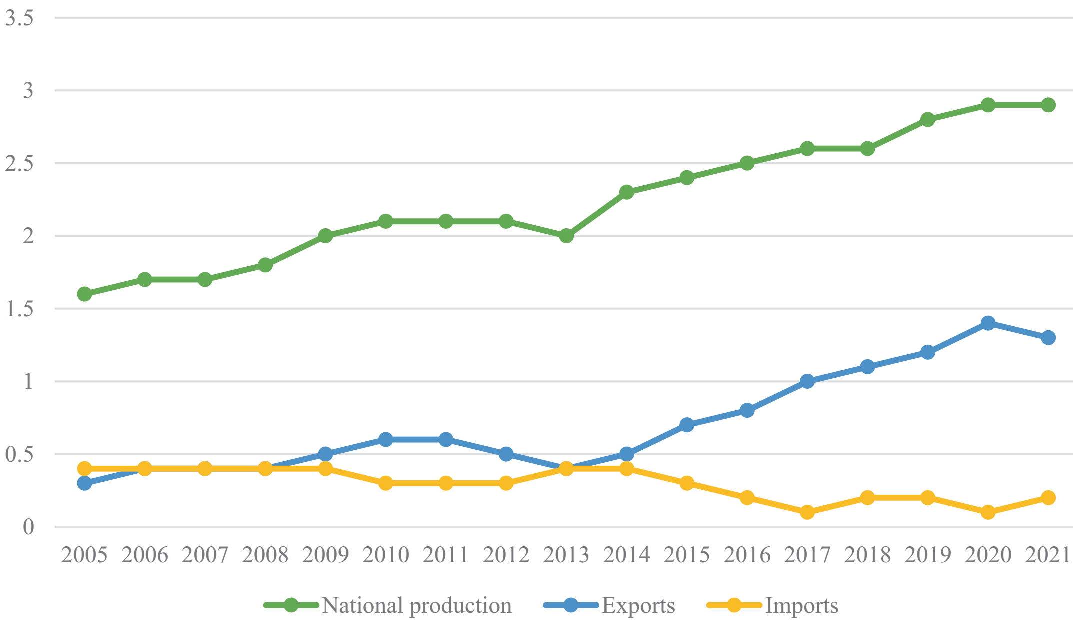

Fig. 9.5 Oil national production, exports, and imports in Brazil 2005–2021 (in millions of barrels per day). (Source: IBP, 2022)

insecurity regarding investment (Klare, 2020). In 2021, the still slow recovery of the economy led, however, to a 5.7% increase in global demand for oil, according to the US Energy Information Administration, which forecast a global demand of 102.5 million BPD for 2023 (EIA, 2022). The EPE's forecast in 2020 was that "international oil prices should continue to rise in the medium term until they stabilize at values close to breakeven prices of more expensive projects in fields currently considered unprofitable" (EPE, 2020).

In any case, large companies and fossil fuel-producing countries can be hit hard by the energy transition. They have resisted the transition, whether by sustaining investments in unconventional assets (shale reserves, ultra-deep-water reservoirs, etc.) or by investing in natural gas as a transition fuel, as it is less polluting (Van de Graaf, 2018). Natural gas emits 45–50% less carbon dioxide than coal and 21–33% less than oil (Paltsev, 2016), and has become part of efforts to reduce carbon emissions. Natural gas is being put by many as a *bridge fuel* that reduces emissions while cleaner energy solutions are developed (Ladislaw et al., 2014), a strategy that does not prevent the rise of the planet's temperature. The best role for natural gas would be to supplement renewable sources during periods of the low incidence of winds and solar (Paltsev, 2016). However, some suggest that fossil energy sources will remain relevant to the global energy matrix even after the energy transition, coexisting with renewable energy sources (Paltsev, 2016; Scholten, 2018).

There are structural factors that increase global energy demand (demography, income), and this means that the loss of oil's relative importance may coincide with a nominal increase. Even more important is to consider the impact of depletion. As the International Energy Agency argued, production from existing fields declines at a rate of roughly 8% per year in the absence of any investment, more significant than any plausible fall in global demand. Consequently, investment in existing and new fields remains part of the picture. However, as overall investment recedes and markets become increasingly competitive, only those with low-cost resources and tight environmental and cost controls would be able to benefit (International Energy Agency, 2020, p. 60 and 82). This is precisely the case with the presalt layer.

The pressure for energy transition and the uncertainties on medium- and long-term developments do not stop investments in oil and gas. They have led to a selective approach by the major oil companies, focusing on efficient, low-cost, and reliable sources, among which Brazil offers the presalt fields.

Petrobras' operations and technological innovation have reduced the average cost of extracting presalt oil relatively quickly. For instance, the lifting cost went from US$ 9.1 per barrel of oil equivalent (oil + gas) in 2014 to US$ 8.3 in 2015. It reached a cost of less than US$ 7 per barrel in 2018, and in the following year has reached a cost between US$ 5 and US$ 6 per barrel (Petrobras, 2019). No surprise, then, that international companies, like Shell and Equinor, have made the presalt a fundamental part of their strategy. In an interview about ExxonMobil's expectations for presalt exploration, Stephen Greenlee, the company's global president of exploration and production, stated that the presalt:

> it is an entirely different type of investment, but the returns are comparable to the best unconventional assets. Today, there is nothing better to bring to our portfolio than these reserves that Brazil has discovered in recent years. That is why we are so excited. (Folha de S. Paulo, 2018)

In addition to oil, the importance of presalt natural gas reserves for the energy transition in Brazil must also be considered. Natural gas is considered a bridge fuel that can promote the reduction of emissions, while cleaner energy solutions are developed and implemented (Ladislaw et al., 2014). However, in the medium term, for the oil companies to survive, they will have to transform themselves into energy companies, also investing in renewable projects.

So the answer is that the winning ticket came just in time to contribute to policies to support the expansion of renewable energy sources. In the next section, we will analyze the evolution of renewable energy sources in Brazil since the exploration of the presalt reserves began.

9.5 Energy Transition in Brazil

Contrary to what might ordinarily be assumed, the rapid expansion of Brazilian oil production from the exploration of presalt reserves did not prevent the development of renewable sources in the Brazilian energy matrix by itself. The Brazilian government has invested heavily in the oil industry since 2007. These investments were put into action while a policy of financial energy renewable incentives was applied. This has enabled an accelerated growth of electricity generation from intermittent energy sources – wind and solar energy. The energy source that has most expanded in the country is wind energy, whose installed capacity grew from 1326 MW in 2011 to 19,962 MW in 2021 (EPE, 2021a, b). In 2021 alone, this increase reached 3051 MW, according to data from the National Electric Energy Agency (ANEEL). Wind power plants account for 11% of electricity generation in Brazil, exceeded only by hydroelectric power (Machado, 2021).

In 2020, 66 new wind farms began operating in Brazil and, in 2021, despite the Covid-19 pandemic, another 54 had already entered operation by November, totaling more than 750 installations of this type installed in Brazil (Vasconcelos, 2021). Installed capacity reached 21.03 GW.

Among the explanations for the success of the expansion of wind energy in Brazil several stand out: first, the characteristics of the Northeast region, where the winds have a constancy and intensity favorable for electricity generation. Currently, the Northeast accounts for 90% of the wind energy generated in Brazil. Another crucial factor is the complementarity between wind energy and the dominant hydroelectric energy source. Periods of higher incidence of rainfall correspond to unfavorable winds for energy generation, and vice versa (Losenkann & Hallack, 2018).

Photovoltaic solar energy has also rapidly expanded its share in the Brazilian energy matrix, despite its relatively late development compared to wind energy. The production of this type of energy only becomes significant in 2017, when

Brazil had an installed capacity of 935 MW, growing vigorously since then. In 2021, the installed capacity of solar energy reached 4.3 GW (EPE, 2021a, b).

The data presented here refer to the so-called centralized generation of photovoltaic solar energy, obtained in large plants. They have become economically viable with the purchase of energy supply by the federal government through specific auctions and, more recently, by the direct purchase of large consumers in the free market (Vasconcelos, 2021). Another 7.3 GW of installed photovoltaic solar energy capacity (not counted in the official calculation of the electric matrix) correspond to the so-called distributed generation. That comes from the 800,000 consumers who produce their energy from solar modules installed on the roofs of homes, businesses, and small plots of land (Vasconcelos, 2021).

As for Brazilian hydroelectricity, fears of a negative impact of presalt oil expansion to make the Brazilian energy matrix "dirtier" have so far not materialized. The share of renewable sources in the generation of Brazilian electricity has grown in the last decade. Thanks to the expansion of wind and solar energy infrastructure and, even more importantly, a process of increasing electrification in the general use of energy in Brazil is underway. This trend converges with global expectations related to the transition to a "low carbon" economic model.

On the other hand, Government planners in the energy sector expect a decline in the share of water sources in total electricity generation from 83% around 2000 to 46% by 2031, well below the current 65% (EPE, 2020). This decline is due to rising costs and restrictions, for environmental and social reasons, to the construction of new dams in the Amazon, the only region of the country where large new hydroelectric plants are still possible. The main reasons for resistance to new water energy enterprises in the Amazon are (i) the need for the displacement of populations and rural economic activities; (ii) damage to flora and fauna, especially in areas where endangered species are found; (iii) changes in the water of the reservoirs themselves as a function of the remaining submerged vegetation; and (iv) the change in the river regime. As it turns out, none of these restrictions have to do with oil (Leite, 2007).

As for biofuels, sugarcane ethanol and biodiesel have maintained their central position in the energy supply for transport despite Brazilian self-sufficiency in oil production and the increase in natural gas production. Brazil has a long history of the use of ethanol, starting in the mid-1970s with a massive state program to produce sugarcane alcohol in place of gasoline to face fuel prices from the first "oil shock." This program was later abandoned, in the face of falling oil prices in the 1980s and the fiscal crisis of the Brazilian state, which made subsidies to ethanol mills and sugarcane producers unfeasible. Biofuels resumed their role as an energy alternative in 2000 when oil prices rose again (Barros et al., 2012). A sustained policy of encouraging ethanol and biodiesel began, which has remained unchanged to date, throughout governments of different political and ideological options. This long-standing policy helped to contain pollution. The sugar and ethanol industry is also crucial in the Brazilian energy matrix because burned waste from ethanol production is used in thermal plants to generate electricity. About 12% of all electricity consumed in Brazil is obtained from this energy source.

The generation of renewable energy in Brazil presents a wide range of possibilities to be explored by energy transition policies, due to its diversity and its elevated levels of production. The export of Brazilian renewable energy using hydrogen as a means of storage and transportation is on the agenda of many international energy companies.

The expansion of the use of renewables in place of fossil energies also depends on the electrification of energy systems. Mainly in the transport sector, where the increased use of electric cars can give greater importance to electricity produced by renewable sources (Scholten, 2018).

Although Brazil, as explained, has one of the cleanest energy matrices in the world by comparison, there is a structural problem moving forward: the transportation sector. In 2019, it was the largest energy consumer in Brazil, responsible for 32.7% of the total, more than industry.

However, while 58% of the energy consumed in the industrial sector comes from renewable sources, in the case of transport, it is only 25% (EPE, 2020).

In the case of automobiles, Brazil has managed to limit the increase in gasoline consumption by supplying engines fueled by hydrated (100%) and anhydrous ethanol (with a 27.5% mandate). Brazil has long been the only country globally that offers hydrous ethanol throughout its distribution network, and by now almost the entire car fleet uses engines capable of running on gasoline or ethanol.

A report by researchers from the Brazilian Center for International Relations (CEBRI) points out that “while the [international] automotive industry has been developing new models and investing in battery capacity, aiming at the de-carbonization of the fleet of light vehicles in Brazil, the light transport fleet is already strongly renewable, with biofuels accounting for more than 40% of the energy consumed in the segment” (CEBRI, 2021, p. 23).

Nevertheless, the explosion in consumption did put pressure on the gasoline demand. Biodiesel is not extremely competitive, and the industry is not investing in preparing engines to increase the mandate. Biodiesel – a product obtained mainly from soybeans and animal fats – is mixed with diesel, in proportions defined by law. This mixture went from 2% (B2) in 2005 to 7% (B7) in 2014, reaching 10% (B10) in 2018 (Tavares, 2019). In 2021, the government even retreated and lowered the mandatory mix from 13% to 10%. The goal is to reach 15% in 2025. The fight against inflation was used to justify this measure, but it generates unpredictability for producers and does not consider the positive externalities of biofuels.

9.6 Conclusion

The basic premise of the article is to understand if and how the discovery of oil in the Pré-sal has affected the energy transition to renewables in Brazil. We show that presalt oil and gas reserves are a strategic asset that can support Brazil’s energy transition, instead of being a hurdle for a decarbonized energy matrix. How can hydrocarbon assets be strategic in the energy transition? Even if governments and companies succeed in lowing carbon emissions on the scale required, oil consumption will retain its place as a fundamental fuel for the world economy in the following decades.

As we have shown, the increasing presalt oil production has not raised domestic consumption of gasoline, diesel, or other petroleum derivatives. The electrification of the automobile fleet and the growth of sugarcane production is being a complementary trend to intensify decarbonization in the transportation sector. One creative solution introduced in Brazil was hybrid cars fueled by a mix of ethanol and electricity.

The rent provided by the presalt endeavors might create new opportunities for financing energy transition investments and developing technologies for renewable sources of energy, depending on Brazil’s policy choices regarding the allocation of the presalt rent.

There are many possibilities for synergies between oil, gas, and renewable energies: for instance, the use of oil refineries for processing biofuels and hydrogen, or the use of offshore oil and gas as platforms for wind turbine installations.

The energy transition, as many authors have pointed out, is a complex, multidimensional, and uncertain process. One cannot imagine that it will occur worldwide according to a single model, based on the realities of North America and Western Europe. In the case of Brazil, for example, it would be folly to mechanically replicate the replacement of vehicles with explosion engines by electric cars. The country has a successful experience in using large-scale biofuels to supply a large part of its automotive fleet. As pointed out by Fattouh et al. (2018), the speed of transition at a global scale is uncertain, and “it is difficult to define what the endgame is, which technology wins, and how the final mix of energy will look. It is quite likely that the outcome of the transition will be different across regions.”

In the Brazilian case, the oil and gas sector must be seen in the conditions that involve these two sources in Brazil and the context of the national energy matrix and the political economy of energy.

Its broad margin of autonomy regarding the global energy transition is based, first, on the predominance of hydro resources in the electric sector, which makes Brazil one of the countries with the largest share of renewable energy in its energy matrix. Thanks to that, the use of fossil fuels in electricity generation is secondary, and the energy matrix is "clean" in comparison to international standards.

Another fundamental feature of the Brazilian energy model is the decisive role of biofuels in transportation. The wide use of sugarcane ethanol and biodiesel allows Brazil to significantly reduce CO_2 emissions in the transportation sector. The mandatory mix of biofuels and oil derivatives at service stations and a flex-fuel fleet of light vehicles that comprises more than 90% of the total are significant features of this model.

The rapid growth of wind and solar sources generation in Brazil reinforces the potential for a smooth transition to a low carbon energy model without jeopardizing the perspectives of national economic development, which demands increasing volumes of energy. The new contributions from the so-called new renewable sources provide the additional energy to supply demographic growth, industrial and urban development, and access to higher standards of living for most Brazilians. Otherwise, it would be necessary to increase the consumption of fossil fuels in the electric sector or to build new dams in the rivers of the Amazon (the only region still available for big hydro-energy projects in the country), with unacceptable social and environmental impacts.

In short, the Brazilian energy transition does not need to follow in other countries' footsteps nor adapt itself, mechanically, to policies and guidelines set by international forums or by organizations that look at the world from the highly industrialized countries' point of view. Brazil can define its energy transition agenda for itself. Energy transition is a dynamic process, in which goals and strategies are built and changed over time.

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10 Transition Policies as a Local Problem. The Cases of Neuquén and Río Negro (Argentine Patagonia)

Diego Pérez Roig, Mariana Fernández Massi, and Diego di Risio

10.1 Introduction

The success of the actions and policies implemented to tackle climate change depends on a complex articulation of interests functioning on different scales and in different dimensions. Over the last decades, and at different points of coordinated work, national states have reached a relative consensus on the need for an energy transition aimed at reducing greenhouse gas emissions. However, there are major divergences as to the distribution of responsibilities, in addition to the forms, deadlines, and most desirable pace to achieve it. This is because the search for long-term agreements must not be limited to mitigating the global risks and impacts of climate change, but must also aim at building strategies for "sustainable development" in economic and social terms. This in turn requires the integration of agendas that are deeply rooted in the subnational and local levels. This chapter aims to contribute to the study of this problem, taking as empirical references the cases of the provinces of Neuquén and Río Negro in northern Argentine Patagonia.

For about a decade, the exploitation of "non-conventional hydrocarbons" (NCH) has been consolidated as a strategic objective of the energy and economic policy pursued by the Argentine state (Barrera, 2021; Cantamutto, 2020; Pérez Roig, 2020a, 2021b). Various estimates suggest the existence of a plentiful amount of these resources, especially in the Vaca Muerta geological formation, which is considered a "world class" asset (see EIA, 2013). At the national level, policies driving its wide-scale development pursue two objectives (Pérez Roig, 2020a, 2021b): (a) to guarantee energy supply at the "appropriate" qualities, quantities, and prices to ensure capital accumulation; and (b) to foster productive chains and exportable balances to counteract the cyclical tendencies toward crisis in the external sector that result from the "structural heterogeneity" or the "dependent" nature of Argentine capitalism.

Neuquén and Río Negro are central actors in this strategy, driving it at the subnational level, as NCH production boosts economic reactivation at the provincial level. The province of Neuquén is currently leading large-scale developments for NCH exploitation, both in Argentina and, more generally, outside North America. The nonconventional extraction industry has infused vitality

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D. Pérez Roig (✉)
IPEHCS-CONICET, Neuquén, Argentina

M. F. Massi
IDIHCS-CONICET, Ensenada, Argentina

D. di Risio
Global Gas & Oil Network, Buenos Aires, Argentina
e-mail: Diego@ggon.org

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into the provincial economy after a prolonged period of stagnation caused by the maturation of its historically most productive oil fields. In neighboring Río Negro, there is less extraction activity of the nonconventional kind and what there is occurs within a more diversified production matrix. However, this extractive industry is also presented as an alternative that can generate a surplus, given the drawn-out crisis in the fruit and vegetable sector, which is the province's most important economic activity.

Against this background, the question is how the contradictions and limitations of these development strategies are interwoven with the problems posed by the energy transition. What are the local impacts and consequences of a development model based on the exploitation of these energy sources? The answers to these research questions are based on a case study approach that implies the triangulation of different methods and techniques of data collection and analysis. The main sources used are official. The public policy analysis refers to information provided by state agencies and companies at different levels, such as the National Energy Secretariat; the Undersecretariat of Energy, Mining and Hydrocarbons of the province of Neuquén; Gas y Petróleo de Neuquén S.A.; and the Secretary of State for Energy of the province of Río Negro. The elaboration of this body of legal sources is complemented by the quantitative analysis of raw data provided by the National Institute of Statistics and Censuses (INDEC) and the provincial offices of statistics and censuses of the provinces of Neuquén and Río Negro. We also referred to other research for background purposes and consulted newspaper archives as documentary records.

10.2 Nonconventional Hydrocarbons as Strategic Objectives for Energy and Economic Policy at a National Level

After a decade of remarkable expansion, in 2012, the Argentine economy plunged into a drawn-out phase of stagnation, recession, and crisis. There are different explanations for this but most (Piva, 2019; Wainer, 2021) agree in highlighting two main reasons. On the one hand, the deterioration of international conditions that, between 2003 and 2011, encouraged the export of primary, agro-industrial, and manufactured products with low relative value added. On the other hand, at the national level, there were persisting contradictions and limits derived from the "structural heterogeneity" or "dependent" nature of Argentine capitalism, which usually manifest themselves as a chronic emergence of a bottleneck in the external sector during periods of growth.

This process coincided with the development of a strong incentives policy for the exploitation of NCH. Between 2010 and 2013, different surveys and evaluations estimated the existence of a vast reserve of nonconventional resources, lying mostly in the Vaca Muerta geological formation. Projections published by the US Energy Information Administration (EIA) in 2013 ranked Argentina second and fourth in the world in terms of its technically recoverable resources of shale oil and shale gas, respectively. This apparent abundance was incorporated into the government's agenda as a double opportunity (Pérez Roig, 2020a, 2021b). The massive development of projects for the use of NHC would ensure domestic energy supply and avoid fuel imports, which have historically contributed to the country's macroeconomic imbalance. On the other hand, it also meant being able to attract international investments, the opportunity to develop other links in the value chain and the creation of surpluses for export, capable of offsetting the balance of payments.

The second term of President Cristina Fernández (December 2011–December 2015) was followed by the administration of Mauricio Macri (December 2015–December 2019), which reveals profound differences in the approach taken to fulfilling these objectives. In the first case, a framework of stimulus policies was woven into the partial expropriation of Yacimientos Petrolíferos Fiscales (YPF)[1] and involved introducing a subsidy scheme aimed at protecting

[1] In 2012, the Argentine State expropriated 51% of YPF stock, which was in the hands of Repsol, a Spanish multinational, that had acquired control of the company in 1999 (Barrera, 2014; Pérez Roig, 2020a).

both the competitiveness of local production and household consumption (López Crespo et al., 2016). In the second case, there was a drastic offload of the higher structural costs of NCH production over what was paid for demand, and YPF was relegated from its flagship role as a catalyst for investment (Arceo, 2018; Barrera, 2021).

Despite the economic and political limitations inherent to both strategies, during the 2012–2019 period, the results ended up consolidating NCH as "State policy." After the initial phase of the learning curve, from 2016 to 2019, the average horizontal length of the shale wells doubled, going from 1179 m to 2121 m, as did the average number of hydraulic fractures per well, rising from 15.6 to 31.9. This led to significant increases in productivity and the ensuing return on investment. In the case of oil wells, the proportion of commercially viable wells went from 27% in 2015 to 83% in 2019 (Field Development Consultants, 2021). Considered as a percentage of total oil and gas resources extracted, the extraction of "nonconventional" oil and gas[2] grew from 1% to 19% and from 5.5% to 42.7%, respectively. This level of input made it possible to halt and even reverse the decline in production that had been dragging on since the late 1990s and mid-2000s. This has been the basis for the elaboration of medium-term scenarios in which the hydrocarbon sector is gaining more importance as an export commodity (Secretaría de Energía de la Nación, 2018).

Although climate change and the need to develop adaptation and mitigation initiatives are a familiar issue both on the national agenda and those of Neuquén and Río Negro, so far, state policy envisages continuing with the wide-scale development of Vaca Muerta and other similar formations. For instance, the objectives outlined in the Guidelines for a 2030 Energy Transition Plan, produced by the Energy Secretariat in 2021, are limited to a modest expansion of renewable electricity generation and more CNG-powered vehicles, as well as rein in any increases in emissions. Meanwhile, the goal of achieving self-sufficiency and greater economic development based on NCH exploitation continues to be at the forefront, implying significant year-on-year increases in oil and gas production. Supported by major capitals in the sector, the commitment to natural gas is justified by being characterized as a "bridge fuel," less polluting than other hydrocarbons. The argument is that Argentina should not only increase the gasification of its energy matrix, but also contribute to transition processes in other countries.[3]

The attempt to make the climate agenda compatible with this economic-productive development strategy may be defined, according to Bertinat, Chemes and Forero (2020), as a "corporate energy transition." This perspective denies the existence of a fundamental contradiction between unlimited capitalist accumulation and the relative scarcity of material and energetic resources. According to the authors, the abstraction of the energy question in terms of its complex vessels of communication with other spheres of social reproduction enables two complementary operations. First of all, it limits the causes of the climate crisis to the quantitative analysis of greenhouse gas emissions, the reduction or limitation of which thus becomes the main objective of public policies and private strategies. This means—which is no coincidence—that all the issues that arise for NCH due to their larger emission volume and decreasing energy performance are overlooked. Secondly, it transforms the energy transition process itself into an area where valorization of capital becomes the prime concern, both through productive investments to stimulate efficiency and the production of "clean" energy, and through the proliferation of various compensation mechanisms linked to financial instruments.

A "transition" of this nature is thus another way of perpetuating power relations that can be observed in their crudest form in the territories of

[2] This considers the sum of *shale oil* and *tight oil,* and *shale gas* and *tight gas.*

[3] In November 2021, the president of Shell Argentina declared that *"Investments in oil and gas are extremely important as we need them to finance investments in renewable energies [...] Argentina has an important role to play in the global energy transition by exporting gas*" (Bellato, 2021).

extraction. In general terms, this is because it protects the concentration of economic, technological, and symbolic resources, limiting the possibilities of democratizing the processes of public debate, decision-making, and policy implementation. As we will show below, this not only supposes the offloading of "costs," which leads to an exacerbation of inequalities of different kinds, but also a progressive dissolution of the conditions enabling the possibility of another type or other types of productive and energy transition(s). In Neuquén, the "success" of NCH exploitation goes hand in hand with the proliferation of its socio-environmental impacts and the repression of all related demands, the super-exploitation of workers, and the growth of the model based on oil enclaves. In Río Negro, for its part, the incipient development of NCH has had a direct and indirect impact on land use, leading to an increase in the reduction of land earmarked for food production.

10.3 Neuquén: Light and Dark in the NCH Boom

10.3.1 Decline of the Main Traditional Deposits and Tendency to Fall into a Fiscal Crisis

About 64% of Neuquén's territory consists of the Neuquén Basin, a vast oil region of 124,000 km^2 shared with the provinces of Río Negro, La Pampa, and Mendoza (see Fig. 10.1). Although the first oil was discovered in 1918, Neuquén did not acquire a stronger "energetic" profile until the 1960s and 1970s (Arias Bucciarelli, 2008; Díaz, 2008; Giuliani, 2008). A series of discoveries in the eastern part of the basin —which also led to finds on the Río Negro side—gradually built up its niche profile, complemented by the construction of the El Chocón-Cerros Colorados hydroelectric complex. However, the key causal factor was the discovery of the Loma La Lata (LLL) deposit in 1977, the most significant in YPF's history and one of the most important for the oil industry in South America as a whole (Hechem, 2010). Thanks to the sheer size of its reserves, state policy was given new impetus in the 1980s to "gasify" the national energy matrix, through the construction of a network of gas trunk pipelines connecting Neuquén to the main centers of consumption.

However, toward the end of the 1980s, the province's economy still relied on a relatively diversified production sector. The share of the oil sector in GDP fluctuated between 24% and 32% during that decade.[4] Fruit crops, the manufacturing industry, and construction still wielded significant influence, due to public investment in energy and infrastructure works, as well as a range of different national and provincial industrial promotion policies (Giuliani, 2008; Preiss & Zambón, 2004). In this respect, the 1990s was a turning point with long-term consequences. As part of the general restructuring of Argentine capitalism (Piva, 2012), neoliberal policies opened up the hydrocarbon sector to private investment and valorization (Barrera et al., 2012; Kozulj & Bravo, 1993; Pérez Roig, 2020b). Neuquén was an important point of attraction due to the magnitude of its proven reserves, both for the companies that had already been operating in the sector, since oil activity was opened up by the dictatorship, and for those that joined during the decade. These transformations led to structural changes in economic, social, and political relations.

Spurred on by competition, the oil companies deployed immediate recovery strategies for their investments (Barrera et al., 2012; Pérez Roig, 2020b). The drastic increase in extraction amounts (see Fig. 10.2) boosted the growth of provincial GDP (see Fig. 10.3), but tipped the balance toward an emphasis on the primary products that make it up.[5]

In addition, by failing to allocate a proportional investments amount to exploration, that logic accelerated the maturation of oil fields,

[4] Measured in constant pesos of 1986.

[5] Measured in constant pesos of 1986, the oil sector's share of GDP rose from 32% to 45.5% between 1989 and 1995. Taking 1993 as the baseline, during the convertibility regime, this gravitation reached a peak of 68% in 2000.

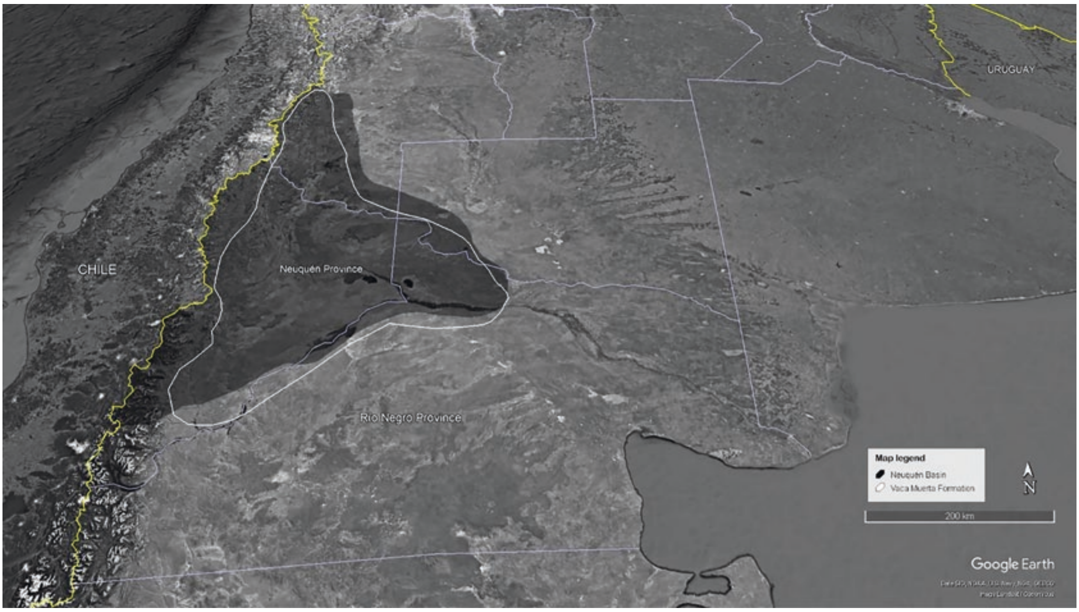

Fig. 10.1 Neuquén basin, Vaca Muerta formation, and provinces of Neuquén and Río Negro. (Source: Own elaboration based on data from the National Energy Secretariat)

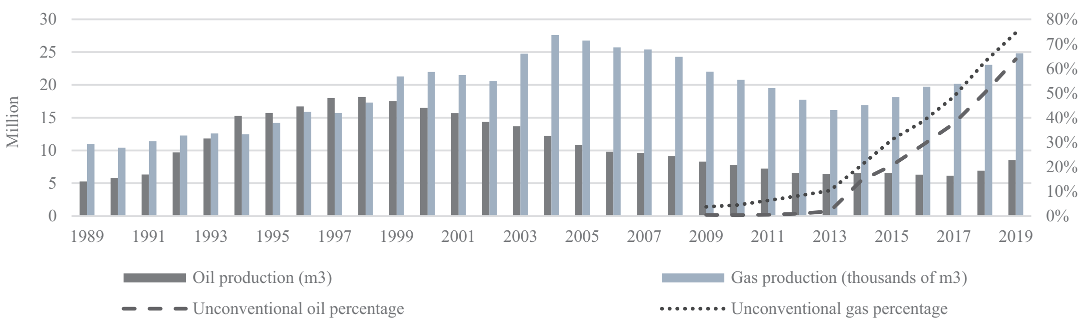

Fig. 10.2 Oil and gas production in Neuquén (1989–2019). (Source: Own elaboration based on data from the Provincial Office of Statistics and Censuses of Neuquén and the National Energy Secretariat)

leading to a progressive fall in proven reserves. The process of industrial disintegration, triggered in particular by the "fragmentation" and subsequent privatization of YPF (see Barrera, 2014) and the government's policies of structural adjustment, led to impoverished living conditions for the population and heightened social conflict during the second half of the decade (Bonifacio, 2011; Klachko, 2002; Palermo, 2012; Petruccelli, 2005).

The fiscal crisis and the high levels of provincial debt,[6] as well as the decline in convertibility (see Piva, 2012), prompted the provincial government of Jorge Sobisch (1999–2007) to introduce a set of policies aimed at reducing public spending, reforming the state and attracting private investment. The latter included highlights such as the celebration of a "strategic alliance" with

[6]Sobisch assumed his second term as governor with an economic and financial deficit of 1.7% and 5.1% of GDP, respectively. Between 1995 and 1999, the stock of public debt rose from USD 116 to USD 496 million.

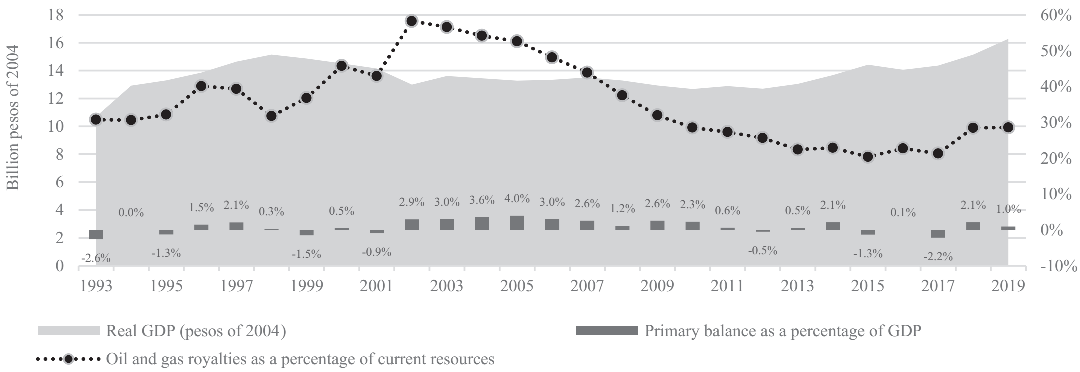

Fig. 10.3 Evolution of real GDP, the collection of hydrocarbon royalties and the primary balance of the Province of Neuquén (1993–2019). (Source: Own elaboration based on data from the Provincial Office of Statistics and Censuses of Neuquén)

Repsol-YPF, based on the anticipated extension of the LLL concession, and the launch of new tenders for marginal areas for hydrocarbons exploration and exploitation.

As from 2002, the policy of expanding the hydrocarbon frontier and deepening the "enclave" gained momentum thanks to a series of internal and external factors. As mentioned earlier, neoliberal reforms coupled with the competitive strategies of the private sector were responsible for the disintegration of the oil complex. The importance given to the primary sector undermined the relevance of the complex as a direct employer. In this sense, the biggest impact of the hydrocarbon industry was its influence on provincial finances and thus on the state's capacity to create jobs and make public investment (Kozulj & Lugones, 2007). During the convertibility regime (1991–2001), the collection of oil and gas royalties became the main source of income for the state at provincial level.

Figure 10.3 shows that between 1993 and 2001, its share of total resources grew from 31.5% to 42.9%. In 2002, the currency devaluation doubled this income in pesos—as it is valued in dollars—thus representing 58.2% of total current resources. This decision coincided with the beginning of a boom cycle in the international prices of oil and its derivatives. However, during the following decade, two internal factors offset the potential fiscal benefits of this trend. To begin with, a raft of policies was implemented to separate the national space from the dynamics of the world market, maintaining markedly lower domestic prices (Barrera, 2013; Pérez Roig, 2021a). This was exacerbated by the sustained decline in the volumes extracted (see Fig. 10.2), largely due to a reluctance to invest in more complex extraction techniques to compensate for the maturation of the main deposits.

The decline in output, and the corresponding decline in royalty revenue and stagnant GDP, coincided with a period of growth in current expenditure which, as can be seen in Fig. 10.3, tended to erode the province's economic outcomes from 2006 onwards. In the immediate term, this public spending rise may basically be explained by wage increases and the growth in state employee numbers at the provincial level (Giuliani, 2008, 2013), with which the state compensates for the existence of the "relative overpopulation" that the most dynamic segment of the economy cannot employ.[7] But the rise in public spending was also linked to the existence of a contentious society[8] demanding other types of outlays to be sustained and capable of blocking attempts to readjust in times of fiscal crisis. This

[7] Between 2002 and 2012, the oil sector represented only 14% of registered salaried employment in the private sector.

[8] The dynamics and logic of the social conflict in Neuquén, greater than the national average, with a tendency to overwhelm institutional channels, were defined as a "counterculture of protest" (see Petruccelli, 2005).

contradiction undermined the composition of public debt[9] and spurred the state's efforts to strengthen the oil enclave.

10.3.2 Promoting NCH and Its Contradictions

The main objective of the Jorge Sapag administration (2007–2015) was to drive NCH exploitation. In his inauguration speech, the Governor declared the need to promote "*an increase in reserves with greater investments in exploring deeper and more complex geological horizons*" (Neuquén Legislature, 2007: 3261). Shortly afterward, he published the Guidelines for the "Master Plan for the Development of Neuquén" (March 2008), which included the goal of "promoting gas production by exploring areas with tight sands and fields with low porosity." Years later, the "2012–2016 Five Year Plan: Neuquén More Energy" proposed to "replicate, by adapting and reducing the terms, the successful experience of Canada and the United States in developing non-conventional deposits." Recently, in line with the "corporate" conception characterised above, different authorities have highlighted the potential contributions of Vaca Muerta in the process of national, regional, and global energy transition.[10]

The NCH development strategy has been reflected in a wide range of policies implemented by the provincial government ever since then. Initially, there was an extensive process to renegotiate and extend the exploitation concessions due to expire in 2017. In return for extending the predictable investment horizon in thirty-two areas, between 2009 and 2010, around USD 400 million were collected in non-tax revenue.[11] The law detailing the framework for these extensions required these funds to be used for investments in "self-sustaining development and productive diversification." Towards the end of 2009, however, the province's delicate economic situation made it necessary to use these funds to pay debts to suppliers, service dollar-denominated bond maturities and pay the annual bonuses for public employees (*Río Negro*, 26/6/2010).

At the same time, the province created Gas y Petróleo del Neuquén (GyP), a mixed company with majority state ownership. In 2009, GyP was awarded the ownership of dozens of blocks not yet under concession, giving way to the start of the "New Horizons Plan." Despite its low capitalization, this transfer of areas enabled GyP, within the framework of the incentives implemented by the national state, to reach major agreements to extract NHC with international capital.

One offshoot of this process is the emergence of an antifracking movement that questions the legitimacy of the policies implemented at different levels (Pérez Roig & Riffo, 2022). In this sense, it highlights the other side of productive development and the corporate energy transition based on NHC. The origins of this movement are deeply rooted in the traumatic effects of the government's neoliberal policies and the Mapuche communities' struggle against the impact of the hydrocarbon industry on their lands, as well as more recent episodes of protests organized by citizens to reject mega-mining projects in the interior of the province (Riffo, 2018). After 2009, the growing importance of NCH as it moved up the state agenda at both national and provincial levels, compounded by the more widespread understanding and dis-

[9]While debt in pesos to the national government fell from 80% to 22% in its relation to current income between 2002 and 2011, debt to bondholders rose from 2% to 20% over the same period. Most of this growth can be explained by the issuance of bonds worth USD 250 million between 2006 and 2007.

[10]In April 2022, during the "Energy transition" event organized by the IDEA business forum, the Governor of Neuquén, Omar Gutiérrez, argued that *"there is a false contradiction between the large amount of hydrocarbon resources that Neuquén has and the energy transition. These resources accelerate the transition, not delay it"* (Neuquén Informa, 2022). In the same vein, YPF CEO Sergio Affronti stressed that the vast national endowment of resources puts Argentina *"in a different situation to other countries. We have to help the decarbonization of neighboring countries, through a very leading role, and more in the long term, producing liquefied natural gas"* (Diamante, 2022).

[11]This extraordinary income explains the economic results obtained in 2009 and 2010 (see Figure 10.3).

semination of the socio-environmental impacts of fracking in North America, brought about a gradual articulation at organizational level to include multisectoral demands. This convergence reached its peak when YPF signed a contract with Chevron Corporation in 2013 to launch the first NCH pilot project for large-scale development in the Loma Campana area.

As the original owner of the resources and granting authority, Neuquén had to reach an agreement with YPF to establish the new area for non-conventional exploitation, in addition to defining its fiscal treatment, environmental controls and dispute resolution procedures. Once endorsed by the provincial Executive Power through a decree, the Agreement Act entered the Legislature for final approval. Both the in-committee discussion and the ordinary session held in the parliamentary building took place against a backdrop of major protests by citizens, to the point that the premises had to be "shielded" by the local forces of law and order. During the last day of debate, there was a massive public demonstration and thousands of people took the streets, answering the call issued by trade unions, student bodies, organizations representing the Mapuche people, human rights organizations and citizen assemblies. The demonstrators were vehement in their rejection of the technological fracking package, the violation of the territorial rights of the indigenous communities, the presence of international capital which they associated with previous experiences of resource plundering and environmental contamination, as well as the existence of secret clauses in the contract signed between the two oil companies. Shortly after it began, the demonstration was brutally repressed by the provincial police. Two people were detained and 20 more injured, including union members, journalists, and students who were hit by rubber bullets, in addition to a university professor who received a lead bullet to the stomach (*8300*, 28/8/2013). Meanwhile, in the parliamentary building, the debate went on for 6 h. The ruling parties of the Province and the Nation opposed the requests of the other blocs to suspend the session and managed to get the agreement passed.

This event may be taken as a turning point for a number of different reasons. This process of articulation and convergence of demands opened up an unprecedented space for the people to question Neuquén's "oil economy" (Pérez Roig & Riffo, 2022). At the same time, this possibility set off a series of different types of political responses aimed at breaking the unity achieved hitherto. On the one hand, there was the relentless persecution and stigmatization of the anti-fracking movement, which the provincial government labeled "environmental terrorism."[12] On the other hand, as it owed the oil companies, there was a muscular promotion campaign deployed through different cultural assets, and an emphasis on executing public works and providing services, added to enticement of employment promised in the localities closest to the exploitations (Riffo, 2018).

Likewise, the YPF-Chevron project laid the regulatory foundations for the exploitation of NCH, enabling production to truly take off both at the provincial and national levels (see Fig. 10.2). The large-scale extraction in Loma Campana made it possible to complete the first phase in the learning curve about the natural properties of Vaca Muerta, the basis for the subsequent increases in productivity and extraction in the 2016–2019 period. Since then, encouraged by different promotion policies implemented by the national state (Pérez Roig, 2021b), nonconventional exploitation concessions have multiplied (see Table 10.1).

But this relaunch of the oil enclave underscores the contradictions and dilemmas involved in an eventual energetic and economic-productive transition. Throughout the period (2012–2019), the growth of NCH investments and extraction has had positive effects on the evolution of the gross regional domestic product (GRDP) and employment in the primary products segment of the hydrocarbon sector (see Fig. 10.3 and

[12] During the celebration of Oil Day 2013, the deputy governor of the Province, Ana Pechen, urged the main hydrocarbon companies to "educate the population" against "environmental terrorism" (*Río Negro,* 14/12/2013).

Table 10.1 Unconventional hydrocarbon exploitation concessions in Neuquén (2012–2019)

	Number of areas	Holder	Operator	Partners
YPF	15	15	9	Chevron; Dow; Equinor; Pampa Energía; Pan American Energy; Petrobras; Petronas; Pluspetrol; Shell; Total Austral; Wintershall
GyP	8	8	–	ExxonMobil; Shell; Pan American Energy; Total Austral; Vista Oil & Gas
Others	12	Wintershall; ConocoPhillips; Tecpetrol; ExxonMobil; Capex; Pluspetrol; Pampa Energía; Vista Oil & Gas		
Percentage of area of Vaca Muerta under concession				28.6
Percentage of area of Vaca Muerta securitized by YPF				13.8
Percentage of area of Vaca Muerta securitized by GyP				5.1

Source: Own elaboration based on provincial decrees and resolutions

below).[13] However, the "extreme" nature of these projects also exacerbates inequalities and impacts of a different nature. In the first place, despite the lack of publicly accessible information and ongoing attempts to keep this out of the public eye, the record of "environmental incidents" has been rising (Martine, 2022), and these have also tended to be more serious. For example, it was estimated that the explosion at the YPF.Nq.LCav-26 well in the Bandurria Sur concession, which happened in October 2018, resulted in a degree of contamination from the spill of drilling liquids and hydrocarbons greater than the sum of all the drilling incidents which occurred in 2015 and 2016 (*Río Negro,* 10/11/2018; Cabrera, 2019).

Second, the exponential growth of oil waste—basically drilling muds and fracking fluids—has overwhelmed the capacity of processing and treatment plants. Both the urban location of these "refuse dumps" and the waste collection, treatment, and final disposal procedures used have been the subject of multiple complaints. A recent report (Bianco et al., 2021), drawn up on the basis of the records of the official inspections carried out at the largest of these plants between 2013 and 2021, reveals a long history of polluting actions as well as reiterated noncompliance with current regulations, which had the complicity of high-ranking officials and the government of the Province, as well as the municipality of the city of Neuquén.

Third, although the data available is not yet conclusive, activity monitoring has provided evidence of a link between increased seismic activity and the implementation of widespread hydraulic fracturing (Correa-Otto & Nacif, 2017). In Sauzal Bonito, a rural community lying in the middle of several large areas of nonconventional exploitation, reports of seismic movements leading to material damages have multiplied (Álvarez Mullaly, 2021).

Fourth, the expansion of the oil frontier, in addition to the greater extension and intensity of the impact made by these activities, has redoubled the historical pressure brought to bear on native communities, leading to the criminalization of their demands. The most significant example of this latest advance is the Mapuche community of Campo Maripe, which since the 1920s has exercised its traditional and community possession of lands included in the YPF-Chevron agreement. Since 2014, six of its members have been prosecuted for the crime of "usurpation," after putting up resistance to the unlawful takeover of their territory (Gutierrez & Millaman, 2016; Hadad et al., 2021).

Finally, it should be noted that the development of NCH exploitation has also had negative consequences for workers in the sector. Between 2012 and 2019, private employment in the crude oil and natural gas extraction branch went from

[13] As shown in Figure 10.3, the development of NCH fields also affected the make-up of the royalties collected, although this impact must be qualified in the light of the currency devaluations in 2018 and 2019.

13.500 to 21.900 registered wage earners, increasing their share in the total number of employed from 14.3% to 17.3%.[14] However, as investment plans bowed before the twin compulsions of fierce sectoral competition and world market volatility, this growth has not been exempt from violent fluctuations,[15] leading to an overall deterioration in working conditions. In 2017, modifications were made to labor agreements (Landriscini, 2019) with the purpose of improving the international competitiveness of "nonconventional" projects. Among other aspects, these addenda introduced a number of "flexible" workforce hiring and employment clauses, as well as a reduction in safety standards at the sites. The most significant consequence of these changes was the death of eight workers between 2018 and the first half of 2019 (García, 2019).

10.4 Río Negro: The Threat of De-diversification

10.4.1 Competition for Land Use: Fracking Among Apples and Pears

In 2019, before extraction levels plummeted in the wake of the COVID19 pandemic, the province of Río Negro accounted for 6.1% of the country's nonconventional gas extraction and 4.8% of nonconventional oil. The most relevant hydrocarbon-producing area in the province is the Fernández Oro Station (EFO, in Spanish), located in Allen, a town in the Alto Valle region of Río Negro province. This region of about 652 km^2 and more than 600,000 inhabitants is an area of intensive fruit growing using irrigation, whose main production is apples and pears destined for export and stone fruit, grapes, and cherries.

The development of fruit crop production activities in the region was possible thanks to an ambitious plan to dig 1977 km of canals and dikes, complemented by a 500-km drainage network of collector and subcollector canals, making up a gravity fed irrigation system that, unlike a pumped water system, does not use electricity. The works to build the infrastructure for this system began in 1910 and were completed in 1928, when the area's fruit-growing industry was born, transforming the region into an area of intensive irrigated fruit crop production.

Export-oriented fruit production gradually came to be the principal driver of economic activity in the region, largely sustained by family-type farms. As part of the framework of policies designed to attract a European migrant population to settle in the region, credits were granted to help prospective farmers purchase land, and a particular form of social production was promoted: capitalized family producers. These are production units based on family work, with a certain amount of capital, integrated into the framework of capitalist exchange but able to continue producing in contexts of crisis at the cost of the overexploitation of their own labor force (Alvaro, 2013).

This fruit-growing model fell into crisis at the end of the 1970s due to the conjunction of specific economic situations and overall structural transformations, undermining the sustained growth exhibited by this kind of activity until then. On the one hand, there was a pronounced drop in external demand and thus in international prices, exacerbated when Brazil, one of the key export markets for the region's production, started developing a degree of self-sufficiency. On the other hand, producers in debt were badly hit by the hike in interest rates (Bandieri & Blanco, 1991). This saw the start of a process of decapitalisation of the family producer model, gradually displaced by the advance of large export companies that deployed vertical integration strategies to develop their own primary production. Thus, in the 1980s, a process of differential modernization began at the level of

[14] During the same period, total registered salaried employment in the province grew by 33%. This increase is a marked contrast with the national dynamics—with a growth of only 1.5%—and shows the undeniable aggregate effects of investment in NCH on the labor market as a whole.

[15] Between the third quarter of 2015 and the second quarter of 2017, employment in the sector fell by 15%.

family farms, leading to changes in management systems and in the variety of crops grown. Bigger companies and independent capitalized producers took the plunge and were able to adapt in technological terms, while those family producers who lacked the economic and financial conditions to do so had to deepen their dependent relationship on the trading companies (Tsakoumagkos & Bendini, 2002).

This transformation of the sector led to the creation of an exclusive fruit growing model, which in the last three decades has come to the fore during periodic crises. Although its sectoral claims usually focus on the fall in prices and in demand or the much-vaunted exchange-lag, the recurrence of these crisis episodes and the continuous expulsion of family producers from the sector is the fallout of an unequal power structure (García & González Alvarisqueta, 2015). Thus, some talk about a crisis in the fruit-growing sector in the region. But, in fact, this refers to the crisis affecting the particular fruit growing model with a tendency to expel those small producers who were the driving force for the sector in its origins.

Within this framework, in recent decades, the area given over to fruit production has decreased, progressively and steadily. Profitability problems for small producers and the lack of generational change with younger people taking over from their older relatives are leading to a "fruit culture without fruit growers" (Nievas, 2015). The way in which producers are leaving this activity is quite varied: they either change crops, or sell, rent, or subdivide their land. Latterly, this process has accelerated, given the competition regarding land use, where there are two options: on the one hand, the occupation of agricultural land for urbanization, which has been happening since the 1990s, and on the other hand—which is a more recent development—the expansion of the hydrocarbon frontier based on the development of non-conventional techniques[16] (Catoira, 2017). Between 2011 and 2020, the area dedicated to seed fruit crops in Río Negro fell by 22.4%, and in Allen, the epicenter of the EFO, this decrease reached 24.9% (SENASA, 2021) (see Fig. 10.4).

The real estate business, in particular that linked to the boom in private neighborhoods that began in the Noughties, is focused on seeking out land with the best agricultural quality (meaning lower levels of salinity and a higher organic content) as well as greener areas closer to the river. For its part, hydrocarbons activity, by clearing land to make new roads and building drilling platforms, is obstructing the soil's natural renewal process, generated by continuous irrigation and exposure to the sun, which is so characteristic of the region. This competition for land use not only affects areas no longer used for production but also jeopardizes the very system on which the fruit-growing industry is based.

The coexistence and the proximity of urban areas and hydrocarbon exploration fields to fruit-bearing orchards pose significant health risks to the latter. Aspects such as light pollution, following the installation of artificial street lighting, prevents the natural pollination of fruit trees by insects and fosters conditions favorable to the proliferation of the codling moth (*Cydia pomonella*), a major pest, particularly for apple and pear trees. Constant vehicle traffic along dirt roads builds up dust on plant leaves, conducive to the development of the red spider mite (*Panonychus ulmi*), another fruit tree pest. This is compounded by the risks of groundwater and surface water contamination as well as the effects of the progressive felling of poplar groves, which serve as wind breaks. At another level, the abandonment of several hectares of former fruit orchards threatens the integrity of the overall irrigation system. Those hectares that are repurposed and transformed into residential subdivisions or hydrocarbon exploration areas stop using the irrigation system. This not only alters the balance and inter-connectedness of the network but also defunds the irrigation consortia which oversee daily management and maintenance (Catoira, 2017; Rodil, 2015).

Thus, although some advocate a complementary coexistence between fruit growing and

[16] The amounts of the rental contracts paid by oil and gas companies are attractive for land-owning producers, given the critical situation affecting them. See: https://www.clarin.com/politica/alto-valle-neuquen-rio-negro_0_rJqfBv4jDmg.html

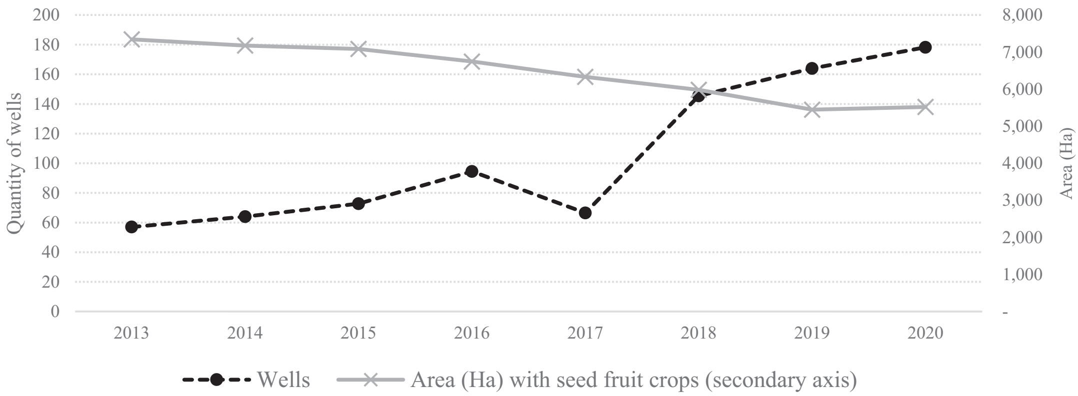

Fig. 10.4 Evolution of the quantity of wells in the EFO and the area dedicated to seed fruit crops in Allen and Fernández Oro (2013–2020). (Source: Own elaboration based on data from SENASA (2021) and the National Energy Secretariat)

hydrocarbons production,[17] in the immediate term, the substantial health risks posed by the latter make it hard to manage agricultural production based on good practices. This, in turn, jeopardizes the quality certifications required by these farms to export their produce. In the medium term, the situation fosters the irreversible process of productive soil loss in an area blessed with optimal water resources and agroclimatic factors for food production (Mendía et al., 2017).

10.4.2 The Promotion of Hydrocarbon Activity and the Resistance to Its Advance

The process to push forward the frontier of hydrocarbon exploration has been driven by the state, within the framework of national policies promoting the extraction of NCH, as well as at the provincial level. The provincial government launched its own exploration plan in 2006, but it was only in 2010 with the discovery of the vast nonconventional gas reserves in the Vaca Muerta field that this process gained new momentum. In 2009, when the EFO was owned by the U.S. company Apache, it joined the Gas Plus III Program, one of the gas extraction incentive policies deployed by the national government. In 2014, the EFO passed into the hands of Yacimientos del Sur (YSur), a subsidiary of YPF.

Although this is the principal area being exploited in Río Negro, the provincial government has pushed for exploration in other areas awarded to different companies. However, due to the relevance of the areas where it operates and the investments made, YPF continues to play a leading role. In 2016, YPF was awarded the largest area in the province, with 6900 km^2 located between the banks of the Negro and Colorado rivers (Chelforó). In 2018, an area bordering the EFO (Cerro Manrique) was tendered, also ending up in the hands of YPF. The investment projected by the company for activity in the EFO and Cerro Manrique areas between 2018 and 2022 comes to USD 582 million (Bellato, 2018). There are a further thirty-eight areas awarded in the province, all at different stages of progress in exploration and extraction. This number can basically be explained by a series of successive bidding rounds for nonconventional areas held over the last 5 years. Unlike what happened in Neuquén, in Río Negro, the oil companies tend to be smaller. The Empresa de Desarrollo Hidrocarburífero Provincial Sociedad Anónima (EDHIPSA) was created in 1995, dissolved in 2001, and reconstituted in 2003, and now has a stake in twelve of these areas. In all cases, it is the

[17] See, for example, the positions taken by the candidates running for governor in the province during the last electoral campaign: Diario Río Negro, 27/03/2019.

provincial company, which operates the areas, usually with a second company.

In fiscal terms, the development of nonconventional exploitation and, in particular, the activity around the EFO have produced changes in the make-up of the royalties collected by the province. The effect of the depletion of conventional reserves in the north of the province, mainly oil, was offset after 2015 by the increase in royalties collected for nonconventional gas activities. The increment in royalties from gas, largely due to activity in a single area, explains the government's optimism regarding the impact of tax revenues ensuing from the large-scale development of nonconventional resources. However, in the last decade, income from hydrocarbon royalties in the province has reduced its share in current income (see Fig. 10.5).

The development of this activity also requires investment in specific infrastructure. The core of the EFO is a gas and oil separation plant, which shares its name with the areas. It bottles liquefied gas to be transported in trucks, while gas is injected into a gas pipeline (Neuba) and the oil into the pipelines of the Oldelval company, to be later transported to refineries outside the province. However, with the increase in extraction volumes, the current gas transport and distribution infrastructure are insufficient, prompting work on a project to expand the Andean-Patagonian pipeline system, connecting the provinces of Neuquén, Río Negro, and Chubut. In 2019, the first tranche of the work was inaugurated, which includes a 20-km gas pipeline in the province of Río Negro running parallel to the existing one in the Pilcaniyeu-Bariloche section. However, the main works required to transport greater gas volumes to the main processing and consumption centers lying outside the region have been announced and then postponed numerous times in recent years.

It is worth mentioning that, as in the case of Neuquén, the boost given to hydrocarbons activity has not been without a commensurate degree of conflict. On the contrary, the progress made in developing extraction sites in areas so close to urbanizations has had the effect of making its impact on nature and public health extremely visible, prompting significant resistance from local communities. These impacts range from high noise levels during drilling, explosions, oil spills on the ground and in local water supplies, and vibrations leading to cracks in houses near the wells and along the roads travelled by heavy machinery. There is also growing concern about the rise in health issues associated with respiratory conditions, as well as the proliferation of cases of cancer and miscarriages (Rodil, 2015). However,

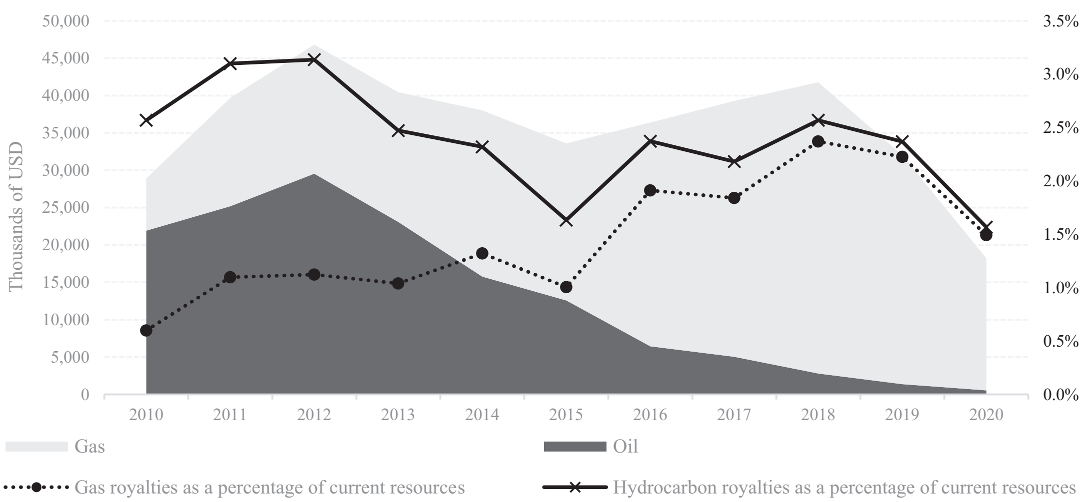

Fig. 10.5 Evolution of hydrocarbon royalties in Río Negro (2010–2020). (Source: Own elaboration based on data from the Ministry of Economy)

the state's monitoring of the situation is extremely deficient, and there are insufficient health records of the kind needed to determine the causes of these conditions, and thus, the link between these health problems and hydrocarbon activity remains a source of dispute between the different actors.

Significant progress has in fact been made at local level to limit the advance of the hydrocarbon frontier. In 2012, the city of Cinco Saltos adopted an ordinance prohibiting fracking in its territory, and in 2013, a similar ordinance was passed outlawing fracking in Allen. Even though latter was supported by different political groupings, in December that year, the provincial Court of Justice declared the ordinance to be unconstitutional. A few years later, in 2017, a similar ordinance was adopted in Fernández Oro, and duly pronounced unconstitutional in 2018, showing the differences lying at the heart of the matter between municipal and provincial governments. In none of these cases, the fracking ban was postulated as a solution to long-standing structural deficits, which cover a broad set of dimensions. Instead, it was conceived as a necessary step to halt and prevent the irreversibility of these problems.

Beyond the advances being made by the hydrocarbons companies and the support given by the provincial government to their activities, there is a resistance movement, which is organized to a greater or lesser extent, since the negative impacts of this activity are quite evident. Even as it poses a threat to the diversified make-up of the provincial productive structure, hydrocarbons activity has little to offer by way of integration into local commerce, industry, and services, nor is it a catalyst for local employment. The share of agricultural employment in the registered private sector in the province between 2002 and 2019 fell from 25.6% of total employment to 19.2%, a drop of 6.4 pp., while employment in the oil and gas upstream sector increased by 0.7 pp., going from 1.6% to 2.3%. In this sense, the neighboring province of Neuquén offers a fairly accurate mirror of activity: hydrocarbon dependency introduces great volatility into both local activity and public accounts, creating huge wage gaps that distort other prices, such as the real estate market, and make it difficult to build alternative paths of growth for the local economy.

10.5 Conclusions

We began this chapter by asking ourselves about the way in which the problem of the energy transition is entwined with the need to build "sustainable development" strategies from a multiscale perspective. Such a debate is crucial at this moment in time, especially in the capitalist periphery, where both terms tend to present themselves in contradictory fashion. In Argentina, the current thinking is that the widespread exploitation of NCH would bring about a "virtuous" combination, as the increase in international investment, production, and exports would help to overcome the obstacles to development imposed by external difficulties, while contributing to the energy transition process in Argentina and other countries. However, even leaving aside the doubts cast about the idea of gas as a "bridge fuel," the cases of the provinces of Neuquén and Río Negro show that there is a catch lying within this kind of articulation. Although, according to the evolution shown by certain indicators, it is possible to gain macroeconomic and regional benefits in the short and medium term, this can only be achieved at the cost of deepening or even creating new "sacrificial zones." We consider that this intertwining of objectives and consequences assumes the characteristics of what other authors call a "corporate energy transition": a transition based on the commodification of energy and commanded by actors who concentrate and seek to reproduce a wide repertoire of power resources.

In Neuquén, NCH extraction activities take for granted the superexploitation of the workers in the sector. As a matter of course, they repress the demands arising in response either to the increase in the detrimental socio-environmental impacts perpetrated by the oil industry—or to the occurrence of newer effects due to fracking. Let us remember that, within the framework of the fleeting initiatives plaguing the excessive provincial dependence on hydrocarbons activity prior to the boom in "non-conventional" operations (Giuliani, 2013; Scandizzo, 2016a, b), many of these impacts have already been evaluated and have thrown up results, which are a matter of considerable concern. In 1998, the United Nations Development Program (UNDP) quantified the damages produced around three oil areas in the locality of Rincón de los Sauces at USD 949 million, following a series of spills between February and May 1997. On that occasion, the report warned that such environmental emergencies "limit and undermine the beneficial effects of these economic activities for the province and *jeopardize the conditions for sustainable development, a fact aggravated by the non-renewable nature of hydrocarbons resources*" (UNDP, 1998: pp. 2; our highlight). In 2010, a new UNDP report, prepared for the National Program for Prevention and Reduction of Disaster Risk and Territorial Development, accentuated this warning. After making an observation about the paucity of links between the productive chain and the high dependence of local economic structures on hydrocarbon exports, the work concluded that

> The degradation processes affecting the productive base (especially soil resources) are of central importance, if one takes into account that the desired territorial model proposed by Neuquén implies a change in the productive matrix, moving from a hydrocarbons-based economy to one which is more diversified and vertically integrated, with a predominance of agro-industrial activity. This change also supposes, in the future, taking action to address the pollution problems related to hydrocarbons exploitation (UNDP, 2010: pp. 313).

In Río Negro, the expansion of the hydrocarbon frontier is fuelling a far-ranging crisis in one of the region's traditional production areas, which for decades drove economic activity and job creation. Although this is a preexisting crisis, the continued growth and spread of hydrocarbons exploitation is putting paid to the virtuous reconfiguration of food production. It is also quashing the possibility of developing other productive alternatives in the future able to take advantage of the region's natural agro-climatic advantages. This is not about a lack of controls or problems with implementation, but rather the "undesirable consequences" of this activity on nature and public health, consequences that are inherent to these particular techniques as well as to this form of economic and territorial models in general. Beyond the local impact of the changes in land use in environmental and productive terms, the loss of agricultural land for fruit crops is also negatively affecting carbon capture rates in the Alto Valle region, which until 2010 had been optimal (Mendía et al., 2017), while gas extraction is contributing to increasing CO^2 and methane emissions.

Both cases thus show *a tendency to the dissolution of natural and social conditions that could lay the foundations for other possible ways of achieving the urgent changes needed to transform the energy-production paradigm.* The direction that these paths take cannot be determined in advance, as long as it rests—which is what we wish—on broadening spaces for democratic deliberation and collective creation. However, the opening of such an opportunity does depend on a decisive fact: the "de-fetishisation" of energy as a factor externally linked to the reproduction of our societies. This implies going much further than challenging fracking —a necessary but clearly insufficient step. That starting point, which embraces a critical approach to the logic of energy appropriation and consumption, but expands it to encompass the very social relations that are its foundation, is the only one able to help us exit that trap. Just as there is not merely "technical" solution to the risks and challenges posed by climate change, neither can we expect to overcome the limits of dependent capitalism by seeking to deepen its matrix.

Energy: how do we produce and consume it? But also, for what purpose and for whom?

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Part III

Energy Transitions and Renewables: Production Mix, Technology, and Costs as Limits and Opportunities

11 Renewable Energies in Argentina: The Challenge of Articulating the Energy Transition with the Economic Development Model

Esteban Serrani and Mariano A. Barrera

11.1 Introduction

Although the effects of climate change on the environment and human life is a process that has been ongoing for many decades, it was only in the early years of the twenty-first century that its discussion gained public notoriety, becoming one of the central issues of the global agenda, from a scientific, political, economic, and geostrategic point of view.

From a long-term perspective, it is possible to state that the industrialized western countries are most responsible for this process (Ritchie & Roser, 2020). However, when considering current information from 2019, China, the United States, India, the European Union, and Russia were the largest contributors, although the United States, Canada, Australia, and South Korea have the highest emissions per capita[1] (Ritchie & Roser, 2020). After the unprecedented 5.4% drop in 2020, global carbon dioxide emissions have returned to pre-Covid-19 pandemic levels, and atmospheric GHG concentrations continue to rise (United Nations Environment Programme, 2021). The severity of the current climate crisis and the increasingly pressing future scenarios at the international level (IPCC, 2021) require global climate action to mitigate and adapt to its effects, especially in peripheral countries and vulnerable sectors, which suffer the most from its consequences in employment and working conditions (Hirsch et al., 2017), justice for those who work in the fossil fuel economy and are affected by just transitions policies (Klinsky & Dowlatabadi, 2009; Newell & Mulvaney, 2013) in energy poverty, and democratization in access to energy services (Kumar et al., 2021), among several other related processes.

In the case of Argentina, total net emissions in 2016 were estimated at 364 million tons of CO2e (MtCO2e), which represents less than 1% of the global total (Climate Watch, 2022). After the United Nations Climate Change Conference XXI, held in France in 2015, the Paris Agreement was initialed in April 2016 and the signatory countries came to a consensus on GHG emissions targets for 2030. Argentina submitted its

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E. Serrani (✉)
National Scientific and Technical Research Council (CONICET), National University of San Martín (UNSAM), San Martin, Argentina
e-mail: eserrani@unsam.edu.ar

M. A. Barrera
Economy and Technology Area, FLACSO, Buenos Aires, Argentina
e-mail: mbarrera@flacso.org.ar

[1] Countries with low relative population or net hydrocarbon exporters were left out.

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first Nationally Determined Contribution (NDC), committing not to exceed net emissions of 483 MtCO2e. However, the country made updates and in December 2020 submitted the second NDC, in which they reduced their commitments to 359 MtCO2e (25.7% lower than the initial one). The following year, at the Summit held in Glasgow, Argentina again reduced their committed net emissions to 349 MtCO2e,[2] making it one of the countries with the most ambitious climate goals within the framework of the G20 (United Nations Environment Programme, 2021).

One of the most significant actions needed to adapt to climate change is the acceleration of energy transition processes based on a strong decarbonization process; globally, the energy sector accounts for more than two-thirds of GHGs (Ritchie & Roser, 2020). Following Sovacool (2016), some analyses on energy transitions are focused, on the one hand, on transformations in energy sources and technologies, linked to the evolution of both the energy matrix and more general changes in the dynamics of production and accumulation of the economic system. Other studies focus on systemic transformations linked to resources, services, and agents from the coevolution of socio-technical systems. Beyond this conceptual discussion, energy transitions require a multidimensional process within the energy sector in a specific techno-institutional context, which includes and affects a wide range of technologies and organizational and institutional structures (Kern & Markard, 2016), aimed at responding to the climate crisis. Thus, energy transitions seek to modify economic models by pursuing a less intensive use of fossil resources while achieving a greater availability of low-emission energy from renewable sources.[3] This process is identified as one of the most important elements in the plan to meet climate goals (Newell & Mulvaney, 2013; Petit, 2017).

In this context, is there a single energy transition? Even if the manifest objective is to reduce the share of fossil energy sources in consumption, is it possible to argue that there is a single path to low-emission societies? Peripheral countries face several constraints in their endeavor to move toward a sustainable and substantial transformation of their productive matrices (Andreoni & Chang, 2017; Sabbatella et al., 2020; Serrani, 2020). So, is there a single energy transition model to which all countries must conform, like the stages of economic development for underdeveloped countries proposed by Walter Rostow (1990) more than half a century ago?

In the case of Argentina, many restrictions hinder the energy transition path; some of them common to Latin American peripheral countries, such as technological, geopolitical, and productive ones; and others associated with specific characteristics of the country: the scarcity of international financing, an intensive use of natural gas, and structural constraints linked to the insufficiency of the economy to guarantee long periods of economic expansion as a consequence of the scarcity of foreign currency that affect the payment balance. As will be discussed later, after having had a significant boost between 2016 and 2018, there have been no national and/or provincial plans to expand the installed capacity in renewable energies since 2018, because of the economic crisis unleashed last year that restricted external financing at rates commensurate with the development of the activity.

Consequently, strategies to promote energy transitions should not only consider the limita-

[2] All reports by Argentina are available at https://unfccc.int/BURs

[3] In this chapter, "nonconventional renewable energies" are understood as wind, solar photovoltaic (PV), mini-hydroelectric, and the different bioenergies, such as biomass, biogas, landfill biomass, and tidal, while "conventional renewable energies" are considered to be large hydroelectric plants. Although the latter generate electricity from a renewable resource, they are distinguished from the former by the environmental or territorial impacts they tend to cause, associated with population displacements, creation of reservoirs, etc. Nuclear power plants, on the other hand, share the low emission of greenhouse gases but are not renewable, because they operate based on a finite mineral. For this reason, these two sources of electricity generation are usually differentiated in the analysis, both from those that use fossil fuels because of their low emissions and from nonconventional renewable energies, because of the resource they use or the impacts they generate.

tions and restrictions of peripheral countries but also the singularities of each national case. Among them is the endowment of natural resources and the history of their exploitation, which allow energy demands to be fulfilled and facilitate a sustainable transition. Argentina has one of the most important reserves of shale Oil & Gas resources in the world in the *Vaca Muerta* formation in the province of Neuquén; it also has an insignificant amount of coal and a high penetration of natural gas, both in the primary energy matrix and in electricity generation, which has allowed the country to have a relatively low impact on global pollution, both in terms of the energy mix and the size of its economy.

In this sense, this chapter seeks to answer a central question to understand the vitality and viability of the process opened in Argentina: How should the country move forward with the energy transition in the context of an unstable macroeconomy with recurrent economic crises, a restricted local capital market, and limited access to international credit?

The objective of this chapter is to analyze the recent trajectory of Argentina's energy system to present alternatives on how to ensure the expansion of the energy transition, in order to accomplish the ambitious climate goals committed within the framework of an economic development strategy that will improve the quality of the population' living conditions.

In order to answer this question and to account for the research objective, this chapter is divided into three sections and a conclusion. The first section presents a brief historical overview of the evolution of the energy matrix and the energy transitions developed in Argentina, while presenting the main structural problems faced by the sector in the last two decades. Next, the public policies deployed and the main results for the development of renewable energies in Argentina are presented, showing the power installation and investment needs to comply with the commitments that are to be fulfilled by 2030. The third section reflects on the winding courses and the ups and downs of energy transitions and presents scenarios through which securing a portion of the income generated from the export of fossil resources could be used to leverage the energy transition process in Argentina, given the limitations of access to "cheap" and long-term financing. Finally, the chapter closes with the conclusions in which we reiterate the importance of reflecting on the challenge of articulating energy transition policies with the economic development model, as it presents an opportunity to develop new articulations, complementarities, and intersections between the environmentalist and developmentalist paradigms in the twenty-first century.

11.2 The Energy Sector in Argentina

Throughout its short history, Argentina has undergone several energies transitions. At the beginning of the twentieth century, the country moved from coal to oil, with the installation of a refinery by North American capitals (West India Oil Co.), driven by the discovery of oil by the State in the national territory in 1907, which was boosted by the difficulties to import coal from England during the First World War (Barrera, 2014; Solberg, 1986). With the creation of *Yacimientos Petrolíferos Fiscales* (YPF) in 1922, the first vertically integrated, state-owned oil company in the world, aimed at achieving self-sufficiency, oil derivatives came to play a prominent role in the energy matrix, which was consolidated with the import substitution industrialization model. Between 1922 and 1954, the consumption of oil derivatives (domestic and imported) increased from 21% to 69% of the energy matrix, with a reduction in coal from 27% to 8% (Barrera et al., 2012; Dorfman, 1942; Gadano, 2012). Since then, this trend continued until the 1970s when coal was reduced to only 3% of the primary matrix, well below the European average of 36% (BP, 2021). This resulted in a consolidation of fossil-petroleum dependence, since 80% of the matrix consisted of a single source, while in other regions, this share was reached with two or three different sources.

The discovery of the *Loma La Lata* gas megafield in 1977 and its subsequent massive exploitation allowed Argentina to transform its matrix once again. In only two decades, half of the primary energy consumed came from natural gas, a percentage that continued to grow in the following years, although at a slower pace. This is a differential characteristic of Argentina, since it has a share of this fuel that is almost double the average of countries belonging to the Organization for Economic Co-operation and Development (OECD) (Table 11.1).

Currently, in the different segments of the Argentine energy matrix, there is a predominance of this fuel (Table 11.1). While in primary consumption, it climbed to 55%, if final consumption is considered, this resource accounts directly for 40% and indirectly for about 14% (it is mentioned that although electricity accounts for 23% of final consumption, its generation is mainly based on natural gas). In fact, by 2020, 58.9% of electricity will be generated by natural gas, followed by hydroelectricity and nuclear sources (24%), nonconventional renewables such as solar photovoltaic (PV) and wind (7%), and oil derivatives (7%).

In this regard, two elements should be highlighted when comparing the data on electricity generation sources in OECD countries. The first is the almost null weight of coal in the matrix (1%) compared to the significant role it plays in OECD countries (13% in primary and 20% in electricity). The second is the greater availability of natural gas as a source of energy, since in the aforementioned countries, it is 30%, half that of Argentina's reserves (EIA, 2020).

In short, the penetration of natural gas in Argentina‘s economic structure is widespread, not only in the residential and industrial sector but also in automotive transportation, since natural gas accounts for a significant portion of the fuels used (12%). Although its incorporation in the energy matrix managed to displace the (marginal) consumption of coal and, with greater intensity, that of oil and its derivatives—which contributes to having a matrix with lower emissions than other countries—the high dependence on this hydrocarbon generated serious macroeconomic imbalances in recent years.

In fact, for various reasons, the impact on the economy was generated by the decline in oil production since 1998 and natural gas production since 2004. While oil only reduced the export balance (to the extent that self-sufficiency was guaranteed), the fall in natural gas extraction not only eliminated exports but also significantly increased external purchases, initially of gaseous natural gas from Bolivia and, later, of shipped liquefied gas. As shown in Fig. 11.1, this process implied that Argentina went from having a positive energy trade balance of USD 6 billion in 2006 to a deficit of USD 6.9 billion in 2013, that is, a net annual foreign exchange loss of USD 12.9 billion between peaks. This dynamic of the energy sector was viewed as one of the central

Table 11.1 Primary energy consumption, final consumption, and electricity generation in Argentina and electricity generation in OECD (by source and in percentage during 2020)

Energy sources	Argentina			OECD	
	Primary energy consumption	Final consumption	Electricity generation	Primary energy consumption	Electricity generation
Hydrocarbons	85.4%	77.0%	67.4%	78.0%	51.3%
Natural gas	54.7%	40.2%	58.9%	29.1%	30.9%
Oil (or derivatives products)	29.5%	36.2%	7.3%	36.2%	1.4%
Coal and others	1.2%	0.7%	1.2%	12.6%	19.0%
Hydro and nuclear	7.6%	–	23.7%	13.7%	30.8%
Wind, PV, bioenergy	4.3%	–	7.0%	8.3%	16.4%
Others (includes electricity)	2.7%	23.0%	1.9%	–	1.4%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Own elaboration based on data from the Secretary of Energy of Argentina and BP (2021)

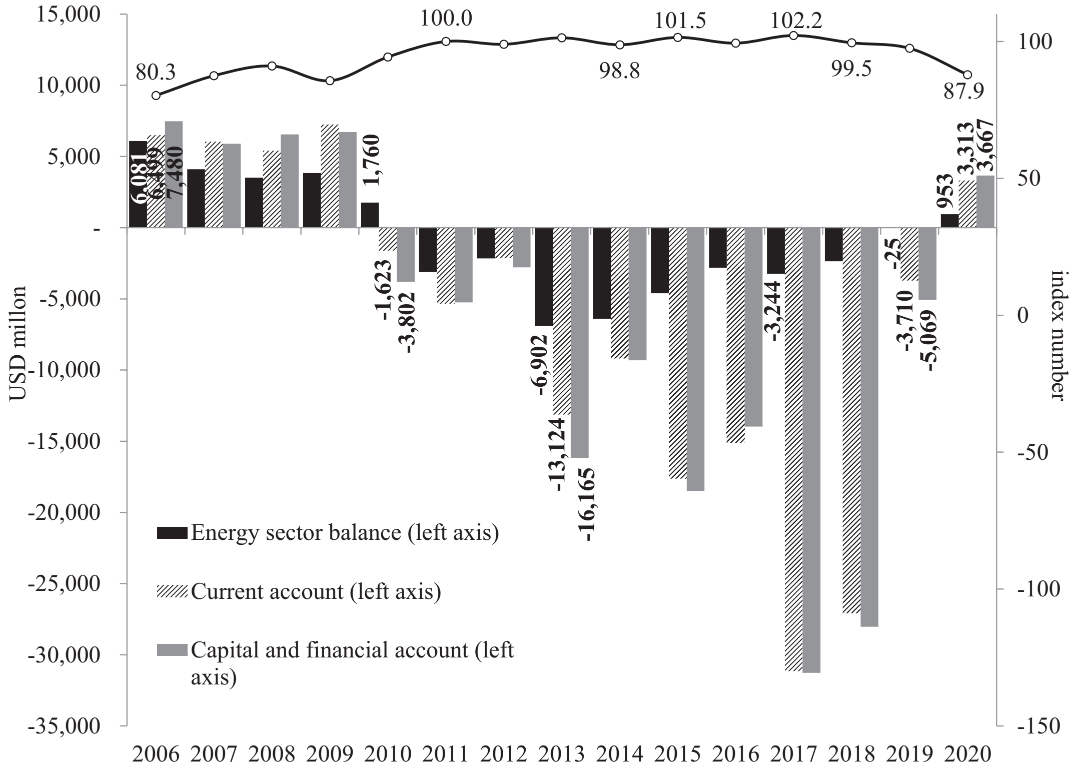

Fig. 11.1 Evolution of the current and financial account of the balance of payments, the trade balance of the energy sector, and the GDP, 2006–2020 (in millions of USD). (Source: Own elaboration based on data from INDEC)

sectors that originated the process of external restriction, which the Argentine economy entered into since 2011 (also the year in which the first energy sector deficit of USD -3115 million was recorded after the aforementioned decline) (Barrera, 2021a; Goldstein et al., 2016; Serrani & Barrera, 2018).[4]

Since that year, the Argentine economy remained stagnant until 2017 and then fell, initially due to the economic crisis of Mauricio Macri's government in 2018[5] and later due to the 2020 Covid-19 pandemic. As a result of these processes, in 2021, the gross domestic product closed 3.5% lower than in 2011 (Fig. 11.1).

This external deficit of the hydrocarbons sector was one of the main elements that led to the expropriation of 51% of Repsol's shares in YPF, the former state-owned company, causing a

[4]As Serrani and Barrera point out, the energy sector's contribution to the emergence of the current account deficit between 2006 and 2014 is 81%, while if the analysis is focused only on commodities, the energy contribution to the fall of the existing surplus reached 159% (Serrani & Barrera, 2018, p. 138).

[5]To analyze the causes of the economic crisis of this government from a critical perspective, we recommend Wainer (2021). To view this analysis from the government's perspective, one can read Sturzenegger (2019). To illustrate, it can be mentioned that at the beginning of 2018, the bulk of the swallow capitals that had entered since 2016—encouraged by the high interest rates granted by the national government with the Central Bank Bills (LEBACs)—above 40%, identified that the economic model was reaching its limit and started to strive for the development of quality process regulations. As a result, the exchange rate went from $20 per dollar to $40, due to the massive outflow of foreign currency from the Central Bank and produced a spiral of inflation and an economic and political crisis in the government, which then decided to sign an agreement with the IMF for USD 57 billion, the highest ever granted by the institution. The rise in the country risk associated with the crisis was a decisive factor to stop the arrival of external financing to the country.

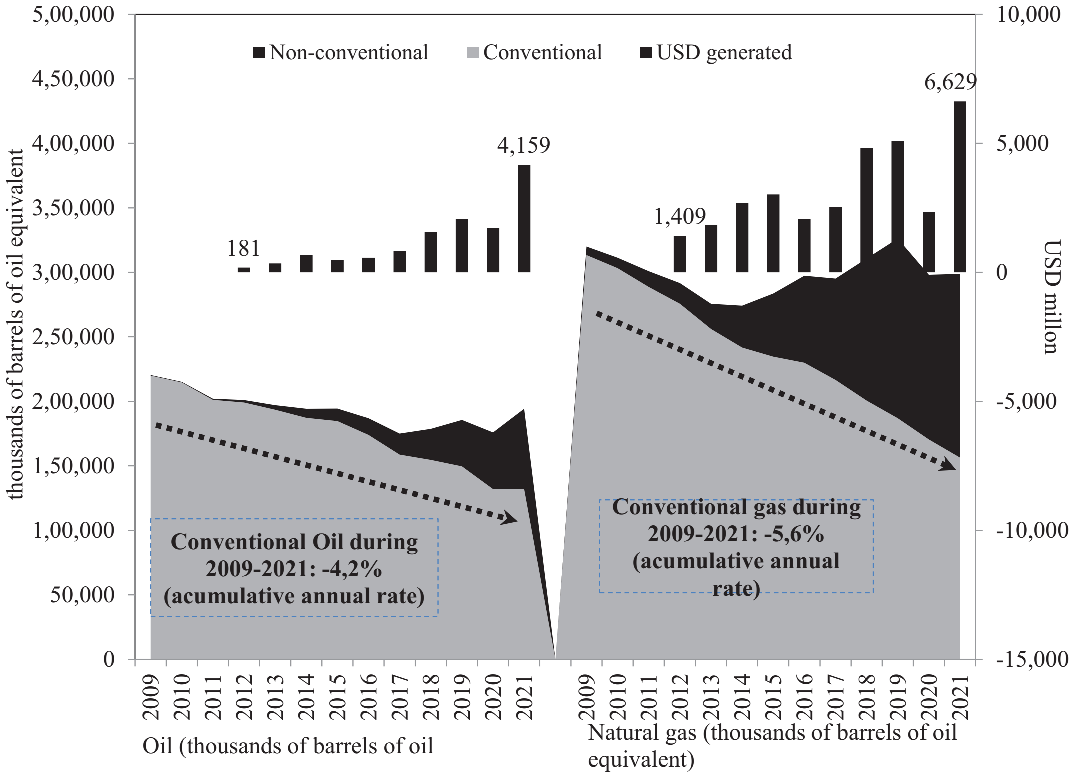

Fig. 11.2 Evolution of conventional and unconventional oil and natural gas production and unconventional production valued at import parity price, 2009–2021 (in thousands of barrels of oil equivalent and in millions of USD). (Source: Own elaboration based on data from the Secretary of Energy of Argentina and Central Bank)

change in the sector's policy[6] and the beginning of the intensive exploitation of shale Oil & Gas in the *Vaca Muerta* formation (Barrera, 2021b; Sabbatella, 2012).

As shown in Fig. 11.2, the exploitation of unconventional resources changed the sector's trend, to the extent that conventional deposits maintained an annual decline of 4.2% (oil) and 5.6% (natural gas) between 2009 and 2021. The various subsidies to natural gas, in addition to the increase in the indebtedness of the state-controlled company, made it possible to increase investment flows to the sector and reverse the decline of the activity, exclusively from unconventional resources (Barrera, 2021a; García Zanotti et al., 2017; Pérez & Serrani, 2020).

After reaching the lowest level of natural gas production in 2014, the trend was reversed with a significant expansion until 2019, which made it possible to replace imports of this fuel (Fig. 11.1). In 2021, unconventional resources enabled foreign currency savings of USD 10,788 million (USD 4159 million in oil and USD 6629 million in natural gas[7]), and between 2012 and 2021, they reached a total of USD 44,972 million.

[6]The main reference is to the adoption of the so-called barril criollo (local oil barrel), which, until 2017, guaranteed an oil price in the domestic market higher than the international one, as well as the creation of the "Plan Gas," which paid the producers 7.5 U$S/MBTU for the gas above the "base" production, adjusted according to a "decline" rate foreseen for each company. The difference between the price received for sales to transporters and the 7.5 dollars was covered by the state (Arceo, 2018; Barrera, 2021b; Serrani, 2019).

[7]This data arises from valuing the production of unconventional oil and gas by the import price, assuming that, given the decline in extraction, any additional production replaces external purchases.

In this sense, the energy sector had an important macroeconomic impact at this stage. Until 2014, it contributed negatively in the process of external restriction, but since 2015 (the period linked to the reversal of the decline in hydrocarbon production), it was relevant in the reduction of fuel imports. The payment balance crisis, intensified in 2018 by the massive capital outflows that accentuated the economic crisis, could have been even greater without the recovery of local hydrocarbon production. Indeed, the current and financial account surplus, achieved in 2020 after the economic crisis that began in 2018 and deepened in the context of the Covid-19 pandemic, was made possible, partly, by the reversal of the energy deficit (Barrera, 2021b).

In sum, given the structure of the Argentine energy complex that has a high penetration of natural gas in all its links, the energy transition must contemplate this energy structure and, at the same time, be a gradual process to avoid negative effects on the unstable local macroeconomy. As will be discussed later, recent history has shown that the energy transition is only possible with long-term policies in stable macroeconomic contexts that allow financing the sector's large investments. To this end, the hydrocarbon resources generated by both import substitution and potential export balances[8] should serve to stabilize the macroeconomy and generate the conditions for the transition. In this context, unlike the main developed countries that still have an energy matrix with a strong presence of coal, in the Argentine case, there is a high penetration of natural gas, a fuel with lower GHG emissions when compared with other fossil resources and recently declared a transition fuel by the European Union. Indeed, given that Argentina has already made the transition to natural gas (displacing mainly oil derivatives and, to a lesser extent, coal) and considering that its historical and current participation in global warming is low in relative terms, the following question arises: How can Argentina ensure that it will manage to advance in the energy transition toward a low-carbon economy, considering both the restrictions and its economic, financial, and resource capabilities?

11.3 Renewables Policy in Argentina

The historical process of consolidating hydrocarbons in the energy matrix was not exempt from important investments, driven mainly by state-owned companies in other energy sources such as hydroelectric and nuclear power plants, which made it possible to provide low-emission energies while expanding the country's scientific and productive capacities.

These investments were made with greater impetus, starting in the 1960s, and entered the system in the following decades after several years of construction. These include the nuclear power plants Atucha I (1974) and Embalse (1984) and the hydroelectric plants El Chocón (1977), Santo Grande (1979), Alicurá (1984), Rio Grande (1986) Piedra del Aguila (1993), and Yaciretá (1994), among others. The raising of capital in both technologies allowed them to reach 52% of the installed power in electricity generation in 1988.

However, the process of diversification of energy sources slowed down with the economic crisis of the 1980s (Sabbatella et al., 2020) and was stopped with the privatization of public assets and the deregulation of energy sector activities from 1989 (Barrera et al., 2012), since the expansion of installed capacity by the private sector focused on assets with high returns on investment in the short term, such as combined cycle thermal power plants, taking advantage of the available natural gas reserves.

Faced with the accelerated growth of the GDP after the 2001/2002 crisis and, with it, that of energy consumption, the successive governments had a double strategy until 2015. On the one

[8] According to studies carried out, in the best of the scenarios presented publicly by officials of the National State, both from the Secretary of Energy and the Ministry of Productive Development, by the midterm this positive balance could reach between USD 35 billion and 48 billion net per year of exports of the resource (Iguacel, 2018; Kulfas, 2019). In 2019, the country's total exports reached USD 65 billion.

hand, their plan was to rapidly increase the installed power of electricity, which they did from thermal power plants (Serrani & Barrera, 2018), further consolidating the presence of hydrocarbons in the matrix, with the consequent problem on the macroeconomy previously pointed out when hydrocarbon production began to decline. On the other hand, the state restarted the diversification of the energy matrix toward hydroelectric and nuclear power plants. Thus, in 2006, the National Nuclear Plan was relaunched and the construction of the Atucha II nuclear power plant, which had started its construction in 1982 and was stopped in the early 1990s, was resumed. Only in 2014 did it reached criticality with a power of 740 MW (2% of Argentina's total power in 2020). Regarding hydroelectric power, in 2008, the project for the construction of two hydroelectric power plants in the south of the country, with a capacity of 1740 MW (4% of the country's power), was put out to tender, but they had to be put out to tender again in 2013 due to difficulties in external financing, caused by the outbreak of the international crisis in 2008 (Sabbatella et al., 2020).[9] At the same time, in 2011, the plans to increase the height of Yaciretá to the height foreseen in the original project were completed and two other smaller hydroelectric power plants were built: *Los Caracoles* and *Punta Negra*, in the province of San Juan.

In this context, Law No. 26,190 of the National Promotion Regime, for the use of Renewable Sources for the Production of Electricity, was enacted in 2006. This law set the goal of having renewable energy sources contribute to 8% of the national electricity consumption by 2015. Three years later, the GENREN (Renewable Energy Generation) Program was launched with a system of auctions to assign 15-year contracts in dollars to supply the system with renewable sources at a fixed price, calculated based on the costs of each project. Contracts were assigned for a total of 895 MW (754 MW of wind energy, 110 MW of biomass, 20 MW of PV, and 10 MW of small hydro), with prices ranging from 121 to 134 USD/MWh, in wind; 258 to 297 USD/MWh, in biofuels; 150 to 180 USD/MWh, in small dams; and 547 to 598 USD/MWh in photovoltaic (Recalde et al., 2015, p. 107). Given the greater weight of wind power, the weighted mean ranged around 155 USD/MWh. However, many of the contracts had difficulties in obtaining financing in the national and international financial system (commercial and multilateral banks), in the context of the global financial crisis of 2008 and local restrictions on access to external credit (Sabbatella et al., 2020).

In short, although Atucha II was put into operation and Yacireta's height was raised, the hydroelectric power plants in Patagonia are still under construction, and despite the launching of GENREN, the sum of wind, PV, mini-hydro, and bioenergy generation accounted for only 1.8% of the national electricity demand as of 2015 (CAMMESA, 2021). In fact, of the 9456 MW of new power installed between 2006 and 2015, despite the Law and GENREN, nonconventional renewable energies only accounted for 2.9% of this increase (270 MW), since most of it was the result of thermal power plants that consume fossil fuels, which accounted for 77.7% in the same period (Table 11.2).

In view of the scarce results, both in the diversification of the matrix and in the incorporation of nonconventional renewable energies to meet the goals set in 2006, at the end of 2015, Law No. 27,191 was enacted, which set new objectives. There it was established that 8% of electricity consumption should be reached by nonconventional renewable sources by 2017, and this should increase to 20% by 2025.

The new law, and the policies subsequently designed, took effect within the framework of two different processes that contributed from different places. First, the Climate Summit held in France in 2015, which would end with the signing of the Paris Agreement the following year, meant a renewed boost from public policies for the incorporation of nonconventional renewable energies in the national energy matrix, not only because of the country's adhesion to the Agreement but also because of the ambitious cli-

[9] In 2022, they are still under construction with an expected completion date between 2024 and 2028, depending on the plant.

Table 11.2 Increase in installed power generation capacity by period (in MW and percentage share of increase in power capacity for the period)

Energy source	Legislation, strategic plans, or investments	2006–2015 Power Increase (MW)	Contribution to growth (2006–2015) (%)
Renewables	Law no. 26,190 and GENREN program	270	2.9
Nuclear	Nuclear plan, Atucha II	725	7.7
Hydro	Start-up of medium-scale power plants	1112	11.8
Fossil	Increase of turbines and closure of CHP plants	7349	77.7
Total period 2006–2015		**9456**	**100.0**
Energy source	**Legislation, strategic plans, or investments**	**2015–2021 power increase (MW)**	**Contribution to growth (2015–2021) (%)**
Renewables	Law no. 27,191, RenovAr program, MATER program, resolution no. 202 and distributed generation.	4351	46.2
Nuclear	Embalse nuclear power plant life extension	25	0.3
Hydro	Start-up of low-scale power plants	95	1.0
Fossil	Fossil backup for the system	4955	52.6
Total period 2015–2021		**9425**	**100.0**

Source: Own elaboration based on data from the Secretary of Energy of Argentina and CAMMESA

mate goals proposed since 2016, as it was noted. Secondly, with the change of government party in December 2015, one of the first measures taken by the new administration was the resolution of the conflict that the country maintained with the holdouts for the restructuring of the sovereign debt carried out in 2005 and 2010, paying the full capital and punitive interest applied by the New York Court (Bona & Barrera, 2021).

From the confluence of these two processes, in the following years a set of initiatives were designed to stimulate the development of renewable projects, with a clear pro-market bias, leveraged mainly by international private financing, to which access was gained after the exit of the default with the holdouts. In this regard, four policies that marked a break in the dynamics of renewable energies are worth mentioning.

The first, the RenovAr Program, launched in 2016, established a project auction mechanism for the supply of nonconventional renewable energies from power purchase agreement projects (PPA), for a term of 20 years with dollarized prices of the sold electricity and competitive prices at regional level for wind technology but higher prices for PV (García de Fonseca et al., 2019). By 2021, 4718 MW of power were installed in 187 projects.

Secondly, 10 GENREN contracts, that had not yet been finalized, were readapted to the new regulations of the RenovAr Program, which allowed the incorporation of an additional 500 MW of power: seven wind projects (445 MW); two PV (10 MW); and one biomass (45 MW).

The third instrument was the Mercado a Término de Energía Eléctrica de Fuentes Renovables (MATER) (Futures Market for Electricity from Renewable Energy Sources), which was intended for large users of the wholesale electricity market with power demands equal to or greater than 300 kW, mainly large industrial or electro-intensive companies, such as petrochemical, petroleum, steel, automotive, cement, and mining companies, to establish contracts with private agents for the purchase of renewable energy. By the end of 2021, a total of 1256 MW of power had been awarded (974 MW wind and 285 MW PV), of which 761 MW (94% of them, wind technology) were enabled.

Finally, after the enactment of Law No. 27,424, distributed generation from renewable sources, integrated to the public grid, was enabled, which allowed consumer users to install equipment in their properties and sell the surplus they did not consume to the grid through the net

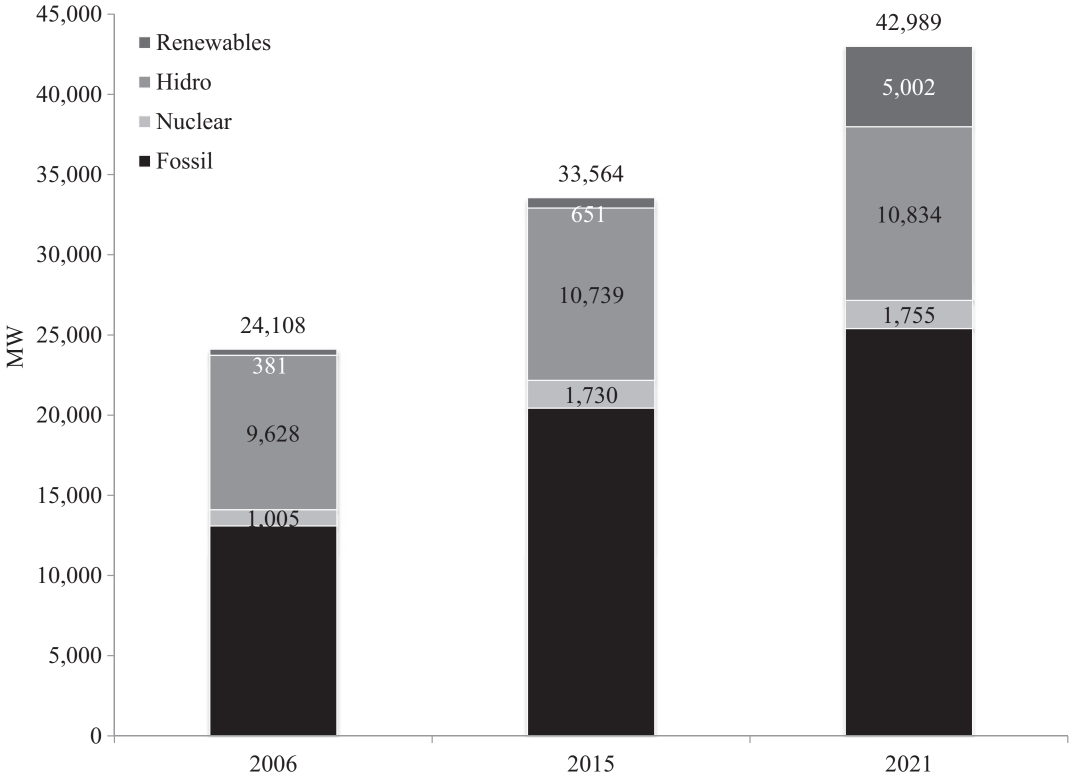

Fig. 11.3 Installed capacity by electricity generation source, 2006–2021 (in MW). (Source: Own elaboration based on data from the Secretary of Energy of Argentina and CAMMESA)

billing system, from which the electricity price authorized for the distributor is charged. At the end of 2021, there were 714 projects with generating users that completed the installation, for a total of 9.1 MW of installed capacity.

In summary, the set of instruments mentioned above allowed the total installed capacity of non-conventional renewable sources to reach 5002 MW by 2021, after adding 4351 MW to the electricity matrix between 2015 and 2021 (Fig. 11.3). Unlike the previous stage, in which nonconventional renewable energies accounted for only 3% of the new capacity, in this period they accounted for 46% of the additional capacity (Table 11.2). In turn, considering the expansion of renewable energy capacity, 87% is explained by nonconventional energies, compared to 13% of conventional renewables. It should be noted that, although there is a significant penetration of renewable energies, fossil sources still represent 25,398 MW of electric power out of a total system of 42,989 MW, that is, 59.1% (Fig. 11.3).

Indeed, the market mechanisms promoted in the various initiatives were effective in achieving the rapid installation of renewable energy projects in the country's electricity matrix. However, with the economic crisis of 2018–2019 which, among other effects, devalued the domestic currency by 230%, there was a significant increase in the cost of financing and access to international credit was hindered, all of which paralyzed RenovAr and the works in progress for MATER and slowed down the incipient distributed generation market, due to the increase in costs associated with the devaluation and the increase in the country risk premium (CAMMESA, 2021).[10]

[10]The developers of renewable energy projects themselves expressed in the media that the economic crisis had brought interest rates to levels incompatible with investment: "Con este riesgo país (EMBI) es imposible conse-

In this context, based on the latest information available from the Secretary of Energy, the incorporation of renewable energy in the electricity matrix, associated with the completion of the extension of the lifetime of the Embalse nuclear power plant in 2019, and the decrease in the burning of diesel and fuel oil, due to an increase in the supply of natural gas, allowed emissions to be reduced by 22.6% between 2015 and 2019 (46.1 and 35.7 MtCO2, respectively). However, the progress made is far from the goals set in Law No. 27,191 for 2025 and the commitments made in international forums regarding the total reduction of GHGs by 2030.

In this context, the challenge for an economy such as Argentina's is to advance in the energy transition within the framework of an unstable macroeconomy, with recurrent economic crises and limited access to international credit. This is not a minor issue, since huge investments in electricity infrastructure are needed, not only in new power but also in maintenance, reinforcement, or expansion of medium, high, and ultrahigh voltage lines, in addition to the local distribution system.

Considering a baseline scenario in which at least 20% of electricity is generated with nonconventional renewable energy sources by 2030, the installed capacity should grow by 7.2 GW according to the Guidelines for an Energy Transition Plan to 2030 published by the National Secretary of Energy under Resolution No. 1036/2021. This means an annual increase of 560 MW, 20% less than the increase in installed capacity between 2016 and 2021 (725 MW), with the implementation of RenovAr that received huge financing. Consequently, this is a significant process of expansion of installed capacity in a context of strong external restriction and closure of international markets.[11]

As shown in Table 11.3, the estimates of the Secretary of Energy to meet the 2030 targets imply a total expenditure of USD 6.5 billion for the whole period, that is, USD 722 million per year: 60% of the economic resources would be allocated to wind energy, 12% to PV, and the remaining 29% to bioenergy and small hydropower.

However, as mentioned above, these are not the only investments needed to increase the electric power capacity, since renewable energies took advantage of the transmission capacity of the Interconnected Transmission System in Argentina, which is currently saturated. Hence, it is necessary to complement the investments required for nonconventional renewable projects with others for the expansion of the transmission lines. According to the estimates of the Secretary of Energy, stated in Resolution No. 1036/21, the transmission system needs USD 2885 million until 2030, that is, an average of USD 320 million per year. Investments are relevant, since, with some exceptions, PV and/or wind farms are normally located far from large consumption centers.

In short, the total investment required to install and transport a total of 5025 MW of nonconventional renewable energy in Argentina, in order to comply with Law No. 27,191 and reach 20% of renewable energy in the electricity matrix, would be around USD 9385 million.

guir financiamiento privado por debajo del 14%" [With this country risk (EMBI), it is impossible to obtain private financing below 14%] (Bellato, 2018). Moreover, the doubling of the interest rate was combined with the restriction of access to foreign currency to pay suppliers, due to the lack of dollars in the Central Bank, all of which caused difficulties for the initial financial structure of the projects (Santamaría, 2019).

[11] At the time of this writing, late April 2022, the Argentine government reached an agreement with the International Monetary Fund (IMF), which was ratified in Parliament. However, a large part of the agreement involves a refinancing of the debt and the taking of a new loan to repay it. In this sense, having reached a new agreement with the IMF, although it avoids default, it does not imply that in the political-economic scenario that is opening up, Argentina will again have external financing amounts equivalent to those of the 2016–2018 period.

Table 11.3 Estimated investments needed to achieve 20% of electricity generation from nonconventional renewable sources by 2030 (by source, in MW and millions of USD)

Energy source	MW	%	Millions of USD	%
Wind	3283	65.3	3858	59.4
PV (including GD)	950	18.9	767	11.8
Bioenergy	422	8.4	882	13.6
Mini hydro	370	7.4	993	15.3
Total	**5025**	**100.0**	**6500**	**100.0**

Source: Own elaboration based on data from Resolution N° 1.036/2021

11.4 Renewable Energies and Financing for the Energy Transition

The energy crisis that was unleashed at the end of the pandemic,[12] and deepened with Russia's invasion of Ukraine, generated serious imbalances in the energy systems of the countries, both due to the increase in electricity generation costs and to supply problems, especially of natural gas. This new international context has led some countries to revise the energy transition model adopted. Although discussions are ongoing (and are still open-ended), there are European countries that are reconsidering operating coal-fired power plants and re-discussing the strategy of suspending electricity generation from nuclear power plants. In the framework of the COP 26, held in Glasgow in November 2021, the European Union highlighted the need to reconsider natural gas as a transitional green fuel and nuclear power as a relevant energy source for lowering total GHG emissions, in the broader framework of meeting the goals of carbon-neutral economies by 2050 (European Commission, 2022). Consequently, recent international experience reinforces the idea that there is no single model of how to transition and that countries should evaluate the best path based on natural resource endowments, financing, and the relative impact on GHG emissions.

In this context, despite having a low relative share in global pollution due to their almost zero use of coal and early transition to natural gas, Argentina has set ambitious targets for the reduction of GHG emissions. In addition to international commitments, the National Congress passed a law that establishes demanding goals to increase the penetration of nonconventional renewable energies in the electricity matrix. Therefore, it is relevant to re-evaluate the strategies that Argentina could follow to boost the incipient energy transition, within the context of the country's low economic growth and limitations in domestic and external financing, which led to the halt of the RenovAr program at the end of 2018.

Given that the country's natural resource endowment is favorable for the installation of nonconventional renewable energies,[13] the main obstacle lies in the economic and financing difficulties of the Argentine economy. Usually, the contribution from the exploitation of nonconventional hydrocarbons is presented as a positive aspect to improve the external payment balance. This sentiment, as evidenced by that fact that it allowed the substitution of imports for around USD 45 billion in the last 10 years, is an aspect that made it possible to mitigate the economy's strong external restriction. However, an element

[12] Multiple processes generated strong imbalances in the system with price increases in the electricity supply of European countries. The severe water crisis in South America had an impact not only on a drop in electricity generation from hydroelectric and nuclear sources (very relevant for the countries in the region) but also led to additional purchases of LNG, which generated greater pressure on the global market, characterized by a growing mismatch between supply and demand of natural gas since 2021. A new circumstantial factor was added to this context, associated with lower winds in some European countries, especially in the Iberian Peninsula, which led to a reduction in electricity generation from wind sources (IEA, 2022).

[13] Argentina has a wind load factor above 50% and PV above 30% (Genneia, 2020a, b).

that has not been well analyzed in the literature is that these resources can also be used as a potential source of financing to boost renewable energies. This proposal seeks to complement the various segments of the energy system, while taking advantage of the window of opportunity at the international level before hydrocarbons (mainly oil) cease to be a globally demanded energy source. It refers to the configuration of an energy model in Argentina that, by expanding hydrocarbon production (initially to eliminate natural gas imports and then to generate exportable balances), would simultaneously finance the growing insertion of renewable and clean energies in the energy matrix. To this end, it is possible to design a mechanism to capture part of the income derived from nonconventional hydrocarbon exports to finance new renewable energy projects in Argentina. This could be developed through the implementation of a moderate (so as not to discourage local production) hydrocarbon export duty rate, for example, 5%, and with the resources obtained, it could finance new renewable energy projects, which would allow sustaining the energy transition toward a low-emission economy over time. For this purpose, two scenarios of oil and natural gas exports are presented, and the potential revenue was calculated by applying the aforementioned rate.

In the first scenario, we take the information presented in 2018 by the Secretary of Energy of the Nation (Iguacel, 2018) in which a path of exports reaching USD 25 billion in 2030 is presented. For that volume, a series of assumptions were made based on the characterization of the potential of the *Vaca Muerta* formation that would allow foreseeing those levels.[14] The assumptions in the report consider:

1. That annual investment volumes would range between USD 10 billion and 20 billion until 2025.
2. That oil production would double in five years and triple in ten years.[15]
3. That natural gas production would triple in 10 years.[16]
4. The balance of exportable production was valued with three price scenarios: 50, 75, and 100 USD/bbl for oil and 6, 8, and 10 USD/MMBTU for natural gas.

In this first scenario, called "Scenario Secretary of Energy (2018)," the projection with the most conservative prices was considered, that is, 50 USD/bbl for oil and 6 USD/MMBTU for natural gas. Thus, assuming that the increase in production presented by the Secretary of Energy is possible, the strongest growth in exports would occur in the first five years, when they would reach USD 23.5 billion[17] (Fig. 11.4). Considering the financing needs for the installation of new power derived from nonconventional renewable energy sources and investments in transportation to meet the 2030 objectives reviewed in the previous section, under this scenario, the economic resources collected from hydrocarbon exports between

[14]The thickness and acreage of the *Vaca Muerta* platform has better characteristics than that of US players. While *Vaca Muerta* has a thickness of up to 450 meters, the Permian, one of the main formations, ranges between 200 m and 300 m. Likewise, the report details that the breakeven is between USD 40 and 50/barrel and USD 3.5/MMBTU in natural gas in 2018, with well drilling, development, and OPEX costs reduced by 50–60% since 2015. Indeed, these elements make *Vaca Muerta* the second biggest platform in unconventional gas resources and fourth in oil in the world (EIA, 2013; Iguacel, 2018).

[15]To this assumption it can be added that there is infrastructure to transport surplus production in the first stage and, at present, investments are already being made to expand the capacity to transport oil to the external market.

[16]Unlike oil, in the case of natural gas, it is necessary to build a new pipeline to transport the additional production, which is currently under bidding, and according to official information from the Ministry of Energy, it is estimated that it will begin its first operational stage in 2023.

[17]Although these are preliminary data, in the first three months of 2022, natural gas exports grew by 241% and oil exports by 83%, which shows a greater dynamism of the activity. Considering the value of external sales of these hydrocarbons, they grew 220%, registering USD 1084 million in the first three months of 2022, mainly concentrated in oil. If that value were annualized, around USD 4.3 billion would be exported in the year, a figure not far from the estimate made by the Secretary of Energy (Iguacel, 2018). Although there is seasonality in natural gas exports, which makes it difficult to annualize external sales, the fact is that the growth of oil production is relevant in a context where domestic demand is covered, so that new flows could be exported in the coming years.

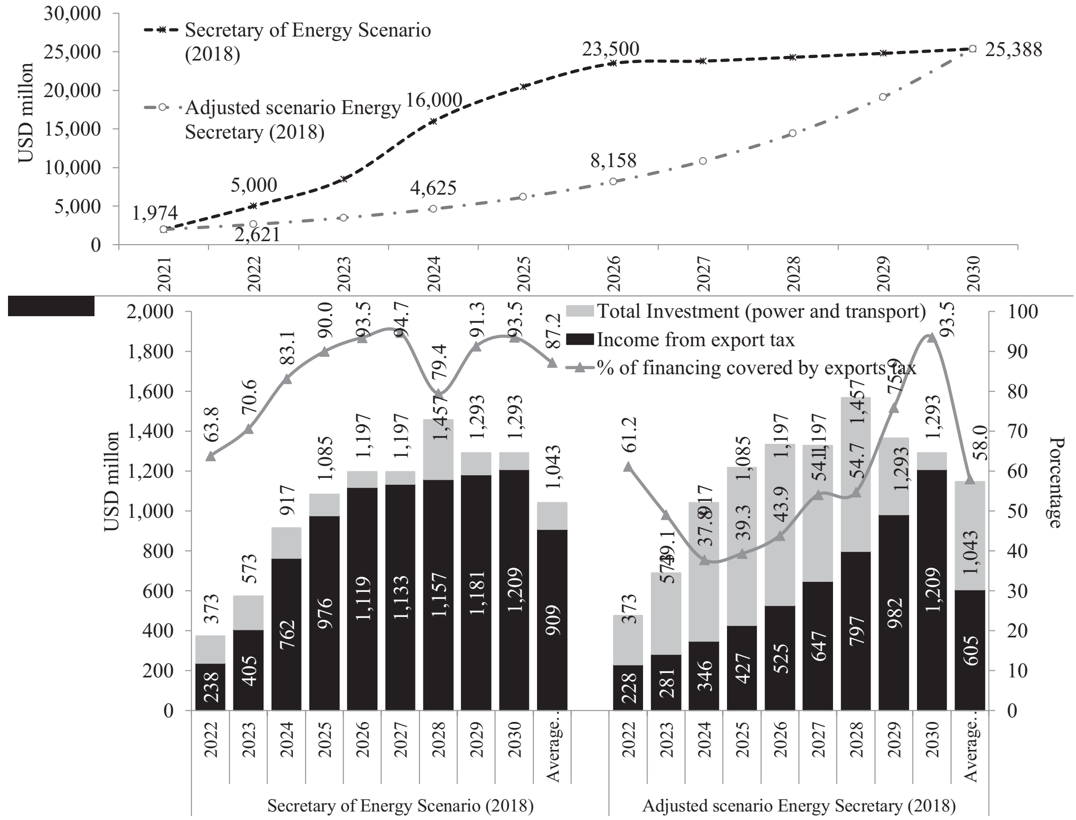

Fig. 11.4 Scenario Secretary of Energy (2018) and Adjusted Scenario Energy Secretary; total investment and income from export tax, 2022–2030 (in millions of USD and percentage). (Source: Own elaboration based on data from the Secretary of Energy of Argentina, Iguacel (2018) and Resolution N° 1.036/2021)

2022 and 2030 would be enough to cover 87% of the USD 9385 million investment needed in the electricity sector, with initial floors of 64% in 2022 (Fig. 11.4).

Given the economic crisis of 2018 that was exasperated by the pandemic and generated negative impacts on the level of investments and production, the initial projections proposed by the Secretary of Energy in Iguacel (2018) were not met. In this context, a second scenario was presented, called "Adjusted Scenario Secretary of Energy (2018)," in which the value of exports in 2030 was maintained as a valid assumption, and an annual flow was estimated based on applying the cumulative annual rate since 2021 (last official export data). Although it is a more realistic assumption that there will be a stronger initial growth in exports, followed by a slowdown (as in the estimates made in the first scenario), this underestimated assumption was accepted for the collection estimates.

Then, in this second scenario, with more conservative characteristics in the initial years, a more moderate revenue collection path is presented, with a floor of 24% of investment needs that reaches 94% by the end of the period, given the characteristics of the projection (Fig. 4). Under this scenario, the collection of 5% of total exports in the period 2022–2030 would cover 48.1% of the investment needs in new renewable power and additional transportation infrastructure (Fig. 11.4).

Far from pretending to provide predictive precision to the scenarios proposed, the only official information available to the public from the Secretary of Energy was used to develop a scheme that primarily aims to present alternatives to finance the necessary works to comply with the climate change commitments signed by Argentina. The conclusion of the scenarios presented reveals the magnitude of the challenge in terms of financing that it implies for a macroeconomically unstable, peripheral country, such as Argentina, to have only 20% of nonconventional renewable energy in the electricity matrix by 2030, in line with the goals of Law No. 27,191.

11.5 Conclusions

Successfully carrying out energy transitions toward low-carbon economies is one of the greatest global challenges of the coming decades. Certainly, it is not a mere process of changing the energy matrix, much less a strictly technical race, but it involves factors of various kinds: productive, technological, territorial, environmental, geostrategic, and those related to local, regional, global social actors, etc. It is also true that there are no unique models to imitate, since each energy transition is planned and carried out after taking the specific characteristics of the countries or regions into consideration.

Based on the analysis of the Argentine case, this chapter analyzes how to guarantee the maintenance of the speed necessary to implement an energy transition in compliance with the environmental commitments assumed by a peripheral country, semidependent in terms of technology, with recurrent economic crises driven by the balance of trade deficit, which causes a constant process of scarcity in the access to "cheap" and long-term financing. We presented evidence of the challenge implied not only by the dimensions of the implicit energy transformations but also by the magnitude of the investment requirements necessary to carry them out: the energy transition entails reviewing the endowment of resources, weighing the structural limitations, and strengthening the complementarity of the energy system as a possibility factor to implement it in a sustainable and sustained manner over time. Considering that Argentina has, as a strategic asset, one of the largest unconventional hydrocarbon reserves in the world in the *Vaca Muerta* formation—and that even in the most optimistic estimates made by international organizations, the consumption of oil and natural gas will remain as a consumption option in the coming decades—it is necessary to consider the possibility that part of the income from hydrocarbons could be a driver to finance the increase of renewable energies in the national electricity matrix. Given the substantial investments needed in the electricity sector, the use of part of the resources coming from hydrocarbon exports would be an option that would allow restarting a process that currently has no clear horizon.

Indeed, the energy transition toward a low-carbon economy is an environmental necessity, but at the same time, it could represent a window of opportunity to leverage the country's productive and technological system: those who have their own resources to finance the development of renewable energy projects are in a better position to hire both local labor and technological developments and goods with high added value, produced in the country for future renewable projects. Although the magnitude of the transition challenge also implies attracting funds from multiple international sources, the ability to leverage an industrial policy linked to the value chain of the clean energy sector will be based on the extent to which endogenous lines of financing are generated. The transition also includes ensuring that the costs of the transition are not unequally distributed and that the countries and the different social sectors equitably appropriate its potential benefits.

In short, the energy transition that has opened in recent years is a clear opportunity to review new articulations, complementarities, and intersections between the environmentalist and productivism paradigms that were, in recent years, so far apart in public policy discussions, as they constitute a decisive factor in reflecting on the type of development model needed in Latin America in the coming decades to solve its deep-rooted, structural problems.

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12 The "Wind Revolution" in Uruguay and the Role of the Public Sector in Guiding Energy Transitions

Reto Bertoni and Pablo Messina

12.1 Introduction

The need and urgency of an energy transition, to help mitigate the emission of greenhouse effect gasses, represents a challenge for humanity in the context of the Anthropocene. The international literature has discussed – in a comparative historical perspective – the duration, rhythm, and drivers of the transitions, with the aim of identifying patterns, elaborating typologies, and/or discovering critical factors on which to base so as to contribute to the design of energy policies.

In this scenario, revisiting and discussing successful cases on a national scale can contribute to understanding the dynamics that emerge from these complex processes, where the political economy creates some tension between the design and implementation of public policies. The transformation of a sociotechnical regime such as the energy matrix is conditioned by structural factors and global forces, but the dynamics of change depend – ultimately – on the action – or inaction – of relevant actors at the national level.

The critical analysis of the so-called wind revolution in Uruguay can contribute to the discussion on the determinants of energy transitions and, in this sense, offer inputs for theoretical reflection, but it also learns some lessons for a "second energy transition"[1] in the country, selected – among others – to receive resources from the United Nations Fund for the purpose of implementing a decarbonization program for sectors such as transport and industry.

This chapter not only tries to discuss the achievements, but also some of the limits or challenges involved in the emerging trajectory. In that sense, we asked: Were they all new developed policies or were they sustained by some old institutional constructions? How did the quick transition affect the possibility of the national industry sector to get more involved in the process? What was the incidence about the privatization of the generation sources of energy? What was the role of the capabilities and public assets?

After this introduction, the work is structured as follows: a brief tour of the academic production on the subject is made (Sect. 12.2); then the main stylized facts of the transition and the policy instruments mobilized to obtain those results are presented (Sects. 12.3 and 12.4 respectively); finally, the lights and shadows of the process are discussed, addressing some "topics in debate" (Sect. 12.5). In the last section, the conclusions and a possible research agenda are presented.

R. Bertoni (✉) · P. Messina
Universidad de la República, Montevideo, Uruguay
e-mail: reto.bertoni@cienciassociales.edu.uy; pablo.messina@fcea.edu.uy

[1] In Uruguay, the term "second energy transition" has been generalized to refer to the process that would deepen the transition of the country's transport and industry sectors toward green energy.

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12.2 The Wind Revolution Under the Magnifying Glass of Locals and Foreigners

At an international level, studies on the use of renewables and the associated energy transitions give an account of long-standing processes in pioneering countries such as Denmark, Sweden, or Spain (Meyer, 2007) and are part of the debate on the necessary transformations in the global energy matrix to meet the challenges of climate change. Discussions about the character, duration, technologies, and policies linked to this process can be found in the works of Smil (2010), Sovacool (2016), Fouquet & Pearson (2012) and Fouquet (2016). But, in all cases, it is a vision "from the center." The processes of change of the energy matrix in peripheral capitalisms have less treatment in comparative studies.

For the Uruguayan case, we have works by foreign researchers who have analyzed the changes in the energy matrix of Uruguay and, in particular, the transformations in the electricity generation matrix with a focus on the "wind revolution"(Costa Correa et al., 2022; Fornillo, 2021; Wynn, 2018; Newell, 2019; Suárez et al., 2020).

The first one constitutes a specific study of the change of the Uruguayan energy matrix toward nonconventional renewables, focused on the development of generation through wind energy. Methodologically, it relies on various "text-mining" methodologies and also carries out prospective inquiries, seeking to identify the main challenges of the energy sector in Uruguay in the future. In their analysis, they affirm that the transformation of the energy matrix went from being an academic niche to an established regime of electricity generation (Costa Correa et al., 2022).

Fornillo (2021) prioritizes the importance of public policy and, very particularly, the existence of a public company that acted as a guarantor for the understanding of the success of the change in the energy matrix in Uruguay. He understands that the wind farms enabled the development of a new geography of distributed generation in Uruguay, which would allow a decentralized and participatory system, giving rise to a growing popular control of energy. In our view, it starts from a wrong premise about how the electricity system works in Uruguay, which leads to disregarding the risk of capture by private capital of the energy system as a whole.

Wynn (2018) makes a comparative analysis of nine regions in which nonconventional renewable energies have come to have a significant share. Considering the case of Uruguay, it stands out the speed of the transition and the role of planning, regulation, and existence of a vertically integrated company to guarantee success in such a short period of time.

On the other hand, Newell (2019) reflects on the conditioning factors of "political economy"in global governance that exist when thinking about energy transitions, while emphasizing the importance of the State from a neo-Gramscian perspective. The text identifies three motives for the transition toward renewables: ensuring a prominent place in the production of the technology associated with these generation sources, reducing dependence on energy imports, and mitigating the problems of climate change. Uruguay would be located – along with India – among the countries that adopted such a policy to reduce imports and, in particular, the so-called oil bill. This view, partially shared, does not address the set of problems that a peripheral country like Uruguay has from the point of view of global governance when thinking about an energy transition. One of the most important elements (and absent in the literature) are the problems of financing the change of the energy matrix in a peripheral country.

Finally, the work of Suárez et al. (2020) makes a detailed description of the types of contract and financing mechanisms for wind energy in Uruguay. Since it is a work carried out with the institutional support of the IDB, it has a particular detail about the lines of credit of said financial agent. The analysis highlights the set of measures that had to be taken to guarantee the "bankability" of wind projects, measures that are explained exclusively for financial reasons and not for energy reasons.

Although this is not a work that addresses the issue of renewable energies in Uruguay, it is important to refer to the contribution of Mazzucato (2013), who discusses the role of the State in financing investment in nonconventional renewable sources and, very particularly, in the development of technology for the generation of electricity with wind energy. It particularly highlights the importance of "development banking" to finance projects whose results can be visible in the long term. In a later article, it incorporates the detailed study of the type of financing agents for the development of technology in wind generation and its characteristics (Mazzucato and Semieniuk, 2017), constituting the most important work on the subject to date. Her thesis is that finance conditions shape and transform what is financed (or not). Additionally, they point out that the literature on innovation and development (I + D) has not paid enough attention to the processes of diffusion and disclosure and show that these are often essential to stimulate basic investment in I + D itself.

At the national level, the primary works can be broken down into those that focus on the dynamics of the process from the perspective of sociotechnical systems, the institutional environment, and the role of politics in explaining the rapid development of wind power (Ardanche et al. 2017; Ruchansky and Blanco, 2017; Factor, 2017; Bertoni et al. 2020). On the other hand, there are works that emphasize the process of privatization of the electricity matrix that renewable energies – particularly wind power – have specified in the generation link. In some cases, this phenomenon would have been conditioned by institutional-accounting restrictions for the development of public investment (Esponda and Molinari, 2017); in others, the emphasis is placed on the economic groups that invest in wind power and their strategies of productive diversification (Geymonat, 2019).

As for the former, Ardanche et al. (2017) focus on the prior creation of a "cognitive niche" since the early 2000s. The same, later became a sociotechnical transfomation project with the assumption of a progressive government from 2005. Subsequently, the great political agreements such as the multiparty agreement of 2010 and certain social consensuses allowed the rapid development of renewables in our electrical matrix. The work also carries out a detailed mapping of key actors in the process of changing the energy matrix that involves academia, state and public companies, private generators, and unions, among others. A relevant aspect that emerges from this approach is how the cognitive asset, resulting from the action of the public sector, University of the Republic – UDELAR, National Directorate of Energy and Nuclear Technology of the Ministry of Industry, Energy and Mining, influenced the design of the instruments to attract private capital.[2]

In another order and prioritizing the importance of multiparty political consensus, in Factor (2017), the accent is placed on some institutional aspects, highlighting as keys to the process of change in the energy matrix, the current regulatory framework and the possibility that it grants both to contract energy without offering firm power, as well as the transfer to consumers of the costs of the contract, giving confidence to project developers and financial entities. They also highlight the international arbitration and the fact that the PPA contracts were in dollars, assuming the UTE the exchange risks.

Finally, Bertoni et al. (2020) incorporate the aforementioned institutional aspects but add the importance of the existence of a financially solid public company, with a strong innovative imprint and monopsony power, which acted as guarantor and, to a large extent, as one of the keys to the success of the process. Additionally, the authors highlight the importance of political and social consensus for the rapid development of renewable energies in Uruguay, although they find a possible distortion factor in the change in the rules of the game in 2012 (abandonment of the tenders and acceleration of the process of installing wind farms), and this is linked to the difficulties in establishing productive linkages

[2] In addition to wind mapping and capacity factor estimates, the accumulation of information and management capabilities of a more complex electrical matrix, due to the incorporation of intermittent power in the network, were critical factors.

through the national investment[3] component, and they emphasize the union resistance that existed to what is understood to be a process of privatization of electric power generation.

The privatization of the energy matrix, as a corollary of the change of matrix toward renewables, has as its main background the work of Esponda and Molinari (2017). There it is emphasized that the low levels of traditional public investment in the new wind farm are explained by the restrictions imposed by the rules of the game that operate in public investment. Strictly speaking, his explanation is that IMF accounting manuals from the 1980s prevail in Uruguay, which, in a context of debt crisis, forced public investment to be recorded on a "cash basis." In this context, privatization or the proliferation of instruments such as leasing or other modalities makes it possible to record lower levels of fiscal deficit. The need to keep the fiscal deficit low to guarantee the Investment Grade rating, combined with the accounting rule of the public sector in Uruguay, constitutes the decisive factor to explain the current ownership structure of the wind generation sector in Uruguay (Esponda and Molinari, 2017).

In addition, Geymonat (2019) analyzes the ownership structure of renewables. According to the author, the participation of foreign capital prevails but differs depending on the energy source, exceeding 80% in biomass and photovoltaic and being close to 60% in wind energy. For the latter case, most of the investments come from Europe (Spain and Germany, mainly) and secondly, capitals of the region, where Argentina and Brazil stand out. On the other hand, within the national capitals, it discriminates its actions in three types. Those who tend to control a generating enterprise in its entirety, those who have specialized in the business and are dedicated to different phases of it (mainly project developers), and finally those capitals that are diffused in a larger shareholding package. An important contribution of his work is to show that the national capital, which has participated in the wind expansion, forms part – mostly – of large economic groups with a long history in the country, even in the case of new developer ventures that have managed to export services to the region. In addition, it finds that although national capital is a minority with respect to foreign capital, they control the union representation of the private generators AUGPEE.

Shortly, the "wind revolution in Uruguay"has been analyzed from different angles. On the one hand, as an example of rapid energy transition in a peripheral country that contributed to minimizing energy dependence. On the other hand, as an example between the complementarities of the public and private sectors in a process of socio-technical transformation. Within these, there is a smaller set of works that critically analyze the privatization of electricity generation associated with the change of matrix.

This chapter intends to incorporate a set of "topics under debate" that are still insufficiently analyzed in the literature. What impact does energy privatization have on the cost of supplying demand? Are there any costs associated with the process of financialization of energy that the energy transition presupposes? What is the role of public companies?

12.3 Stylized Facts of the Energy Transition in Uruguay

In the last 50 years, the total consumption of primary energy in Uruguay has doubled, going from 2500 to more than 5000 kTEP (MIEM, www.ben.miem.gub.uy) and the supply by source has notably changed its structure, observing an important decarbonization process. Fossil fuels, which represented 70% of gross supply in the 1970s, fell to 40% in the year prior to the outbreak of the SARS-CoV-2 pandemic (Fig. 12.1).

[3] In Altomonte (2017: 37), it is stated that with regard to the efforts to articulate the national technological, industrial development and associated national services, from the inclusion in the so-called price incentive bids for those projects with a greater national component, "the results did not live up to expectations".

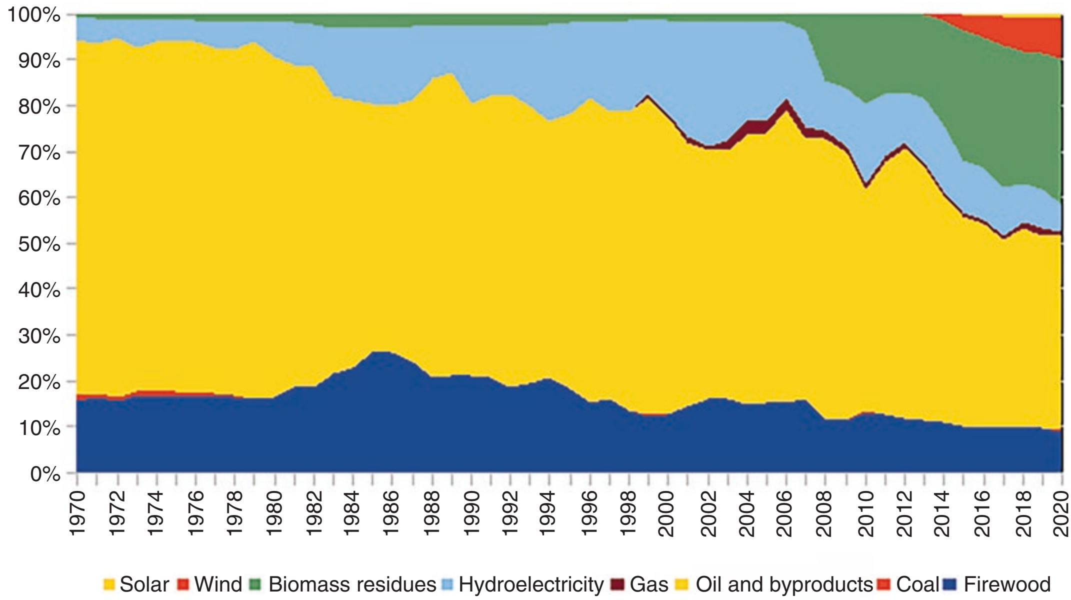

Fig. 12.1 Uruguay: Primary energy consumption by source (1970–2020) (in percent share). (Source: MIEM, BEN, n.d.)

This trajectory is explained partly by a structural factor, the extreme dependence on oil as a primary source in a country that does not have deposits of this or any other fossil fuel (coal, natural gas). Consequently, exploiting autochthonous sources to reduce energy dependency from abroad constituted a recurring problem in Uruguayan energy history. The oil shocks of the 1970s of the last century implied an additional stimulus to look for alternatives and the energy crisis at the beginning of the twenty-first century, the increase in the oil bill, and the concern about the effects of climate change have contributed as catalysts. In other words, Uruguay has been "green" in its energy strategy out of necessity.[4] However, the dynamics of the transformations is the result of the public policies deployed (Bertoni et al., 2010, 2011, 2020).

The last episode in this process is located between 2015 and 2017 and is characterized by the significant incorporation of wind energy, for the generation of electricity, in the Uruguayan energy matrix. As a result, in the last decade, this source increased its participation in the primary matrix, going from 0.1% to 9% of the total supply. This has had a significant impact on a significant drop in the share of oil in the primary supply of around 10 percentage points.

In this context, it is of interest to investigate the changes that have occurred in the electricity sector in the last decade due to the magnitude of the transformation in the generation matrix and, particularly, to describe in this section and discuss – in the following sections – the factors that propitiated the so-called wind revolution in Uruguay (Fig. 12.2).

[4] The incorporation of modern forms of energy into the Uruguayan energy matrix manifested itself in a growing dependence on foreign sources to obtain fossil fuels. The absence of these in the territory and the need to incorporate technologies associated with the technical system of electricity led Uruguayan society to discuss early technical and institutional alternatives to ensure supply. The only abundant indigenous sources to meet the challenge were water and wind (Bertoni, 2011). Research to develop a "national fuel" and to exploit hydraulic resources in Uruguay dates back to the first decades of the twentieth century (Martínez, 2007; Waiter, 2019). The first evaluations of the wind resource were carried out in the 1950s by the engineers Emanuele Cambilargiu, Oscar Maggiolo and Agustín Cisa (Bertoni, 2020).

The installation of 1500 MW of wind power in less than ten years, in a country where the total installed capacity for electricity generation is around 4900 MW, constitutes an extraordinary phenomenon, due to its scope, but also due to its speed (Table 12.1). In 2005, Uruguay did not generate electricity from wind, between 2019 and 2020 this source generated – on average – 35% of the total, which has led the International Energy Agency (IEA) to qualify the country as a leader in Latin America in energy production from non-conventional renewable sources and fourth in the world in terms of electricity generation with wind and solar sources (CAF, 2021).

Various articles have spoken of Uruguay as an example to follow (Wynn, 2018; Costa Correa et al., 2022), since, faced with the global challenge of implementing actions for the decarbonization of energy matrices, the Uruguayan case can contribute elements to the debate on the timing of the transformations necessary to achieve a "greener" global matrix (Sovacool, 2016).

Although in Uruguay, the participation of hydroelectricity has been historically important, the irregularity of the hydroelectricity in the plants, located on the Uruguay and Negro rivers, forced to have an important firm capacity in thermoelectric plants. As can be seen in Fig. 12.2, years of good rainfall records in the basins made it possible to generate between 80% and 100% of electricity from hydroelectric plants (2002–2005), but in years characterized by droughts, the participation of these power plants falls to 50–60% (2006, 2008–2009, 2011–2012). Climate variability imposes a degree of uncertainty, with significant economic impacts due to the need to supply thermal power plants with imported fossil fuels.

The incorporation of nonconventional renewable energies such as biomass, wind, and solar waste not only significantly reduced the dependence on fossil fuels for thermal generation (Fig. 12.2) with the consequent relaxation of the pressure on the balance of payments, but it also expanded the supply of electricity to the point of becoming the country's net exporter of electricity to the region (Fig. 12.3). Although the energy exchange is not a new phenomenon, its systematic surplus registered in the last seven years (expressed in the graph as net exports) is an absolutely new phenomenon. To manage an order of magnitude, the exports of electricity between 2017 and 2020 averaged 1.2% of the value of total exports (Uruguay XXI, n.d).

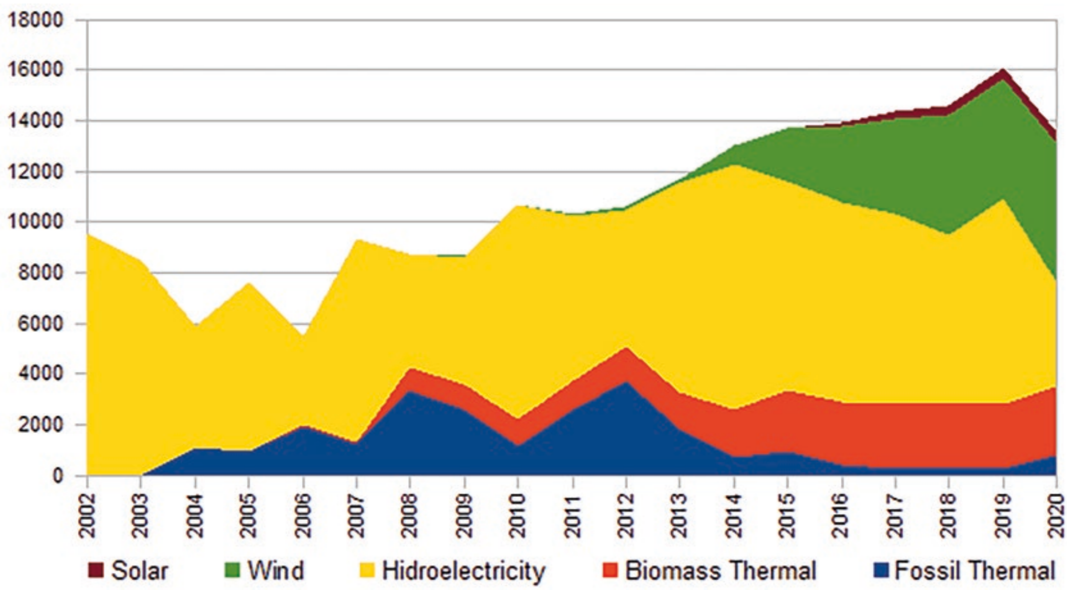

Fig. 12.2 Uruguay: Electric power generation by source (2002–2020) (in GWh). (Source: MIEM, BEN, n.d.)

Table 12.1 Uruguay. Electric power. Installed Power by Source (2005–2020) (in MW)

	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Fossil	497	801	878	876	876	1.076	1.275	1.275	1.105	650	830	1.190	1.190	1.190
Biomass	14	173	173	236	243	244	414	415	425	425	425	425	425	425
Hydraulics	1.538	1.538	1.538	1.538	1.538	1.538	1.538	1.538	1.538	1.538	1.538	1.538	1.538	1.538
Wind	0	15	31	41	44	53	59	481	857	1.211	1.511	1.511	1.514	1.514
Solar	0	0	0	0	0	1	2	4	64	89	243	248	254	258
Total	**2.049**	**2.526**	**2.620**	**2.690**	**2.701**	**2.911**	**3.288**	**3.713**	**3.989**	**3.913**	**4.546**	**4.912**	**4.920**	**4.925**
Wind/total	**0%**	**1%**	**1%**	**2%**	**2%**	**2%**	**2%**	**13%**	**21%**	**31%**	**33%**	**31%**	**31%**	**31%**

Source: MIEM. National Directorate of Energy

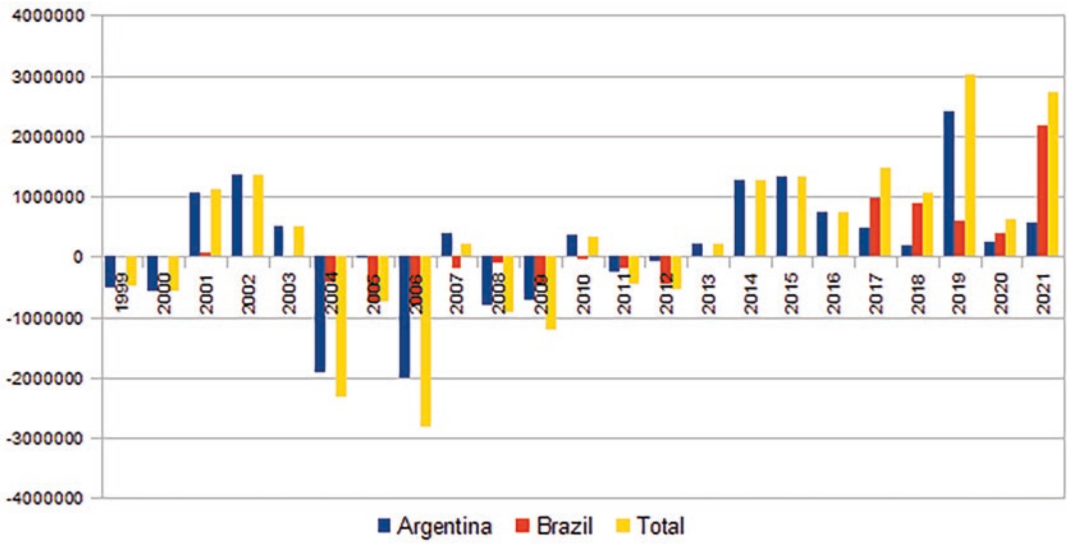

Fig. 12.3 Uruguay: Net exports of electric power (1999–2021) (in MWh) [Note: 2021, 11 months]. (Source: UTE; Taken from https://www.gub.uy/ministerio-industria-energia-mineria/datos-y-estadisticas/datos/series-estadisticas-energia-electrica)

The phenomenon under analysis also represents a milestone in the economic history of the country in terms of the amount of investment. The annual average investment in wind farms was around one billion dollars, which represented between 1.5% and 2% of GDP between 2013 and 2017 and the accumulated – between 2010 and 2017 – exceeded five billion (Fig. 12.4).

In this context, it is relevant to state that the incorporation of wind farms to the electricity generation matrix in the country has resulted in 2/3 of the installed wind capacity corresponding to farms built with private capital, 6% is traditional public investment, through the Administration of Power Plants and Transmissions of the State (UTE), 23% the result of some type of association between this company and private capital in the form of corporations and trusts and 5% under the leasing system (Fig. 12.5). It should be noted that this massive incorporation of private capital in the area of electricity generation is a novelty.[5]

12.4 The Institutional Framework and the Policies That Empowered the Wind

From the institutional point of view, the platform from which the set of legal instruments for the transformation of the electricity matrix in Uruguay was configured has been the “Law of Regulatory Framework of the Electricity Sector” – Law No. 16,832 of the year 1997. In accordance with the aspirations of the “National Electricity Law” (Decree-Law No. 14,694 of 09/01/1977), the regulatory framework proposes the establishment of a competitive market in the generation stage. Consequently, a Wholesale Electricity Market (MMEE) and the Electricity Market Administration (ADME) are created as a nonstate public entity. In addition, said rule enabled the public electricity company, Usinas y Transmisiones Eléctricas del Estado -UTE-, to associate with public or private companies, national or foreign, within the country and estab-

[5] Since 1912, the UTE held a monopoly on the generation of electricity for public service, even though the installation of some private biomass plants – and especially the cellulose plants – constituted an advance in that sense. Between 2005 and 2015, the share of this source increased 15-fold, reaching 9% of installed power in the last year.

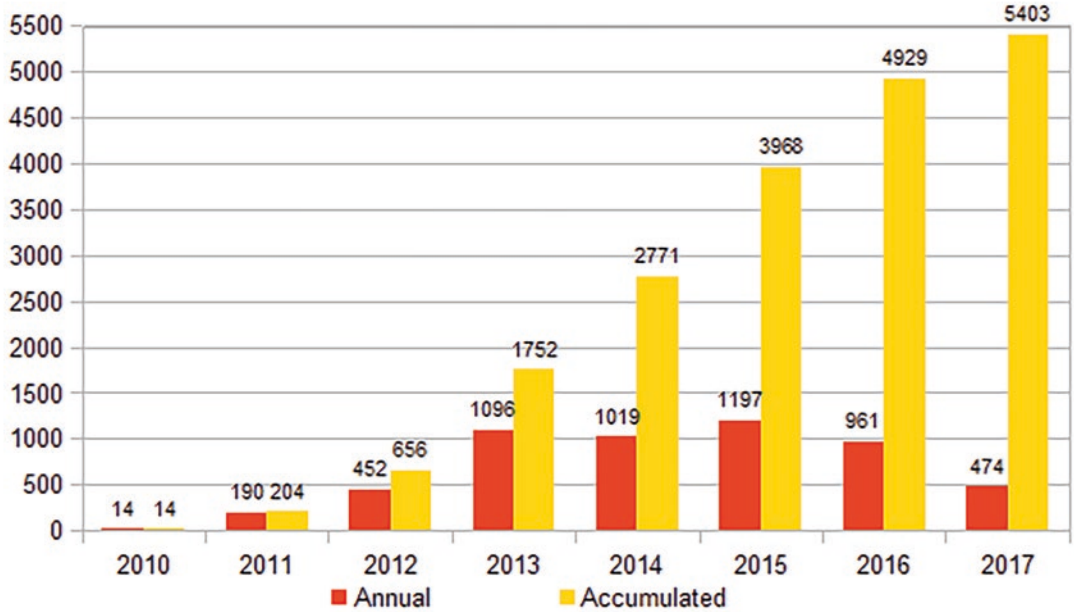

Fig. 12.4 Uruguay: Investment in wind farms during the period 2010–2017 (in Millions of US dollars). (Source: Suárez Alemán et al. 2020)

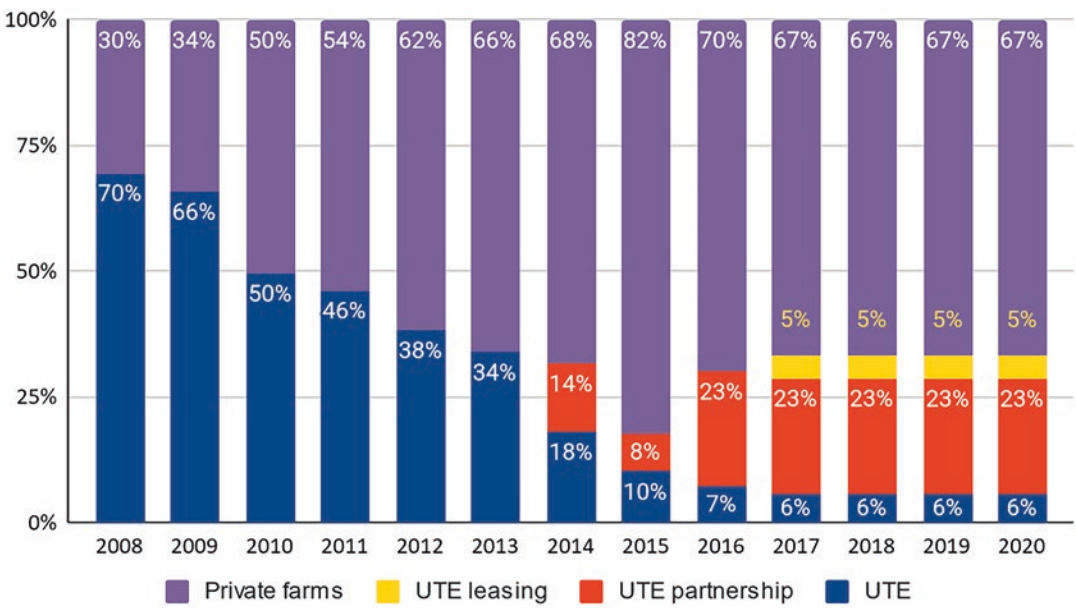

Fig. 12.5 Uruguay. Wind generators. Installed power by type of property (in percentage participation). (Source: UTE and DNE)

lish specific supply and purchase contracts. Additionally, it created the Regulatory Unit for Electric Power, with the purpose of separating the roles of business and regulator from the State (Dubrovsky and Ruchansky, 2010). But although the "regulatory framework" was a necessary condition, it was not a sufficient condition for the process to take place.

Following Ruchansky and Blanco (2017), a long regulatory process is observed: Decree 22/999 and its subsequent modification with Decree 276/002 of the year 2002 advances in regulatory instruments for the conformation of the electricity market and its operation. Decrees 277/002 and 278/002 establish the Electric Power Distribution Regulations. Subsequently, more modifications were made to the Electricity Market that can be traced back to 2010 and devices were created to regulate the entry of new generators. In historical perspective, it is possible to affirm that this proliferation of adjustments in the rules of the game responded to the weakness of the stimuli exclusively coming from the market to attract private investment in the electricity sector.

In this framework, a set of specific policies were deployed, as well as other more general ones, which contributed to the development of wind farms in Uruguay. The first thing to point out is the existence of an explicit energy plan from 2008, called "Energy Policy 2005–2030", which establishes the central role of public energy companies in the process and frames the participation of the private sector. This instrument acquires a major dimension given the political consensus achieved – the support of all the political parties with parliamentary representation in 2010, which made it a state policy.

12.4.1 Tenders as a Competitive Award Mechanism

The main tool used for the development of wind farms was the Power Purchase Agreement (PPA) type of contract, the predominant modality at a global level in the development of non-conventional renewable energies. To concretize them, the Executive Power set up bidding processes through which bidders were selected, explaining the principle of transferring purchase costs to rates. The UTE was in charge of carrying out each call for bids, preparing the specifications according to the policy guidelines and the regulations that regulate acquisitions for public companies.

After some trials, Decree 403/009 authorized UTE to carry out competitive procedures for the contracting of 300 MW of wind power and regulated a first stage. Consequently, UTE – in February 2010 – launches the specifications for the call for energy purchases for a total of up to 150 MW of wind power (Tender K39607). All the capacity was awarded in a context of surplus supply of projects.

In 2011, a second stage was implemented through decree 159/011, whose established goal was another 150 MW, which allowed reaching the objective established in the Multiparty Agreement signed in 2010. Prices in 2010 ranged from US$ 85 and US$ 87 per MWh, while in 2011 the average was US$ 65 per MWh (the cheapest offer being US$ 62.5).

Among a set of stimuli to attract private investment, these contracts establish a higher energy purchase price for early entry into service, the purchase guarantee of all the energy sold – and of that which the system does not could absorb due to operational restrictions – and the subsidiary responsibility of UTE and the Uruguayan state before financial entities (Bertoni et al., 2020).

As Esponda and Molinari (2017) point out, in Uruguay the development of private wind energy did not take place within the framework of the free market game, but rather it took place under a monopsony regime, where the State through the UTE ensures the purchase of energy for 20 years, thus assuming the risk of business demand, and thus facilitating the obtaining of financing by private agents.

That of 2011 was the last competitive experience given that, in December of that year, through the issuance of Decree 424/011, the signing of contracts for the sale of electricity with UTE was authorized for those projects that had not been awarded. The cheapest price that resulted from the competitive process (62.5 USD/MWh) and the maximum power at 50 MW were set as the offer price. In total, 13 initiatives for 537.8 MW were received (Ruchansky and Blanco, 2017). In that sense, new contracts took place with the condition of accepting 62.5 U$D/MWh as the price in which the contracts were established. This is one of the main reasons why the energy wind supply surpassed the 900 MW originally planned as the maximum.

When auctions were abandoned as a competitive adjudication mechanism, there was a change in the rules of the game. The acceptance of it – without resistance – by all the actors can be explained due to a convergence of interests and expectations. For private investors – who had the initiative – the price per MWh guaranteed by UTE ensured the profitability of the business – although some had submitted prices above US$100 per MWh in the tender).[6] For UTE, the price was considered convenient, and it was seen as an opportunity to accelerate the installation of wind power due to the estimated demand projection. For the Executive Power, it meant the opportunity to comply in advance with the goal established in the 2005–2030 Energy Policy.

12.4.2 A Commitment to Production Chains: The "National Component" Policy

Under the leadership of the National Directorate of Energy and in coordination with the National Directorate of Industries of the Ministry of Industry, Energy and Mining (MIEM), the aim was to favor the incorporation of national added value to wind farms. The sectors identified as potential participants in the national component were the electrical industry (transformer industry and cable industry), heavy metallurgical, construction (civil works, foundations and assembly), plastic industry, software and electronic industry. In the development of electricity generation infrastructure projects, which had UTE as a fundamental actor, mechanisms were implemented to promote supply or national integration (Bertoni et al., 2010).

The public-private articulation was fundamental. The Chamber of Industries of Uruguay (CIU) was responsible for designing an evaluation methodology and defining the criteria to consider what is a "national component." In addition, the CIU itself was the certifying entity of the national component in said investments, and together with the public sector, called business rounds to encourage the participation of national companies in these projects.

The decree 403/009 began to require a minimum percentage of the national component of the investment equivalent to 20% of the total amount of investment planned for the construction of the wind farm. In turn, a bonus mechanism was determined in the comparative price of the incorporation of national inputs that exceeded the 20% minimum required.

Unfortunately, the scarce national industry capacities, combined with the quickness of the transformation process, inhibited the industrial possibilities of getting involved in the capital goods supply. In fact, the main national components were two: the civil workforce and the technical studies (design projects, legal system analysis, etc.).

The incorporation of the national industry took place in the links with the lowest added value of the wind chain. One factor that could influence this limited contribution was the acceleration of the adjudication process in 2012, making it difficult to reconvert some branches.

Nevertheless, regarding the development of technical capacities associated with services, the requirement of a minimum national component allowed the development of national capacities instead of prioritizing the hiring of international companies with significant experience in developing this type of business. In fact, many local companies have managed to export this type of service to the region and have internationalized, as is the case with Ventus, SEG Engineering and CCI.

In construction materials, as is the case of cement, a high supply of national products was verified, although it is not easy to identify if this

[6] Oscar Ferreno. Interview conducted for this job.

was due to the policy, or that -given the characteristics of these inputs: whether such policy had not existed the materials would also have been mostly of national origin.

Regarding the national provision of capital goods, the success of the policy seems less auspicious, despite the creation of new incentives for the incorporation of capital goods of national origin.

12.4.3 The Role of the Public Sphere as the Basis and Guarantee of the Wind Revolution

In comparative historical perspective, the emergence of the industrial and commercial domain of the Uruguayan state starts quite early. Already in the second decade of the twentieth century, a series of public entities were created to fulfill some productive functions or to provide certain services. Then the Administration of the State Electric Power Plants[7] –UTE – was born, to whom the law conferred the monopoly of generation, transmission, and distribution. The permanence in the exercise of the executive power of the Red Party throughout the first half of the twentieth century, gave continuity – beyond the emphasis in different historical moments – to an institutional framework in which strategic areas in the economic plane had the public sector as relevant actor (Carracelas et al., 2006).

Although in the second half of the twentieth century, the strategies of economic liberalization were undermining the areas of action of the state, some of the key premises regarding the leading role of the public sector in certain strategic spaces were maintained, even when the prescriptions of the "Washington Consensus" in the last decade of the century had worsened in the region, on more than one occasion, due to the exercise of direct democracy by citizens, preventing privatization (Dominzain, 2012).

In Uruguay, unlike other Latin American countries, a generalized wave of privatizations in the last quarter of the twentieth century and the subsequent wave of renationalization in the first decades of the twenty-first century did not take place. In this sense, it did not suffer the transaction costs associated with this dynamic. The continuity, strength, and legitimacy of public companies constituted an important asset as an organizational-institutional platform to design public policies aimed at strategic sectors, including the energy sector (Altomonte, 2017).

In another order, the study of development possibilities around wind energy in Uruguay has some 60 years of history, and it is an essentially academic phenomenon, linked to the public university (Ardanche et al., 2017). The signing at the beginning of the 1990s of an agreement between UTE and the Faculty of Engineering of the University of the Republic to evaluate the wind potential of Uruguay and implement a pilot project (installation of a 0.15 MW wind generator in the Sierra de los Caracoles) constituted a key milestone in the transfer process (Ruchansky and Blanco, 2017).

The change of political force in the government made the links between academia and the public sector closer. Several researchers from the University of the Republic (UDELAR) went on to occupy key positions, both in the National Directorate of Energy and in the UTE. A "common language" and a "circle of trust" among experts who have previously worked together were key to moving quickly towards the energy transition (Ardanche et al., 2017). The other item to highlight is the incorporation of parks of its own by the public electricity company. This also helped in providing knowledge on wind resource management in Uruguay. The public electricity company has installed 504 MW of wind power – approximately 1/3 of the total – through different modalities.

Finally, the UTE has been a guarantee support throughout the process. In fact, the expansion of the private sector in wind generation was promoted by the UTE, generally through PPA contracts. However, its key role does not end there.

[7] Originally this state company was called the General Administration of State Electric Power Plants (Law No. 4273 of 10/20/1912).

In this sense, it is worth analyzing what happened in the Spot Market.

Given the profitability guaranteed by the PPA contracts, the commitment to the Spot Market by the private sector was marginal, representing 8% of private wind generation and 5% of the total. The Spot price has not had the level and evolution that private agents expected. Figure 12.6 shows that, between the years 2016 and 2020, the price sanctioned in the Spot was considerably lower than that of the PPA contracts, except for the year 2021, in which it averaged 87.1 US$/MWh. In general, the price was much lower, in particular in 2019, where the level was extremely low (7.6 US$/MWh). In this context, it is plausible that private generators have chosen to negotiate PPA contracts.

Between February 2019 and March 2020, a "direct negotiation" process began through which the wind farms – which until then generated only for the Spot market – began to have contracts with the UTE. The contracts are PPA and have an adjustment parameter analogous to those contracted by auction. The base prices were US$ 45 per MWh, prices substantially lower than the average of the other contracts, which is around US$ 70.

The incorporation via direct negotiation by the UTE of those parks that bet on the SPOT market admits different readings. On the one hand, it reinforces the idea of the UTE as the ultimate guarantor of the private sector, incorporating them into the PPA contract regime, in case the bet turned out to be unattractive or unprofitable, as the evidence suggests. On the other hand, some UTE actors see this measure as a way to avoid the proliferation of "business between private parties," while guaranteeing good prices in the contract.

12.4.4 The Horizontal and Sectoral Policies that Contributed to the Promotion of Nonconventional Renewable Energies

A complementary instrument that helps explain wind development in Uruguay is the general investment regime (Law No. 16,906 and subse-

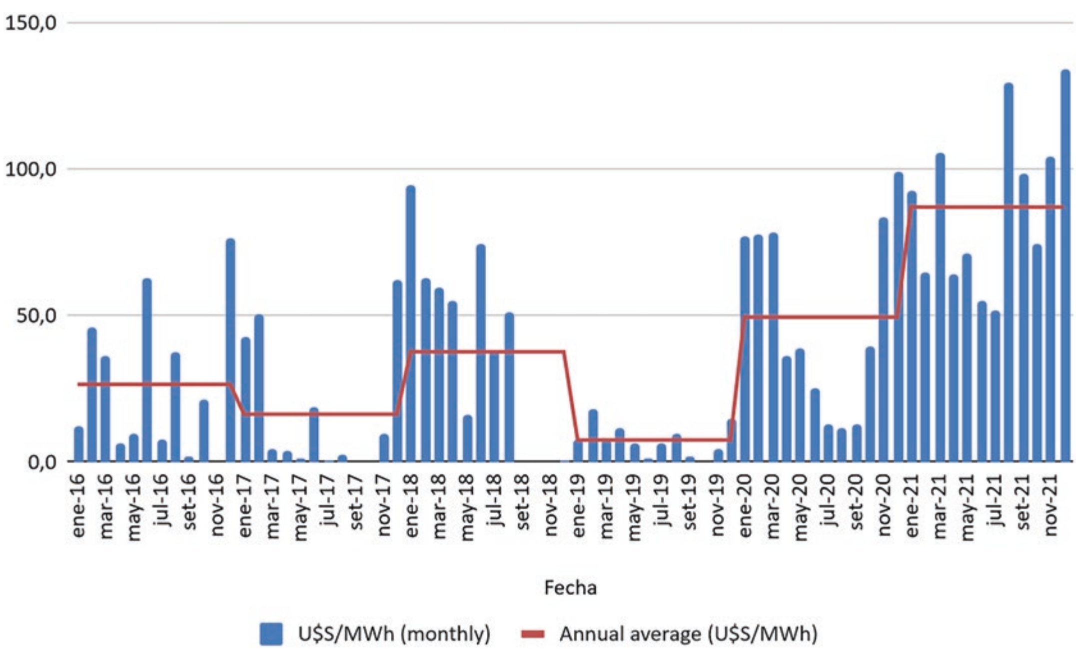

Fig. 12.6 Uruguay. Price of electric energy in the spot market monthly and annual average (2016–2021) (in US$/MWh). (Source: Own elaboration based on data from Administración del Mercado Eléctrico–ADME (v/a) (n.d.))

quent amendments) and regulatory decrees. In particular, Decree 02/012 – of the year 2012 – includes renewable energies among the activities that are considered to use clean technologies and, therefore, can benefit from additional incentives, such as the possibility of discounting a higher percentage of the Tax on Income from Economic Activities (IRAE).

On the other hand, Decree 354/009 already granted specific tax incentives for undertakings whose purpose was the generation of electricity from nontraditional renewable sources, under Article 11 of Law No. 16,906. Specifically, in the case of wind energy, the exemption implies 90% of IRAE for investments made between 07/1/2009 and 12/31/2017; 60% between 01/1/2018 and 12/31/2020; and 40% between 01/1/2021 and 12/31/2023 (Article 3). These exemptions only apply to electricity sold in the forward market. Adherence to the fiscal instrument was very high (Bertoni et al., 2020).

12.5 Topics in Debate for a Balance of the Wind Revolution in Uruguay

Based on the transformations observed in the electrical matrix in Uruguay, various factors operated that must be considered when evaluating the process and the results.

In the first place, the country suffered a deep economic-social crisis at the beginning of the 2000s that had its manifestation in the energy sector; secondly, in 2005, the government was taken over by a left-wing coalition –the *Frente Amplio* – with a clear definition favorable to reaffirming the role of the state in economic and social development and, particularly, in strategic planning to overcome structural problems in various fields. It is in this context that the design and implementation of the "Energy Policy 2005–2030" is explained, a key instrument to understand the dynamics of changes in the energy matrix in Uruguay and subsequently in the electrical matrix.

In addition to these "endogenous" phenomena, three "exogenous" phenomena must be considered, namely: the extraordinary rise in the international price of oil in the first decade of the twenty-first century and its impact on a country without fossil reserves; the economic crisis of 2008 in the "capitalist center" and, consequently, the possibility of accessing financing in the international capital market at relatively low rates; and, finally, the existence of a mature technology linked to the generation of electricity from wind energy and an oversupply of capital goods linked to such technology.

The convergence of local problems and strategies with the international situation, although it was not random – given that public policy acted as a catalyst – should be considered a key element to understand the wind revolution in Uruguay.

Next, some relevant aspects of the process are explored to discuss its determinants/conditions and its impact, as well as to extract some lessons for a second energy transition.

12.5.1 The Role of Public Goods

The institutional solidity, but also the fact that the decision makers in the public sector had the human and organizational resources suitable for the implementation of a strategic plan in energy, was very relevant.

The existence of a public university, in which 80% of the knowledge production carried out in the country is concentrated and where 78% of the researchers of the National System of Researchers (SNI) carry out their activities constituted a key asset. It should also be noted that the University of the Republic (UDELAR) has historically shown a strong commitment to solving problems in Uruguayan society, mandated by article 2 of its Organic Law.

UDELAR had a significant accumulation in energy matters and, from this, it was possible to have useful knowledge and trained human resources to support technological change and solve emerging problems (Ardanche et al., 2017).[8] The extraordinary sociotechnical change that has taken place is impossible to explain without considering decades of research, teaching, and university extension. Complex processes, paths and trajectories positioned UDELAR in dialogue, tension and action with the government and the private sector.

Additionally, the creation – in 2006 – of the National Research and Innovation Agency finished configuring a very relevant organizational-institutional framework to support and accompany the challenges of energy policy. This agency has the purpose of promoting and fostering inter-institutional coordination in a transversal way, articulating social and productive needs with scientific, technological and innovation capacities.[9] In this context, the "Energy Sector Fund" was managed, which had resources from the public oil company (National Administration of Alcohol and Portland Fuels - ANCAP), the state electricity company (UTE) and the Ministry of Industry, Energy and Mining, entities that constituted the agenda committee to establish priorities among the qualified projects from an academic evaluation committee.

It is impossible to understand the dynamics of the energy transition in the Uruguayan electricity sector without considering this platform, based on which it was possible to design and implement a public policy that, based on a multiparty agreement (2010), was instituted as a state policy that managed to articulate with a set of capacities rooted in various social actors and allowed consensus on a common project. Investment in the energy sector and in wind farms was stimulated by having information and academic and technical support for the preparation of projects, the estimation of performance, and the opportunity to attract resources for their implementation.

12.5.2 The New Electricity Generation Matrix: Water and Wind, Complementation or Competition?

According to the results of a study carried out by the Uruguayan Association of Private Electric Power Generators, released in March 2021, the mix of sources and load dispatch management has allowed a reduction in the cost of supplying demand by 43% when comparing the five-year periods 2007–2011 and 2015–2019 (AUGPEE, 2021). Although the comparison has problems given that in the first 5-year period there were significant episodes of drought (2008, 2009, 2011) that affected the supply of hydropower, it is clear that the electricity system has achieved greater stability and, as has been shown in 2020 and 2021, it is more resilient to hydrological variations. In this sense, two key objectives of the energy policy would have been achieved: security of supply and reduction of oil dependency.

A critical perspective on the costs associated with supplying the demand can be found in Sanguinetti and Messina (2017). The exercise carried out by the authors, with scenarios of average hydraulicity and with "dry" years, offers interesting elements to discuss the impact of incorporating wind energy – with the predominance of private generation, as has been carried out.

These two works are the only ones that propose possible counterfactuals in which it is suggested that the cost of supplying the demand could have been lower. In dialogue with this line of argument, even acknowledging a scenario of greater stability of the system, we consider it relevant to discuss the eventual cost overrun that UTE's commitment to purchase all the electricity generated by private wind farms may imply in accordance with PPA contracts (at an average cost of US$70 per MWh) and, therefore, the dispatch priority for this source over hydroelectricity.

[8] To make investment decisions, you need a solid understanding of the expected energy performance and the associated level of confidence. The wind map was developed by the Faculty of Engineering of the University of the Republic in 2009, through an agreement with the Uruguayan Wind Energy Program (PEEU) and made available to investors. http://www.energiaeolica.gub.uy/index.php?page=mapaeos

[9] Law No. 17930 of 12/19/2005, article 256 (accessed 12/08/2022).

The statement that the reduction in dependence on water flows, because of the contribution of biomass – since 2007 – and wind power – since 2016, offers stability to the system is not objectionable. However, the dispatch conditions established in the PPA contracts prevent from taking advantage of the years of good hydroelectricity to prioritize the dispatch of cheaper energy.

As shown in Fig. 12.7, The irruption of wind power in the electricity matrix corresponds to a drop in the share of hydroelectricity in generation. While it remains at high levels, between 2016 and 2019, hydraulic energy does nonturbined, which would be suggesting competition between sources, while the 2020 drought episode causes the wind to appear, compensating for the meager performance of hydropower (Fig. 12.7).

In any case, it is necessary to delve into this issue, since it could be read that a high percentage of nonturbined hydropower at times of good hydraulicity would be the cost of ensuring supply in dry years (2020). If this investment is optimal and if the rigidity of the PPA contracts is ideal in economic terms, this is what should be evaluated.

To the extent that the need to establish the forms and instruments of a "second energy transition" in Uruguay has been incorporated into the political agenda, it would be important to assess the degree of rigidity imposed by some contractual instruments in decision-making regarding the management of a strategic asset such as energy.

12.5.3 The Wind Boom and Financialization

The PPA contracts had – and have – the task of ensuring profitability for private investors, but also – and fundamentally – they provided the opportunity to access credits to finance this investment, generating conditions of "bankability" of the projects. Suárez et al. (2020: 4) point out that the impressive growth of wind energy in Uruguay cannot be explained without the presence of "increasing levels of sophistication and financial innovation that increased the bankability of the projects" and emphasize that the PPAs were "the cornerstone that provided bankability to wind projects" (Suárez et al., 2020: 30).

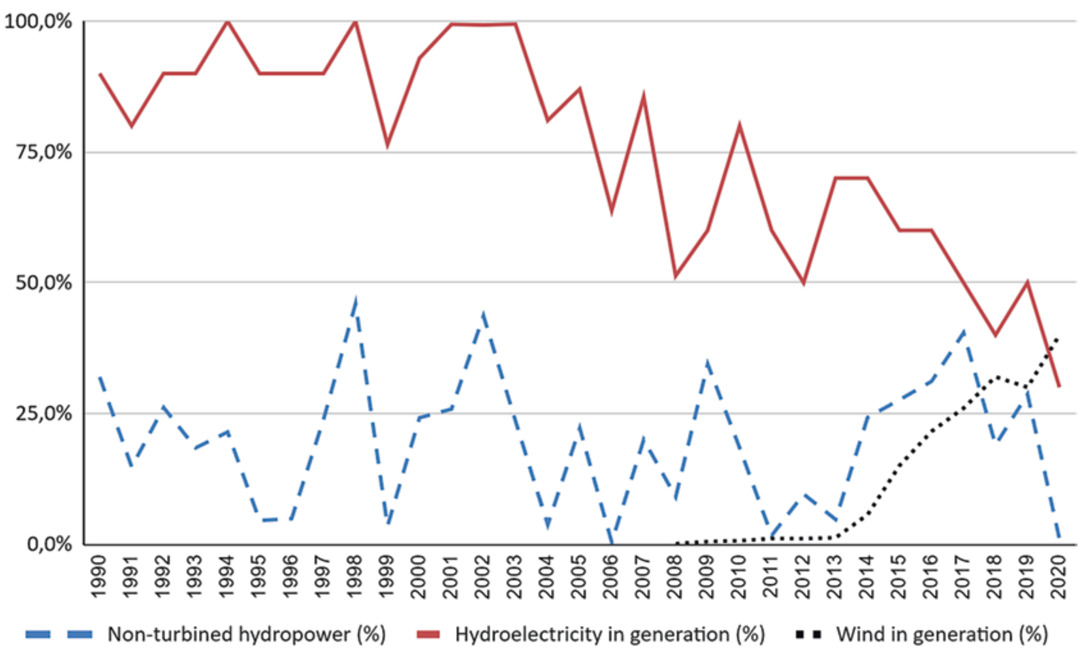

Fig. 12.7 Water and wind in electricity generation. (Source: National Energy Balance and UTE)

The private sector then found the opportunity to use the credit modality with the imprint of "project finance" that can be defined as a credit mechanism that is not based on the support of the project promoters, nor on their solvency or assets, but on the technical, economic, and financial performance of the financed project. Consequently, "the repayment of the capital and the interest service and other financing expenses depend exclusively on the project's capacity to generate a sufficient cash flow to cover the financing and a return for the investors" (Martínez de Hoz y White, 2018: 9).

The Uruguayan state created the necessary conditions for the wind business to reach levels of bankability capable of being valued positively by international financial capital. From this perspective, it is interesting to discuss – as Mazzucato and Semieniuk put it – to what extent finance conditions shape and transform what is financed (or not) and, consequently, what is financed. The prevalence of one or another type of financing privileges certain technological areas. Consequently certain levels of risk and particular areas of innovation, a process in which the directions of the innovation process are induced (Mazzucato & Semieniuk, 2017).

Uruguay, as a small peripheral economy, has not been able to influence further than generating the "investment climate" in the financialization of wind generation and in this sense, it would be very important to discuss how it has impacted on the pace and direction of the wind revolution that some authors have pointed out as the real subsumption of the productive sphere to the world of finance (Chesnais, 2019). The National Director of Energy himself stated in 2015 "...one has to understand that the wind business is basically a financial business... "What is the cost of energy? Repay the initial investment. This means two things: first, get the best price; second, get the best interest rate".[10]

To the extent that during the years 2011 and 2015 the preference for liquidity was not so high in the global financial markets and before the rain of potential investors, the Executive Branch authorized the award of almost 1000 MW to private investors. This decision involved weakening one of the pillars of the 2005–2030 Energy Policy, which was established to prevent the private sector from being dominant in the different subsectors.

Additionally, there is an issue that emerges in peripheral countries – such as Uruguay – when analyzing contracts. They commit the payment in US dollars of the generation of the wind farms and the price adjustment based on the parity of purchasing power, as well as the recognition of international arbitration in the event of a conflict of interest.

A part of the economic literature, the one that critically analyzes the costs of globalization for peripheral countries, points out that the need to appeal to foreign investors and/or credits from international banks to develop investment dynamics makes it necessary to design a scaffolding institution capable of capturing and maintaining reserves in "hard currency" as a way of granting "reinsurance" to the fulfillment of commitments (Lapavitsas, 2016). In the case that concerns us, the financing of the wind revolution, brings into play what some authors call the problem of the "hierarchy of currencies" (Piqué, 2016) and installs an emerging problem since the collection for the sale of energy electricity is made in national currency, but payment to suppliers must be made in foreign currency – in this case dollars.

As the Inter-American Development Bank itself points out, "having assets in one currency and liabilities in another – or monetary mismatch – has played an important role in some of the recent Latin American financial crises...".[11] Taking note of this type of risk to design future instruments in a second transition appears recommended.

[10] Interview with Ramón Méndez on Radio El Espectador (07/05/2015). Quoted by Esponda, 2018.

[11] https://www.iadb.org/es/noticias/el-doble-filo-del-descalce-monetario

12.5.4 Dynamics of Auctions and Awards: The Price of Energy and the CNI

Most of the works that analyze the "wind revolution" in Uruguay value very positively the mechanism of the auction or bidding as a competitive mechanism to carry out the adjudication of wind projects. However, as appears from the documents reviewed, in 2012, UTE directly awarded nine wind farms among those bidders who had submitted to the call in 2011 to the extent that they were willing to sell electricity at the lowest price of the bids awarded in that auction.

Although some authors understand that the auctions were intended to discover the generation price and subsequently offer a regulated rate without an auction process (Factor, 2017), there is no doubt that there was a change in the rules of the game. As a matter of fact, most of the renewable generation in Uruguay has not been contracted through competitive processes, but through the acceptance – by private investors – of a rate decided administratively (feed-in tariff) and through public investment not traditional by UTE. Undoubtedly, this mechanism allowed an acceleration of the process of incorporating wind energy into the Uruguayan electricity matrix and contributed to the achievements – in depth and speed of change – that have been presented in Sect. 12.2.

In perspective, it is possible to speculate on the fact that the maturation of wind technology, the learning in terms of project design and development, as well as the macroeconomic context – at least until 2015 – could have operated in the direction of obtaining better prices. This would seem to indicate the prices obtained by Argentina in the bidding processes carried out in 2016 and 2017, which averaged 57 dollars per MWh, the first and 41 dollars per MWh the second, in contrast to the 65 dollars average paid by Uruguay in the resulting awards of the application of Decree 424/011.

There are conclusive opinions that the counterpart of the low prices obtained in the auctions in Argentina is that the projects -to a great extent- have not been developed,[12] which would reinforce the idea that Uruguay took advantage of the opportunity and that success would lie in the fact that the projects were completed in time and efficiently.

However, some indicators on a global scale invite us to analyze and discuss the cost of wind energy in Uruguay, in comparative perspective. According to Lazard (Table 12.2), already in 2015, the average price per MWh paid by Uruguay through PPA contracts is very close to the upper threshold, even in the "without subsidy" [13] category, and in the following years, the difference increased, suggesting that the country, by completing the power installation with the contracts entered into in 2012, would have missed the opportunity to take advantage of the downward trend in prices.

In the same sense, it seems to point to the concretion of UTE contracts with private generators that until 2019 only offered electricity in the Spot Market and that in that year and the following signed PPA contracts through direct negotiation with UTE, setting a base price of 45 dollars per MWh (see Sect 12.4.3).

Additionally, the acceleration of the process could have had a negative impact on the "national investment component" (CNI) policy, as pointed out by Bertoni et al. (2020). The national industry, beyond the structural weaknesses that are handled in that work, could be unable to make the necessary investments and adjustments to respond – in such a limited time – to the concentrated demand especially for capital goods, equipment, and construction materials. Infrastructure.

It is possible, as the qualified informants interviewed for this study have stated, that with the information handled in 2012 and given the prospect of maintaining and increasing electricity demand, that the decision to abandon competitive

[12] Oscar Ferreño in an interview conducted for this work.

[13] It should be noted that the maximum level without subsidies incorporates some "tax expense" since it implies the noncollection of corporate income tax during the first five years (see https://www.youtube.com/watch?v=Ls9USMq1VA4). Therefore, the upper price range without subsidy would be slightly higher.

Table 12.2 Wind energy cost in global perspective (price range)

Año	US$/MWh (without subsidy)	US$/MWh (with subsidy)
2009	101–169	s/d
2010	99–148	s/d
2011	50–92	s/d
2012	48–95	s/d
2013	45–95	s/d
2014	37–81	14–67
2015	32–77	14–63
2016	32–62	14–48
2017	30–60	14–52
2018	29–56	14–47
2019	28–54	11–45
2020	26–54	–
2021	26–50	9–40

Source: Lazard (https://www.lazard.com)

processes was rational (Interview Ferreño and UTE). However, once again, with a view to a second energy transition in the country, what is analyzed in this section should be considered.

12.6 Conclusions

Academic literature and stylized facts show Uruguay as a model country in terms of carrying out a rapid and successful energy transition incorporating nonconventional renewable energies. A state policy and the previous existence of an institutional framework with a vertically integrated public company as the axis of gravitation constitute clear explanatory factors of this performance.

Paradoxically, state leadership in the planning and generation of guarantees was used to promote a privatization process in generation. Seen as a favorable result by many and worrying by few, the truth is that the change in the energy matrix together with the change in generation ownership presents a set of future problems and challenges that deserve consideration.

The virtuous public-private articulation with state leadership and the public company should not be ignored when interpreting the facts. The planning imprint of the government installed in 2005 offered a very propitious scenario to materialize this type of articulation. In the same sense, the existence of an important accumulation and a "knowledge powerhouse" in the public university, the University of the Republic, and the synergies produced by the installation of the National Research and Innovation Agency should be valued. Finally, the emerging dynamism of the National Directorate of Energy finished configuring a very favorable context to deploy the energy policy. Looking ahead to a second transition, the role of the public sector in guiding transformational change should not be underestimated.

It is necessary to carry out more in-depth studies that contribute to a comprehensive evaluation of the costs and benefits of privatization in electricity generation associated with the change towards nonconventional renewables. Among the emerging problems of the new electrical matrix, the difficult management of intermittent sources should be pointed out in a scenario in which the acceleration in the investment process gave rise to a potential supply of electrical energy, above local demand. Although exports may constitute a solution to the problem, the conditions established by the PPA contracts generate restrictions on dispatch and, although it is necessary to deepen the analysis of their impacts, the evidence handled in this work suggests the need to discuss the mechanisms capable of avoiding competition between cheap public sources and relatively expensive private sources when defining the optimal dispatch mix.

In the medium and long term, the commitment established in the PPAs to pay a price in dollars for the energy generated by private agents in the system can become a distorting factor. The reason for this is that the charge for electricity in the local market is made in Uruguayan pesos and therefore the exchange rate must be permanently monitored to avoid a mismatch that requires intersectoral transfers to deal with it, with the consequent political economic implications.

The design of the energy policy, incorporating the idea of linkages with other productive sectors in the process of installing power in the country, led to managing the "national investment component" as an instrument. The analysis of the available evidence leads us to think of a modest impact of it as an industrial policy. In this sense, the acceleration of the installation process of wind farms seems to have operated as an obstacle to the possibility of national companies to adapt their scale and productive capacity in such a limited period. It is possible that the positive assessment of taking advantage of the project oversupply opportunity in 2011 and the uncertainty about the evolution of the capital markets in the immediate future have justified the decision to award 1000 MW beyond the competitive instruments. The question that should be considered is whether industrial policies can be designed with these short-term parameters.

Finally, in the third decade of the twenty-first century, Uruguay seems to be embarking on making relevant decisions regarding the second energy transition. The analysis of the experience of the wind revolution should occupy an important place when defining the meaning and scope of the process and, especially, what is the role that the public sector and, in particular, public companies will play in it. Some signs from the current government seem to point to a greater incidence of market forces and to obtain – through various instruments – a greater leadership of the private sector in the dynamics of change. Considering what is analyzed in this work, it is necessary to warn about the importance of public control in the transformational dynamics and to prevent public companies, in particular the UTE, from becoming a kind of UBER of electricity, at least if it is valued positively the fact that they maintain their founding philosophy of contributing to the development of national production and social welfare in the country.

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Energy Transition: An Analysis of Private and Public Agents Working Toward Energy Sustainability in Colombia

13

Eduardo Reina-Bermudez and Oscar M. Hernández-Carvajal

13.1 Introduction

While the authors were writing this chapter, Canada was experiencing temperature increases that had not occurred in centuries, historic floods were occurring in Asia, and large hail was falling on European countries, ruining hundreds of cars. Thus, the warnings of the environmental movements are today a reality. As Noam Chomsky describes in his book Cooperation or Extinction (2020), the doomsday clock ticks every closer toward extinction.

This chapter starts from the recognition that planetary limits are being reached. Cities need to move toward sustainable development because of high levels of pollution generated by greenhouse gases, the expansion of urban centers increasing energy demand, changes in demographic dynamics, and climate change and its potential dangers to the energy supply. These planetary limits also come from the conceptualizations of energy diversification, transitions, and transformations, as well as their triggers. From the efforts of CLACSO's working group on Energy and Sustainable Development, we can see this is a transition that Colombia is simultaneously undertaking.

This work is justified by the importance of the topic, which involves a first-order component for the achievement of the Sustainable Development Goals and COP 21. The objective of this research was to establish the level of transition of renewable sources of energy. It is necessary to problematize this transition in the confluence of efforts between the public sector at the national and regional levels and private sector organizations.

To track renewable energy projects, we reviewed a national newspaper's coverage during the period 2018–2020. Due to the novelty and the need to advertise renewable energy entrepreneurs, that period had extensive journalistic coverage. The results allow us to understand the location of growing renewable energy plants in Colombia and principally near industrial zones. Other remarkable results include local transport systems improving their bus fleets.

This chapter includes two sections of our theoretical framework and the Latin American and Colombian context, our research methodology, the results, and our conclusions and final considerations.

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E. Reina-Bermudez (✉) · O. M. Hernández-Carvajal
Semillero de Investigación Estudios Sociales del Desarrollo y los Territorios, Universidad Nacional Abierta y a Distancia-Colombia, Bogotá, Colombia
e-mail: luis.reina@unad.edu.co; oscarm.hernandez@unad.edu.co

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13.2 Energy Transitions in Perspective

This literature review shows energy transition in a public policy context, from an economic perspective. The energy transition essentially consists of regulatory changes and investment in energy production, distribution, and storage to modify the energy matrix for a given purpose. The novelty of the energy transition, and for many authors of the energy transformation (Pearson & Foxon, 2012), is that the situation is not only motivated by the internal availability of resources or economics, but by survival of the human species within the framework of sustainable development that is expected to be achieved in 2050 with technologies that allow zero carbon emissions (IRENA, 2018a; Guerrero, 2020).

Climate has a differentiated impact on the possibilities of agency in Colombian territories; current global warming alters these possibilities and therefore requires institutional adaptations and changes in land use planning (Lampis & Pabón-Caicedo, 2018). However, there are problems with externalities of individual consumption decisions based on financial rationality, which make it necessary to coordinate and plan the energy transition to curb climate change (Allen, 2012).

The origin of energy transition is associated with the dangers of nuclear energy in Germany in the 1970s. Such fears outlined that it was necessary to move toward the use of renewable energies obtained from natural sources (Fornillo, 2018). But not all countries have used nuclear energy, nor is the term energy transition specifically circumscribed to mean from nuclear to natural sources. The growing literature has analyzed various energy transitions that have both technical and socioeconomic characteristics.

Previous transitions have occurred at times when energy consumption has also increased (Grubler, 2004). These transitions were from plant-based energy to fossil fuels (Schurr & Netschert, 1960), from coal around 1850 to oil at the end of the second decade of the twentieth century, and to gas during the 1970s (Fouquet, 2009). The present transition that aims to increase the share of decarbonized renewable electric energy or energy with low carbon emission levels (Abas et al., 2015) started with the turn of the millennium. The foundations of this energy transition are efficiency and the adoption of alternative nonconventional renewable energy (IRENA, 2018b). Although scientific and technological developments make this transition technically feasible, this is not enough for it to take place (Allen, 2012). The socioeconomic context of regions and nations influences the time and depth of the change. An example of the latter is that in Germany, one of the countries that has made more progress in the energy transition to nonconventional renewables, the northern and eastern regions have benefited more than others from the transition (Sievers et al., 2019).

It is important to highlight that for many decades, fossil fuels will coexist with renewable energies. The same has happened in previous transitions that developed over long periods of time (from four to thirteen decades) and that involved transitions in the economy and technology related to the dominant energy (Fouquet, 2012; Grubler, 2012). Although the timing for each country differs, energy transitions depend on socio-historical context, including regional and national resource availability, internal energy demands of households and businesses, and public policies and trade relations (Rubio Varas & Folchi, 2012). An example was the rapid transition from plant to fossil fuels in Finland (Kunnas & Myllyntaus, 2009). Small countries have facilities for energy transitions (Rubio Varas & Folchi, 2012). The current transition is not unprecedented and strongly depends on the national context both in terms of availability of energy resources and socioeconomic system.

But what exactly is energy transition? It is "multidimensional, complex, non-linear, non-deterministic, and uncertain phenomenon and, therefore, they are difficult to characterize" (Moss et al., 2015, p. 46). This implies a turn to a different socioeconomic system with noncarbon energy sources (Krzywda et al., 2021). Although,

Fig. 13.1 Moments of the energy transition

in fact, as pointed out by Fouquet (2012), transition should be understood as "the change from an economic system dependent on one or a series of energy sources and technologies to others" (2012, p. 1).[1] The multidimensionality, complexity, and uncertainty of the process are related to the normative changes and political economy of each society, which is intertwined with the necessary development of new technologies and their massification to produce low carbon technologies. It is a socio-technical process (Li et al., 2015).

According to the International Labor Organization, this transition must also include decent working conditions in the energy sector, thus achieving a just energy transition (ILO, 2015). The socio-technical complexity of the transition implies considering changes in the ways in which the actors of the sector perform; the setting of public and private markets are not guided only by the free market but also by public policies and regulations that encourage the transition (Sovacool & Geels, 2016).

In the electro-energy transition, for example, thermoelectric power plants were consolidated as traditional, a vestige of that unfinished transition. This was followed by hydroelectric power plants and nuclear energy, with the accompanied risks of radiation contamination. In the last decades of the twentieth century, photovoltaic and wind energy technologies emerged as strong sustainable alternatives, together with other possibilities such as geothermal energy, piezoelectric energy, and tidal power. These technologies make the electro-renewable transition possible (see Fig. 13.1).

There is a strong debate on how to define the energy transition and its link with social issues, public policy, and peoples' development, and even a discussion on the validity of the term "transition." Some authors argue that if we go beyond the basic notion that is focused only on the energy matrix, we can move toward comprehensive notions of transition that are in line with development visions and even postdevelopmentalist discourses (Gudynas, 2011). At this point, it is convenient to differentiate conventional studies and conceptions of energy transition from expanded ones.

Conventional energy transition is guided by weak development and sustainability. This energy transition implies changing from the primary energies of coal and fossil fuels that generate large volumes of CO_2 when combusted, to kinetic and calorific energies of wind, water, and sun, which are considered renewable and less polluting (Bahadori et al., 2013). But it is not only a matter of changing sources – technological development, both in information processing and in the devices for transforming kinetic and calorific energy into electricity, will have to be substantially improved; this technology development will have to happen hand-in-hand with the adaptation of political and policy frameworks to create adequate market instruments (IRENA, 2020).

What are the conventional theories on energy transition? There is not a unified theory, but rather an accumulation of facts that allow us to identify the drivers. One such driver is the technological push, which will generate changes in the energy matrix as better adaptation and lower costs are achieved (Horbach & Rammer, 2018). The other driver is the government. The Dutch school of energy transition research starts from institutional economics and leads to an actor analysis (Sovacool and Geels, 2016). These studies rely heavily on historical records relating to energy accounts. The seminal author is Palomer Cosslett Putnam (2012) who studied the primary energy use of top consuming countries and esti-

[1] The switch from an economic system dependent on one or a series of energy sources and technologies to another.

mated the use of noncommercial energy for the first time. Early in this research, methodological individualism prevailed (Grubler, 2012). In the field of history, Vaclav Smil (2019) has become the most prominent energy historian. From an economics and development planning lens, much research has been developed by the Dynamic Stochastic General Equilibrium (DSGE). They work to understand economic dynamics related to environmental and energy issues. Although existing models are relevant for understanding the dynamics of ecological macroeconomics, comparability of the models needs to be improved and a new economic approach needs to be incorporated (Hafner et al., 2020). This new economic approach should move beyond neoclassicism and "capture real-world characteristics such as complexity, feedback loops, path-dependency, uncertainty and multiple heterogeneous interacting agents" (Hafner et al., 2020, p. 3).

In recent years, given the increasing improvements in efficiency of renewable and alternative energy technologies, researchers have become interested and aware of the externalities of this process on economic systems. Among others, the topics of discussion are "clean energy technologies and infrastructures, economics, and management of sustainable energy and environmental impacts of energy systems" (Chen et al., 2019, p. 1579). In addition, legislation and governmental measures to stimulate the transition have also become popular in the research (Freire-González & Puig-Ventosa, 2019).

From a more overarching view, Arnulf Grubler's research on the key principles of energy transitions include (i) purposes of use play an important role in the massification of new technology; (ii) although transitions are usually slow, they are not always slow; and (iii) it is not necessary to use the same pattern and scale of technological systems to achieve the transition (Grubler, 2012, pp. 10–14). The options for this sustainable electro-energetic transition are varied in level and incentives in each country. This is true not just for today, but has been seen in the evolution of energy matrices in Latin America in the past. Energy transition efforts can be associated with diversification efforts. Beyond that, they imply the establishment of new civil agreements – making an energy transition implies carrying out social changes that allow societies to be energetically self-sustainable (Fornillo, 2018). The state role is important because "the characteristics of successful energy innovation systems and policies that drive transitions include inter alia: persistence/continuity, alignment, and balance" (Grubler, 2012, p. 14).

Four economic principles of the transition have been established. First, the technological push is determinant on helping public policies. Second, the liberalized electricity market was disrupted by new and efficient renewable energy technologies (NERETs); because NERETs have almost zero cost, the new offer curve of electricity has a kink. Third, the current energy transition will be incomplete, because some activities cannot be electrified. Finally, different business models are needed to achieve progress by winning consumer preference (Blazquez et al., 2020, pp. 2–8).

Despite voices in favor of the state's impulse to control the energy transition, a separation of the state from the energy sector allows for greater public scrutiny of energy policy (Pollitt, 2012). When societies are willing to assume costs by implementing independent regulators and improvements in governance, this helps generate efficiencies that are facilitated by the nonconcurrence of the state in a market as a producer (Pollitt, 2012).

The concept of expanding the energy transition from postdevelopment equity and the fight against energy poverty should first consider the socio-technical lag. Originating in huge social inequalities and technological lags, developing countries may be mere buyers of renewable energy generation devices. We must consider the multiscale dimensions of the transition, since they vary from country to country and even region to region; in addition, energy production and supply systems involve different vested interests, such as that of hydrocarbon producers (Fornillo, 2018). From this expanded perspective, it becomes necessary to overcome the dichotomy of neo-developmentalism by antiextractives by seeking alternative development along the lines of good living or postdevelopment theories (Fornillo, 2018). In order to achieve this, a nation has to consider the following aspects: (1) modifying the energy matrix as the basis of the transition; (2) moving toward an eco-technical society to transform energy metabolism by consuming and polluting less; (3) consolidating a green industry; (4) establishing a new energy paradigm for development planning; (5) becoming a dematerialized society; (6) making the energy transition a socio-energetic transition that transforms the energy system; (7) moving to a communal, autonomous, and self-organized society, and (8) that implementing the above actions would make it possible to maintain energy sovereignty (Fornillo, 2018, pp. 48–51).

For Guerrero (2020), it is necessary to point out energy transformations that consider access problems, that is, inequalities in rational energy systems, and to understand that energy transformations conceived in this way would contain their own conventional energy transitions. The above approach is in line with Fornillo's vision of integral transitions (2018), while Guerrero (2020) repeats the statements of IRENA's Director General, Francesco La Camera, that regional energy policies should allow for a stable future that starts from a reconsideration of the environment that moves away from the unsustainable systems of the past.

Singh et al. (2019) proposed an Energy Transition Index that incorporates quite a few elements and can therefore constitute part of the synthesis on the issue. The Energy Transition Index proposes two components and several dimensions fed by specific variables, each with a specific weight. In the first component, System Performance, there are three dimensions. The first is economic development and growth. The variables include purchase parity power (adjusted prices for domestic electricity, industry electricity, and private sector electricity), wholesale gas price, pre-tax fossil fuel subsidies as a share of GDP, post-tax fossil fuel subsidies as a share of GDP, and fuel exports as a percent of GDP. The second dimension of System Performance is environmental sustainability whose variables are PM2.5 or particulate materials suspended in air per cubic meter, GDP per unit of energy use, CO_2 emissions per capita measured in tones per capita, and CO_2 emissions per total primary energy supply (kg/GJ). The last dimension is Energy Access and Security, the variables of which are electrification rate, access to clean cooking fuels, net energy imports, diversification of net import counterparts, diversity of primary energy fuels, reliability of supply, and transparency of tariffs.

The second component is Transition Readiness and has six dimensions. The first is Regulation and Policies Commitment (the variables of which are Country participation and commitment to the COP21 agreement, Political stability, Regulatory indicators for sustainable energy on energy efficiency, regulatory indicators for sustainable energy on renewable energy, and regulatory indicators for sustainable energy on energy access); the second dimension is Institutions and Governance, and its variables are rule of law, transparency, and country credit ratings. Capital and Investment is the third dimension and includes the variables of the Investment Freedom Index score, access to credit, investment in energy efficiency, and investment in new renewable energy capacity as a share of energy investments. The fourth is Infrastructure and Innovative Business Environment with variables of Logistic Performance Index score, transport infrastructure, innovative business environment, and availability of technology. Human Capital and Consumer Participation is the fifth dimension and its variables include renewable energy jobs as part of a county's total workforce and quality of education. The final dimension is Energy System Structure; its variables are total primary energy use per capita, electricity generated from renewable power sources, electricity generated from coal power, electricity generated from oil, gas or hydropower, and share of potential global future CO_2 emissions from fossil fuel reserves.

An important bias to note in energy transition studies is that they tend to address it as an urban issue. The subfield of urban transition economics sometimes comes up in these studies. This bias should be overcome to support territorial development planning in a comprehensive way (Naumann & Rudolph, 2020). Experiences in

Colombia have shown that in rural areas, the systems "should be operated in an autonomous manner by members of the local communities" and they should be responsible for their administration for success of the project (Gómez & Torres, 2019, p. 52). For Bonilla (2019), who analyzes Sustainable Rural Energization Plans (PERS), this work involves long-term planning in the territory by going beyond the custom of planning only by project. It also implies defining benefits and burdens after the construction of energy projects.

Research on the energy transition in Latin America indicated that until 2014, some countries, including Colombia, had not made significant progress in the energy transition (Bersalli et al., 2018, p. 171). In Colombia specifically, most research has been done to point out advances to the energy matrix in the participation of renewables (Corredor, 2018; Carvajal & Bermúdez, 2020) although some research has been devoted to cost-benefit analysis (Calderón et al., 2013). Colombia's current energy system is dependent on conventional sources such as gas and oil, with important energy provided by hydroelectric generators, which makes it strong in conventional renewable energy, while other countries even have low conventional renewable energy generation (Corredor, 2018).

Researchers and others in this space should be informed regarding possible subsequent debates, which may include international relations and geopolitical alignment, the influence of the acceleration of the 2030 agenda, and decarbonization achieved by paid or indirect advertising of renewable energy businesses.

13.3 Methodology

History, sociology, social sciences, and engineering have all contributed to the understanding of the current and past energy transition; their publications are in separate journals (Fouquet, 2012). So, the literature review of energy transition researchers typically involves a multidisciplinary approach. Energy transition is usually studied starting from the discrimination between conventional energies, based on fossil fuels, and those considered nonconventional, usually low carbon emissions based on alternative renewable energies (Bersalli et al., 2018). Often only one of these adjectives is used: either alternative or renewable.

In the early years of the field, "energy transition research was mainly performed by individual (…) researchers that have battled against the odds of widely dispersed and obscure data sources, lack of interest (and funding), even against well-intended advice to present rather than the past" (Grubler, 2012, p. 9). Today, a new wave of research faces a methodological problem to go beyond indicating progress in the variations of the energy matrix. A holistic and qualitative perspective is required to accompany the energy transition process as it is happening instead of waiting years to study the history of the transition.

So our research objective is to establish the particularities of development planning and public policies involving state action that stimulate the energy transition in Colombia. The present exploratory and descriptive research also looks at the insufficient understanding of the socioeconomic dynamics that generate transitions (Fouquet, 2012, p. 3). We reviewed public documentation available from the Unidad de Planificación Minero-Energética (UPME) as well as news that appeared between January 1, 2018, and December 31, 2020, in El Tiempo, a newspaper with national circulation in Colombia.

The research consisted of collecting, systematizing, and analyzing primary and secondary data from UPME and El Tiempo. Follow-up research on the national normative evolution and planning was done through examining the gazette of the Colombian Congress, as well as additional relevant information from other sources such as the Latin American Energy Organization (OLADE) and IRENA. Several municipal territorial administrations were also consulted about their progress on energy transition; these sources of information were less reliable due to the lack of knowledge of some officials and the contrast with official documents.

The conclusion showed Colombia is undergoing a transition to renewable energy sources and this study points the way in which this transition is operating in its beginnings stages. We also set out to interpret the sustainability criterion that this implies. We evaluate the existing relations between development planning for the transition and efforts at national and local levels, promoting theoretical reflection on the situation. The qualitative approach methodology is not unusual in the study of energy transition. For example, multi-level perspective and critical discourse analysis has been used to study the Polish energy transition, specifically around negotiations with miners' representatives (Krzywda et al., 2021). As explained by Krzywda et al. (2021), "Due to [their] complexity and comprehensiveness, transitions studies cannot be reduced to statistical models (…) so qualitative methods are recommended here" (p. 3). Another interesting methodology used here is the identification of critical moments (Yuana et al., 2019).

Documentary research was also used to analyze the link between energy planning and energy transition in South America, and especially when considering NDCs. That research sought to answer whether there was an energy transition in South America and to identify the relevance of regional organizations in the energy transition (Santos & Sabbatella, 2020).

13.4 Results and Analysis

Colombia is moving forward in its energy transition and trying to take advantage of its solar energy potential estimated at 194W/m^2 (D1). State leadership is taking the lead in terms of institutional development and energy purchase by seeking a competitive market of nonconventional renewable energy generators through open auctions. Despite the growing efforts in this area, 70% of the electric energy matrix comes from hydroelectric plants (D2) (Hernández & Reina, 2020. p96); their low operating costs versus ERNC are in their favor. The Colombian path has an intermediate point thanks to its gas reserves and as denoted in its liquid fuels policy. The conversion from gas of a large part of the vehicle fleet is part of the process of reducing CO_2 emissions (Hernández & Reina, 2020).

Table 13.1 presents the projects mentioned in our review of media sources

The first of the projects refers to a solar plant for a production plant of a sugar beverage company (D3). The second is part of the government's efforts, as is the third project, which, with 250,000 panels, achieves a reduction of 100,000 tons of CO_2. The fourth will increase its capacity up to 50 MW. Some of these projects had to close due to regulatory changes, as in the case of the fifth project in Cartagena. The sixth project, in the charge of ISAGEN, had delays in the process of consultation with the communities of the territory (D29). The seventh and eighth projects are still under construction. The ninth project was split into three that produce almost 60 MW (OLADE, 2021). The tenth project in the table involves the installation of 10.4 thousand solar panels to supply 12% of the energy consumed by the El Dorado Airport in Bogota. The eleventh row refers to a series of projects in the Caribbean region to be auctioned of nonconventional renewable energies from one of the country's largest energy distributors that will cover a demand of 1.18 GWh. This last effort is divided into 17 solar, four wind, and one biomass project. The thirteenth row refers to an agreement between a television company and energy company; the television company will produce its own energy with 150 panels.

Table 13.1, together with Appendix, shows that the projects are concentrated in the so-called triangle of development in Colombia (including Barranquilla), which are the metropolitan and industrial cities of the country. The territorial distribution of the projects can be seen in Fig. 13.2.

This graph depicts how leadership in terms of production with ERNC projects is concentrated in the Caribbean and in the Central-East region, which includes the Andean departments and the Orinoco basin. The next largest market is the Pacific region, mainly driven by projects of its industries and public power company.

Table 13.1 Projects whose production or capacity data are known

Project	Location	Capacity	Production
Solar farm CELSIA (Company)	Yumbo-Valle del Cauca	9,8 MW/year	16.5 GWh
Solar farm CELSIA	Santa Rosa de Lima-Bolívar	8,06 MW/year	ND
Solar farm El Paso, Enel Green Power Colombia	El Paso-Cesar	ND	86.2 MW
Solar farm Bayunca 1, EGAL S.A.S.	Cartagena-Bolívar	3 MW	ND
Wind farm Jepírachi EPM	Uribia-Guajira	19,5 MW	ND
Farm Guajira 1 y Guajira 2 ISAGEN	Guajira (Alta y Media)	30 GW	ND
Wind farm Alpha EDP Renováveis	Maicao-Guajira	Will generate 212 MW	
Wind farm Beta EDP Renováveis	Uribia-Guajira	Will generate 280 MW	
Solar farm San Fernando (Ecopetrol)	Castilla La Nueva-Meta	59 MW	21 MW
El Dorado (Aeropuerto)	Bogotá D.C	3,917,109 kWh/year	
Project Electricaribe (22 in auction)	Región Caribe	1500 MWh	ND
EMPCALI	Cali, Valle del Cauda	70 MWh	ND
Telepacifico (TV Public Company)	Cali, Valle del Cauda	6,9 MW	ND
CEO	Valle del Cauca	312 kWh	ND
Parque Comercial El Tesoro – EPM	Medellín, Antioquia	590 MW/year	ND

Source: Elaborated by the authors based on documentary research
This table is biased, because it is restricted to projects that are announced in the newspaper El Tiempo. For a complete and updated list, see OLADE, 2021. Table 13.1 shows that efforts are made by the national government, decentralized energy distribution companies (mainly public ones), and industrialists and other large businesses that seek to reduce their costs. The media hype is possibly due to the intention of increasing sales by the companies supplying panels and other energy-saving elements

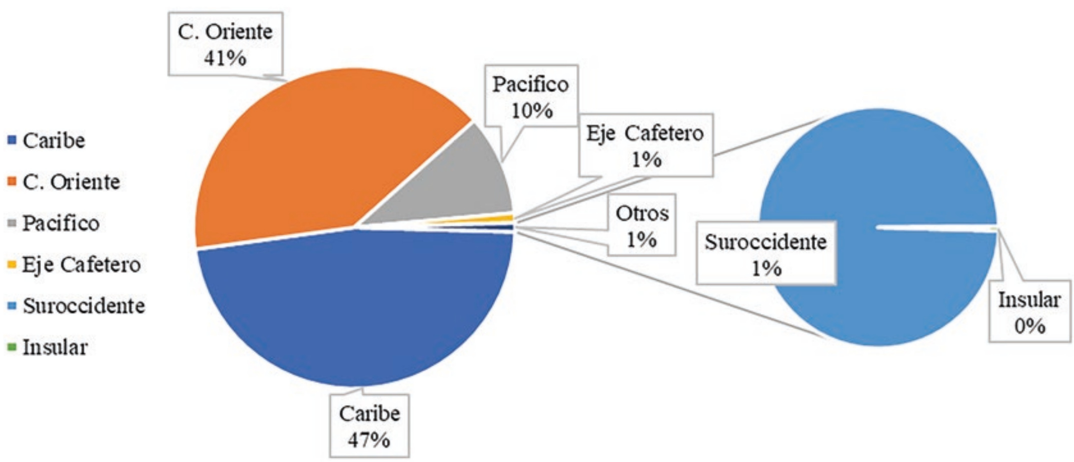

Fig. 13.2 Regional distribution of nonconventional renewable electric energy production. (Source: OLADE, 2021)

This territorialization or spatialization of the energy transition has its origins in large cities. This happens because they are the ones that have an integrated transport system with governance that facilitates the introduction of electric buses. Thus, Bogotá had 595 electric buses by the end of 2020 (D5), while Medellín had 69 by the beginning of 2021. Cali, the capital of Valle del Cauca, had 45 (D6, D7).[2] These are industrial cities that have an integrated transportation system, and which, in compliance with the national Law 255 of 2018, are beginning to transition to electric public transportation.

[2]These data were corroborated by means of petition rights to the referred territorial entities.

Other territorial initiatives are in favor of increasing efforts related to the energy transition. The first of these efforts is Agreement 790 of 2020 of the Bogotá D.C. Council. This agreement mandates the reduction of greenhouse gases by 2030 at half of current levels by replacing fossil fuels in the city. Other efforts by public or mixed companies have emerged in metropolitan cities such as Barranquilla and Villavicencio (D8, D9). These efforts are in addition to those of energy companies already consolidated in Cali, Medellin, and Bogota. In the Caribbean region, in particular, the energy transition is part of the solution to a decades-long supply problem (D10). National efforts have been joined with those from territorial governments as evidenced by the "Pact for Energy Transformation" in which governors of four departments (Cesar, La Guajira, Atlántico, and Magdalena) have agreed to work together to accomplish the energy transition (D11, D12).

In Cundinamarca, CODENSA has used royalty resources to eradicate energy poverty and improve access to energy in the center of the country, often with renewable energy solutions (D13). The system they use, called minigrids, is a mixed system that supplies energy from a set of panels that are backed by diesel production (D14). This could be a solution for other regions where the National Interconnection System is not available.

Along the same vein of overcoming energy poverty and poverty associated with energy consumption, a program was created in the Colombian Caribbean to replace old, high consumption refrigerators with new, efficient ones. This program was led by the Ministry of Mines and Energy in association with municipalities; through the Non-Conventional Energy Fund (Fenoge), it allows replacement of refrigerators in households in the two lowest socioeconomic strata and helps them lower their consumption and energy bill (D30).

It is remarkable that these energy transition efforts originate from territorial entities and not the national state. Nonetheless, we should recognize that the national government is playing the role of driver of the energy transition. This transition will be accelerated in 2019 and subsequent years; the Green Growth Mission of the Santos government (2014–2018) did not bring great progress and left the country lagging Latin America (D14). Since the Santos government, the discourse of green growth has been managed in the same neoliberal and globalization wave that forces cogovernance with the private sector, in recognition of its limitations.

Consequently, the state began to carry out auctions with a hidden ceiling price to purchase nonconventional renewable electric energy and to encourage the configuration of a competitive market by forcing participation through associations of nationals and foreigners and limiting the percentage of ownership in every project of each company (Colombia, 2018). It also established the competencies of the UPME regarding the promotion of efficiency and competition in the renewable energy market. However, the auction initially failed due to the concentration of supply, since bidding groups were supposed to be integrated by partners with up to 25% participation (D15).[3] Unfortunately, the independent buyers obtained 50% or more of the auctions and in general had low participation (broad), concentration, and dominance (D16). In addition, despite guidelines and state policy, a few months after the initial auction, the National Development Plan expanded the possible participation of groups in the projects bidding in the auction from 25% to 35% due to the need to generate electricity in the Caribbean coast (D17).

These initial failures forced several adjustments. They caused an inelasticity in the purchase of renewable energy due to the obligation by law to distributors. It was feared that consum-

[3] The bidders in 2018 were as follows: Enel Green Power, Isagén (Brookfield), Empresa de Energía del Pacífico (Celsia), Trina Solar Colombia, Canadian Solar Energy, Guajira Eolica, SP Villanueva and Solarpack. Buyers: Cedenar, Codensa (Enel), Empresa de Energía de Boyacá (Brookfield), Electricaribe, Electrohuila, Emgesa (Enel), Electrificadora del Meta, and Gecelca. (D15). The following year, other bidders showed interest from 27 companies, among which the following stand out: Termotasajero, Grupo Éxito-Green Yellow, AES Chivor, Enel Green Power, and EPM (D18). The company Termotasajero is mainly a coal-power-generating enterprise and this bid implies a change in FRNC generation.

ers would not perceive price reductions, because bidders would take advantage of the market power given to them by the state (D19). However, the results of the auction showed offers that implied price reductions. The kW was obtained around 150 pesos, so the consumer would get a price from 150 to 160 pesos (D20), 70 pesos lower than the price in 2019, two-thirds of the current price. The auction also got offers by voluntary mechanism of only 95 pesos, only 43% of the current price. This shows the possibilities of massification of the energy transition, at least in household use.

When the results of the auction were announced, many became concerned about the possible adaptation needs of the distribution system within the National Interconnected System. Apparently, the SIN could only absorb an additional 2.4 GW, and the auction implied an increase of 12 GW (D21). The Asociación Colombiana de Distribuidores de Energía Eléctrica (ASOCODIS) had already pointed out the challenges of inserting renewable energy into the distributed generation system, and that several stages should be considered (D22).

The state also generated mechanisms to borrow in the bond market and lend to companies and territorial entities through the green bonds issued by Bancoldex (200 billion pesos) and to territorial entities through sustainable bonds issued by the Financiera de Desarrollo Territorial (FINDETER). FINDETER issued bonds for 400 billion pesos in 2019 (D23) and (D38). Projects financed through FINDETER are required to have positive social and environmental impacts.

The president has also played a role in the energy transition as a media spokesperson. For example, he recently assumed a commitment to reach 1500 MW per year of renewable electricity production for remote areas (D25). After his first year in office, the country had already doubled its production (D31). This commitment, together with plans advanced during his administration, takes advantage of the relatively low prices of renewable energy to demonstrate positive aspects of his administration. Thus, in May 2019, the creation of a commission of experts was announced to advise and propose an energy plan for the country. The Energy Transformation Mission Commission (D26) was made up of twenty experts and delivered recommendations to adjust the electricity market (D27). However, little progress was made in the follow-up of the National Electric Mobility Strategy (D28).

By the end of May 2019, Bill 255 of 2018 on air quality was also discussed and endorsed. This law provided that "mandatory goals are established for the inclusion of electric vehicles for public and official transportation starting with 10 percent." At the time, there were about a thousand electric vehicles and these are projected to be 600,000 in 2030. In addition, commitments were made at the climate summit in 2019 to reach 10% renewable energy by 2022 and by 2030 to reach 20%. Colombia also committed to promote an electric mobility law and to provide tax exemptions for companies to adopt renewable energies (D32). The goal of a carbon-neutral Colombia by 2050 is questionable – the energy transition is still incipient, research is underfunded in the country, and deforestation persists (D33).

By July 2020, the energy transition was revitalized, because this process was perceived as part of the economic recovery from the economic crisis triggered by the COVID-19 pandemic (D34). That momentum would materialize with 27 renewable energy and renewable energy transmission projects (D35).

There are also private actors making investments. Due to Colombia's technological dependence on outside investors, part of what is evident in the arrival of Spanish, Portuguese, and German firms, among others. These foreign businesses take advantage of Colombia's 5% annual growth in energy use and substantial tax incentives (D36). Businesses are beginning to understand they can save money and other resources if they become sustainable in production by embracing alternative renewable energies (D37).

Thus, companies such as Hybritech, Madecentro, Codensa, Empresa de Licores de Cundinamarca, and Comestibles Italo take advantage of tax incentives and invest in becoming prosumers of renewable energy, both solar and biofuel (D39). Some companies, such as Energía del Pacifico, financed the solar park in Santa Rosa de Lima, Bolivar, in 2019 with green bonds from Bancoldex and Bancolombia (D40). That success led to a private financial entity announcing in 2020 a fund to finance similar projects (D41) in search of the same success (D43). This shows progress in the energy transition for business interests that, in addition to environmental benefits, seek financial savings (D42).

Not everything has been idyllic for entrepreneurs investing in renewable energy. Disagreements arose between Grupo de Energía de Bogotá (GEB) and ENEL (represented by its subsidiary Enel Green Power) over the exclusion of the GEB partner from renewable generation projects after they won the auction, which took them to court (D44, D45). This implies that ENEL found legal loopholes and is trying to appropriate property rights implied by the auction results.

Undoubtedly, this transition is not limited to large companies, but due to the methodology of this study, they are the most common. An example of small investments, with domiciliary destination that normally is not announced in the press, is a house in Atlántico territory, the exception that proves the rule (D46). In addition, there are social efforts in this transition. In Cali, its public utilities company is using the framework of the social project *Hogares Energéticamente Sostenibles*, Energy Sustainable Homes, as an opportunity in overcoming poverty (D47). And so domestic use is gradually proliferating, which will later be corroborated, surely, with cross-sectional surveys.

Not all efforts are limited to electricity generation with renewables, but also to alternative energy via biomass. The potential of Valle del Cauca for sugar production residues is particularly important (D48). Potentialities and opportunities are being identified and taken advantage of through a series of trade fairs and academic events, such as BI-ON in Cali 2018 and Exposolar in Medellin in the same year, in which devices are shown and business deals are sought (D49).

In addition, corruption in large works such as Hidroituango opens the door to reflection on alternative renewable energies as an option (D50). Another example that serves as an excuse to consider other ways of energy provision that happened in the city of Barranquilla, where cost overruns were generated by the deficient infrastructure of the energy company that operated there (D51).

There is also an awareness of the incumbent oil sector. For example, union leader Héctor Vaca, faced with a new oil discovery, stated that it should be used to gain time while the energy matrix is changed (D52). This means that the mixed economy oil company Ecopetrol and its union, when faced with the dilemma of the current energy transition, chose to adapt and initiate a shift to continue after the energy transition (Fattouh et al., 2019). Another example is the initiative of the Colombian Petroleum Institute to report on the state of research and production in using renewable energy in the oil sector (D53). Energy distribution companies are also showing interest in entering the renewable energy generation and distribution business (D54).

So far in the text, private organizations or businesses have been discussed. But business is not the only sector to enter the renewable energy conversation; politicians have also ramped up their rhetoric. The topic of energy transition has progressively gained importance in presidential electoral campaign speeches. In 2018, candidate Iván Duque brought up his coauthorship of the law promoting electric cars in Colombia (D55). The same candidate also discussed the need to overcome contradictions between the sustainability and mining activity plans, in addition to indicating the need to review land use planning and generate tax incentives. The candidate Gustavo Petro Urrego proposed a progressive change to sustainable renewable energies to overcome the fossil economy using pollution taxes and technological adoption (D56). Both campaigns discussed energy transition incentives: the first proposed positive incentives and the other a negative tax incentive. Duque eventually won the election and during the

Colombia Independence Day celebration held on July 20, 2020, he proclaimed that it was the purpose of Colombia to be a regional leader in energy transition (D57). Another presidential election is upcoming and the current candidate most likely to win in 2022, Gustavo Petro Urrego, has raised the need for a radical energy transition based on the principle of strong sustainability. He proposes the end of fracking and the commitment to renewable energy production, as well as economic redirection to the agricultural sector and industry. Urrego's proposal is quite different from other presidential candidates who bet on continuing with different levels of transition guided by maintaining oil production and moving forward gradually.

13.5 Conclusions

Weak sustainability guides official efforts for energy transition in Colombia, partly due to the availability of gas reserves in the Caribbean Sea (Carvajal & Bermúdez, 2020); however, the state has deployed regulatory and fiscal efforts to promote the transition. This is being done within the framework of liberalized markets by promoting the association of national and foreign companies. It is also being done by stimulating the plurality of producers through national and territorial renewable energy projects using alternative technologies with instruments such as the concession by reverse auction.

Territorial projects have been financed through the issuance of debt bonds, called green bonds and then sustainable bonds, which avoided delay and that could imply the creation of a specific tax for this purpose. These bonds were later imitated by private banks to support entrepreneurs in their decisions to become prosumers of renewable energy.

The energy transition in Colombia is going through a project-based planning phase; the government's energy policy initiatives to reduce tariffs and taxes and the international decrease in the prices of renewable technology are encouraging investment in private projects. It is expected that this will not be an initial investment peak but will have continuity, and thus, the installed capacity of renewables in the National Interconnected System will increase.

Although in the first three lustrums, there was not significant progress in the energy transition to renewables (even with a 10% ethanol measure in gasoline), this began to change in 2018 with the implementation of planning around the commitments for climate change reversal and sustainable development. The combined efforts of the state, territorial entities, and medium and large companies will undoubtedly be increasing the levels of participation in the Colombian energy matrix of renewables. On the state side, the efforts refer to incentives for a competitive market. On the supply side, renewables have marginal costs close to zero in terms of generation and on the demand side, the state has obligated electricity distribution companies to buy at least 10% of their energy from renewables.

In the territorial entities, and many large metropolitan cities, efforts are being carried out in the mass transportation systems and energy distribution companies. This is especially true of companies that are public or mixed in nature; they are participating in larger numbers in the direct construction of electricity generation plants that take advantage of renewable sources with financing from the national government. These projects should be sure to take into account a territorial development planning perspective to avoid generating problems such as those with indigenous communities in the north of the country.

In the private sector, efforts to transition to renewables are increasing because of the efficiency of alternative technologies in conserving resources. In rural areas, the Sustainable Rural Energization Plans stand out. With the help of international cooperation, projects of different degrees and scales are using renewable energy to reach citizens of remote areas.

13.5.1 Recommendations and Challenges of the Energy Transition in Colombia

The first challenge is to overcome fiscal and lobbying constraints to drive a transition guided by strong sustainability metrics. This implies ensuring that macroeconomic pressures do not undermine efforts to include renewable energies in the matrix, even if in small proportion. The challenge is to reconcile extractivist interests, associated with fiscal dependency and oil groups, with sustainable development based on agricultural and industrial diversification of the economy.

A second challenge is to maintain and strengthen the interests of private banks in supporting the implementation of renewable energies with lines of credit so that the entire cost burden does not fall on the public sector. The third challenge is to continue the planning and implementation of energy projects that fight against climate change. This would imply encouraging the construction and adaptation of vehicles using natural gas.

A fourth challenge is to articulate the efforts being made by the state, territorial entities, and medium and large companies as they gradually continue to progress in terms of sustainability and generation with renewables. A fifth challenge refers to auctions and especially the work of a good governance environment. Alliances that were made between foreign and local companies should also ensure the socio-technical growth of Colombian society. A fifth challenge, closely related to the fourth, would be to broker national public and mixed companies for the purpose of updating technology. And finally, a sixth challenge is to reconcile respect for ancestral territories with environmental development.

Appendix

Table of minor projects announced in the newspaper

Project name	Location	Capacity	Other information
4 CELSIA wind farms	Uribia y Maicao-Guajira	ND	ND
Florida Valley Police Station	Florida, Valle del Cauca	ND	(Paneles solares) 3.600 millions COP
Salazar and Herrera University (IUSH)	Medellín, Antioquía	ND	Associated Social Project
Unicentro Cali	Cali, Valle del Cauda	ND	9 charging stations for electric cars
Almacentro	Medellín, Antioquía	ND	254 panels. Reduction of 20 tons of CO_2 emissions. Financial savings of 50 million COP
Rural Schools Barrancabermeja	Barrancabermeja, Santander	ND	Santander Energy Company. 6 schools. 150 solar panels
Megaservices (Mayor's Office)	Cali, Valle del Cauda	ND	Implementation of panels at service points
Richmond Suites (Hotel)	Bogotá D.C	ND	2 billion COPs investment. Reduces 34 tons of CO_2 per year. Part of the energy is sold to CODENSA, an energy services company
Piedra Parada Shelter	Bucaramanga, Santander	100 kW	ND
Madecentro	Bogotá D.C	99 kWh	ND
Italo Groceries	Bogotá D.C	490 kWh	ND
Cundinamarca Liquor Company	Bogotá D.C	179 kWh	ND
Colsubsidio Hotel	Puerto López, Meta	180 kW	Solar park

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14 Solar Energy and Social-Productive Configurations: Regional Features of the Energy Diversification Process in Argentina

Eliana Celeste Canafoglia

14.1 Introduction

With the global objective of reducing carbon emissions, the awareness, incorporation, and use of renewable energies (such as solar and wind) are key actions before the possibilities of strengthening energy transition processes. Faced with the need to reduce both production and consumption of fossil fuels (coal and hydrocarbons) and cope with climate change, these possibilities are integrated with techno-productive transformations worldwide.

As a heterogeneous process, including different features, and performed at different pace and times in accordance with each country (regions, territories, and cultures), energy transition becomes an abstract concept that encompasses situated changes. This is not a linear, but rather disruptive, process, which is both driven and resisted by various stakeholders and involves a complex negotiation among them.

As a sociohistorical process, changes in the composition of the sources of energy supply by country and their forms of production are closely linked to resources and the adequacy of productive structures. On the one hand, energy diversification enables the identification of features within the transition process, since it implies considering various energy sources and how to obtain them from the generation mix. On the other hand, encouraging generation expansion through renewable sources, thus avoiding exclusive dependence on a single energy resource (Stirling, 2010; Akrofi, 2021), involves comparing possible socioeconomic relations in each country (and among the main economic actors). This will take place in two levels at the same time: that of the production of inputs and equipment for generation (associated with the existent resources) and that of its incorporation for productive-reproductive consumption (residential, industrial, agribusiness).

Our interest here is to discuss the progress in the generation and consumption of energy from renewable sources in an Argentine region whose physical-biological characteristics tend to the recovery, use, and exploitation of solar energy. Upon consideration of implementing these generation systems, the guiding questions for this analysis include the following: What are the productive structures involved in the development of renewable energy projects, specifically of photovoltaic and thermal solar origin, in that region? What characteristics do they have? Which stakeholders are involved? Ultimately, the objective is to define the current socio-productive configuration of the energy complex and identify the features (stakeholders and practices) of energy diversification processes in a specific territory, the Cuyo region.

E. C. Canafoglia (✉)
INCIHUSA-CONICET, Mendoza, Argentina
e-mail: ecanafoglia@mendoza-conicet.gob.ar

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This region became an area of interest for the development of solar energy. The production and the consumption of energy from solar sources find in the western region of Argentina (adjacent to the Andes Mountains) optimal irradiation conditions[1] for its utilization and a positive association with the features of the regional economies.

The perspective adopted here belongs to the economic sociology field and focuses on this particular subnational level. The study of the socioeconomic relations (structures and dynamics) of the Cuyo region is carried out considering it as a regional economy.[2] This definition makes it possible to distinguish changes at the level of geographical regions, recognizing their productive trajectory in relation to the national and international set. From this view, it will be interesting to analyze who are the stakeholders that take part in the production-energy complex, specifically in the generation, distribution, and consumption of energy from solar sources; what characteristics they assume in relation to the type and origin of capital and; the socio-productive articulations present to carry out these developments.

The form how energy is exploited and generated, the pace and intensity of consumption, and the urgent need to mitigate the effects of carbon emissions – the axis of changes in energy generation policies established by country – result from this particular articulation among the stakeholders forming part of the production complexes.

An energy complex includes the activities of energy producers, distributors, and consumers and a structural web of related companies. This implies, under the notion of productive and value chains (complementary or convergent with that of the production complex) that stakeholders may be included who are not settled in the territory, but whose socioeconomic relations condition the functioning of the complex. For instance, these are financial stakeholders and suppliers of basic supplies and equipment.

14.1.1 Theoretical Framework

The processes of energy transition are linked to technical-economic transformation of the modes of production (Kaplinsky, 2021; Pérez, 1985). Throughout history, the great revolutions have been marked by technological developments applied to the field of the production of goods and services that are vital for the reproduction of life. Social relations of production converge in that same process, not without controversies, and are defined into particular socio-productive configurations.

The configuration perspective (De la Garza, 2018) articulates various conceptually and analytically different structural levels, sociocultural dimensions, and stakeholders' practices. This implies understanding the energy transition processes anchored in national (and subnational-regional) history but also linked with transformation and logics of a global economic-political network (Fernández, 2017).

By examining socio-productive configurations from the perspective of the production and consumption of solar energy in a particular territory, we seek to identify the stakeholders in the chain of production and value (production complex) and discern the sociopolitical and economic relations involved therein. The energy complex is defined by a set of activities of exploitation, production, and distribution of energy. The range of activities include from primary production, industrialization, and commercialization to associated supporting services of various types (engineering and construction, maintenance, research and development, information and communication, logistics and transport, inter alia). This concept refers to the notion of a productive or sectorial

[1] Solar irradiation conditions are available at http://www.frm.utn.edu.ar/cliope/atlasofrenewableenergies/; https://sig.se.gob.ar and Romero (2019).

[2] Argentine regions located outside the Pampean area are a constituent part of the peripheral capitalist system: "in each of these regions, the production processes and their respective management, the social structure, the constellation of economic agents, their links with those operating outside their boundaries and the profile of the local political-administrative model are presented with significant structural differences" (Rofman, 1999: 109).

complex (Gorenstein, 2012; Schorr, 2013) defined as a unit of accumulation and distribution, within which the involved stakeholders operate creating close relationships based on the transformations that follow a main product, in our case, the generation of energy. Through this approach it is possible to recognize stakeholders and their relationships (commercial and noncommercial) with agents and institutions, as well as the environment where related activities of different nature are developed (Gorenstein, 2012).

Through the complementing approaches of global value chain (Gereffi & Fernandez-Stark, 2011; Van de Graaf & Kolgan, 2016) and regional economies (Rofman, 2020), it is possible to consider the studies focused on the dynamics of local changes in articulation with international movements (capital, stakeholders, practices, and products).

In that sense, any analysis intended to untangle a specific socio-productive configuration is to be considered in relation to a place-time framework. Among the dimensions of analysis, we will aim to account for the origin of capital (stakeholders and money flow), applied technology, the creation of a labor force, the use of inputs and capital goods, and the organization of a productive process as a relational category.

14.1.2 Methodological Considerations

The methodological strategy used is mixed; it integrates various techniques of construction and data analysis. Based upon the levels of analysis, we resorted to the following:

(a) Data analysis from secondary sources produced by the Secretariat of Energy, the Electricity Wholesale Market Management Company (CAMMESA), and bibliography for the characterization of the productive structure
(b) The compilation and review of current regulations governing the generation of energy from renewable sources, mainly those regulations that promote investment in the construction of new projects
(c) The study of cases within Cuyo regional economy, in particular in the Provinces of San Juan and Mendoza, based on a comprehensive documentary analysis – reports and specialized publications – from secondary sources (Secretariat of Energy, CAMMESA, National Institute of Industrial Technology (INTI), Ministry of Energy and Mining (MinEM)) and a qualitative analysis from interviews with reference people taking part in projects and works related to the generation and diffusion of energy from solar sources (companies, officials, scientists, and technicians)

The tasks involved in the articulation of various techniques included the following:

(a) Identification and characterization of productive stakeholders, making a distinction between production and value chains in the field of energy generation from solar source: solar product plants (manufactured products for the generation and use/consumption of solar energy) and steps in the production and marketing process, such as distributors of solar panels, water heating systems, and other equipment; power generating plants; installation and maintenance; design, construction, and operation of generation plants; design and installation of solutions for electrical energy and comprehensive solutions; and inputs for photovoltaic solar industry
(b) Consideration of training and research institutions and organizations specialized in the generation and distribution of solar energy. In this regard, policies and mechanisms of promotion at different levels were studied, not only in connection to the national energy policy but also at the level of production stakeholders
(c) Review of the current legal framework (laws, regulations, and resolutions) to discern how relations among stakeholders are regulated

Data built this way not only contributes to the characterization of the stakeholders and their relations but also allow us to approach some of the difficulties that arise in the practices of the development and implementation of systems for the generation and consumption of this type of energy. As an empirical research strategy, in particular, the study of cases made it possible to address a contemporary (and ongoing) phenomenon, in holistic terms, in its specific context of occurrence. Thus, we approached the territorial specificity of the way in which the introduction of different technologies occurred in the generation of solar energy.

14.2 The Process of Solar Power Generation in Argentina

14.2.1 Associated Regulatory System: Promotion Policies in Force

The successive policies regarding productive energy matters (i.e., regulations, laws, decrees, and resolutions issued by national and provincial government administrations) are marked by changes in the control of the exploitation and appropriation of natural resources (such as water, soil, minerals, and metals) required for the production and distribution of energy. Legislation addressing ownership and rights over natural resources implies legal provisions as well as a number of mechanisms of control/resistance in the processes of extraction and production (environmental authorizations, constraints, requirements) that may result in compliance or in controversies, as the case may be.

Moreover, the so-called investment promotion policies may have different effects at the economic level. For instance, the regulation of differentiated trade prices within the production – distribution chain or the reduction of tax rates, subsidies, and the facilitation of financing instruments and capital movement – are determinants for the market environment where energy-productivity policies are put into effect.

Like an intricate web, both levels (that of regulated control and appropriation of resources and that of economic promotion of their exploitation) converge to help us understand the dynamics of a production complex. The energy production complex through renewable sources is part of a national and global political agenda.

In this sense, the introduction of renewable energies in Argentina dates back to the 1970s. Efforts for its regulation resulted in the enactment of Law 25,019 (Solar and wind energy System Act) in 1998 and, later, in 2006, of the Renewable Energy Act (Law 26,190) under the form of a Promotion Program. Provisions included, among others, the concept of a long-term electric power purchase agreement, known as PPA, which originally appeared in the 1990s under the logics of financial products called derivatives and the resulting financial engineering.

In Argentina, this type of agreements began to be implemented with the Renewable Energy Generation (GENREN) program in 2009. PPAs were subscribed between private bidders and the National State in an *off-taker* position (taker and/or buyer) through CAMMESA and the Secretariat of Energy. This establishes a difference in terms of the participation of stakeholders, who are able to unilaterally decide the legal scope of PPAs when negotiating the agreements. Following the enactment of the Trust Act (Law No. 24,441, year 1995), the subsequent regulations on domestic capital markets, and the National Securities Commission, methodologies were developed to supply financing to small and medium wind and photovoltaic projects independently from commercial or industrial bank credits (Peralta, 2015).

A review of the recent period puts the Renewable Energy Plan, which comprises the RenovAr Program of the Ministry of Energy and Mining (now Secretariat of Energy) at the center of the scene. According to the Plan, solar energy is produced by the sunrays that reach the earth surface after passing through our atmosphere and become a natural and inexhaustible source of energy. Upon these features, solar energy forms part of the group of renewable energies, that is, energies that do not generate greenhouse gas and whose cycle is short, since it is permanently renewed (Cortellezzi & Karake, 2009: 34).

RenovAr Program, together with the decree that enforces Law 27,191 (2015) and the enactment of Law 27,424 (2017), proposes a promotion system for the use of renewable energy sources. These regulations seek to expand the production and use of this type of energy with the construction of new-generation projects in the first case and the facilitation of their incorporation into the national electricity grid in the second, without prejudice to the powers corresponding to the provinces (Article 1 Law 27,424/2017).

The concept of distributed generation implies not only the promotion of power generation by renewable sources but the possibility of injecting any surplus not consumed by producers into the national electricity grid (SADI – Argentine Interconnection System), through the net billing system. GENREN programs, prior to RenovAr and the most recent Renewable Energy Term Market (MATER, Resolution 281-E/2017), complete the current scheme that enables investment in the construction of solar energy generation projects.

This commitment to new energy sources is part of a broader process of energy transition subscribed in agreements and commitments around the world, such as the United Nations Framework Convention on Climate Change (1992), the Doha amendment to the Kyoto Protocol, the Paris Agreement (2015) or the Summit on Climate Action (2019), and the recent COP26 (UN 2021). The goal is to reduce the effects of widespread consumption of nonrenewable and polluting sources on the environment, such as fossil fuels (that represent 80% of the world and 89% of our domestic supply and consumption).

14.2.2 Energy Production Structure

According to the latest Annual Report of the Electricity Wholesale Market Management Company (CAMMESA, 2022) in Argentina, wind, solar, renewable hydro, biomass, and biogas are the renewable generation sources that contribute to the electricity demand to date. Solar energy as an energy source can be used in two ways: a thermal pathway where sun rays, after appropriate concentration, heat a boiler analogous to that of a common power plant or a photovoltaic pathway, where the energy of solar photons is directly converted into electric power by photoelectric effect in a semiconductor material (usually silicon) (Cortellezzi & Karake, 2009: 35; Grossi Gallegos & Righini, 2007).

As a production and value chain, it involves a number of links: infrastructure and technologies, inputs and materials, solar energy generation (primary), transformation into electric power (secondary), connection to the grid (national or local), and consumption (DNPS – SSPE, 2016: 6). In each phase of this process, different productivity stakeholders operate from the beginning of the raw material until the electric power is generated and finally consumed. The involvement of stakeholders is given through close relationships from the transformations that follow this main product.

During 2020–2021, variation in energy generation from renewable sources increased by 37% (CAMMESA, 2022: 30). Types of generators used (not imported) represented 94.1% to generators, 3.4% to self-powered generators, and 2.5% to co-generators, the latter becoming a growing trend.

Thirteen percent of the total demand of the wholesale electricity market was supplied with renewable generation (17,437 GWh). The share of demand according to sources showed an increase in wind generation (12,938 GWh) by 37.5% (year-on-year variation[3]), while solar generation (2196 GWh) had a 63.4% increase as compared to 2020. Since 2011, the recorded evolution of solar generation has been remarkable, making a quantum leap since 2018 (CAMMESA, 2022: 33).

Said evolution has to do with the incorporation of new stakeholders (solar parks, self-generation, and co-generation) and suggests the effect

[3] The year-on-year variation was calculated by comparing periods 2020 and 2021: t2 – t1/t1*100.

of certain facilitating public policies (e.g., GENREN, RenovAr, MATER). Related regulations also contributed to the increase of this proportion (e.g., Law 27,191).

Among the stakeholders incorporated through RenovAr (2017, 18, 19) and MATER programs, as well as GENREN, those belonging to photovoltaic solar technology were located in the Northwest (NOA), Center, and Cuyo regions of Argentina (Table 14.1). The awarded capacity had to do mainly with projects in the Province of San Juan[4] (191.9 MW, 44%) and, to a lesser extent, in the Province of Mendoza, where six projects with a capacity of 94 MW (18%) were awarded.

In addition, privately managed generation parks were built through MATER bids, as in the case of solar parks in the Province of Mendoza and San Juan Solar Project, where the provincial government was responsible for financing and managing the full development of the production chain.

14.3 Productive Structures: Case Studies

The development of production around power generation through solar source is understandable, from our perspective, when specifying practices and strategies used for the diffusion of energies from renewable sources in general and their articulation with productive structures.

In order to meet the specificity of the generation throughout this source, it is possible to differentiate solar photovoltaic and solar thermal production and value chains. Case studies are focused on identifying the following:

(a) With respect to projects and works
   (i) What kind of stakeholders are involved, including their main characteristics?
   (ii) The production process carried out in the facilities
   (iii) Components used, technologies, works, and professionals involved; their origin and/or local share
(b) With respect to the specificity of the regional (subnational) solar energy production complex: the relationships between participating stakeholders and the prospects for expansion

San Juan Province Solar Project provides an overview on the production and enhancement process within the complex. The Smart Grid related to one of the Solar Parks in the Province of Mendoza calls for reflection on the potentialities involved in the generation, administration, use, and value of renewable source energy. The case of ENERGE is seen as a characterization of a potential trajectory of a local company engaged in the production of solar generation components and projects. The role of professionals, trade workers, and associated industries along the chain show the available production capacity and its potential scope of action.

A particular mention is given to two province-owned energy companies, EPSE and EMESA, included in the time frame we are dealing with and which have a growing insertion in the generation and/or facilitation of processes for the incorporation of energy from solar sources.

The contributed exemplary cases to the overall view of the complex helped to focus on various aspects, structural and procedural, of the productive configuration. The interaction of the concrete practices of the stakeholders involved (oriented by beliefs, expectations, and particular views), together with the agenda of energy, production, and economic policies, gives shape to the incorporation of renewable generation systems. In this process, the dynamics of energy diversification becomes visible as well as the networks associated with it.

[4] 31.9% of all solar energy produced in the country comes from the Province of San Juan (https://www.runrunenergetico.com/san-juan-y-su-incidencia-a-nivel-nacional-en-energias-renovables/ Jan.19, 2022).

Table 14.1 Renewable energy plants in commercial operation. Solar parks in Argentina (year 2020)

Region	Province	Origin	Project name	Allocated power (MW)	Shares in the total of	
					Solar (759 MW)	Power (41,951 MW)
Centre	San Luis	Self-generating	Agritur	0.45	17.2%	0.3%
	San Luis	MATER	La Cumbre II	4		
	San Luis	Renovar Ronda 1.5	Caldenes del Oeste; La Cumbre	121		
	San Luis	Resolution MEyM N° 202/2016	Cerros del Sol	5		
Cuyo	San Juan	GENREN	Chimbera I Cañada Honda I y II	7	25.4%	0.46%
	San Juan	MATER	Ullum Solargen II	6.5		
	San Juan	Renovar Ronda 1.5	Las Lomitas Ullum I, II y III Iglesia – Estancia Guañizuil Ullum IV	177.2		
	Mendoza	Renovar Ronda 1.5	PASIP	1.15		
	San Juan	Resolution S.E. N° 108/2011	San Juan I	1.2		
NOA	La Rioja	MATER	Chepes Parque de Los Llanos	14	24.3%	0.44%
	La Rioja	Renovar Ronda 1.5	Nonogasta	35		
	Catamarca	Renovar Ronda 1.5	Tinogasta Saujil Fiambalá	48.5		
	Catamarca	Renovar Ronda 2	Tinogasta II	6.96		
	Salta	Renovar Ronda 1.5	Cafayate	80		

Source: Ministry of Energy, 2021

14.3.1 Execution Process of Solar Parks: Power Generation

The process of building a photovoltaic solar power generation park consists of several stages: delimitation, appropriation, and obtaining permits on the land where the park will be located; civil works design, determination of inputs, materials, and components; obtaining capital, financing, and setting estimated times for the generation of electric power; obtaining permits for getting connected to the electricity grid; and execution of works, installation of panels, wiring and control center, and, in some cases, the inclusion of a meteorological center.

The stakeholders that carry out this process, although they may vary in each particular work, include the State: a number of public agencies in charge of regulations, promotion, and control and the builders: engineering, procurement and construction (EPC contractors), the developers (vehiculizers and managers the project), and operators (in charge of the park operation and maintenance) (see Table 14.2).

Table 14.2 Process for the construction of a solar park and actors involved

Process	Participants
Previous studies, assembly of the project	Developer of the project. Construction companies or provincial energy
Delimitation and appropriation of land to be occupied	Project developer
Contract design, specification power to obtain, power buyer, price, and permits	Project developer
Capital and financing of the work (similar to mining projects)	Bank/s, private investors, same construction companies, and state
Construction, procurement of materials, recruitment of professionals, and supervision	EPC (construction company) Specialized professionals
Operation and maintenance	EPC for a term of guarantee of the work Operator (construction company, state energy company, local electricity distributor)

During the design, construction, and execution of the work, public stakeholders were involved at provincial and national levels. At provincial level, the municipality of the place where the project was located, the General Land Registry Office, the Environmental Protection Office, hydraulics, irrigation, renewable resources, local energy distributors (EDESTE, Cooperativa Eléctrica de Godoy Cruz, Energía San Juan S.A.), and provincial energy companies (EMESA, EPSE) can be mentioned. At subnational-regional and national level, the high-voltage line transportation company (Distrocuyo), the Ministry of Energy, the electricity regulatory entity (ENRE) and the wholesale electricity market administration company (CAMMESA), tax administrators (DGRSJ, ATM, AFIP, the General Customs Office, and the National Institute for Industrial Technology (INTI) can be mentioned.

As for the capital required, the dynamics of the execution of the project involves the startup and construction capital (capital expenditures or CAPEX) and the operation of the park capital, once the work is completed (operating expenditures or OPEX). Capital comes from incentive programs for the incorporation of renewable energy by the State (Sect. 14.2), from provincial governments, private investors of various origins (shareholders), construction companies, international EPC contractors, and local stakeholders.

Public stakeholders show a high degree of participation at the beginning of the development projects, and progressively, private stakeholders get involved, interested in the profitability of their implementation. To a lesser extent, residential stakeholders (nonprofit individuals) might get involved, motivated by a need to give answers to their own consumption of power generation.

Addressing the specific case studies, San Juan Solar Project began in 2007 and involves the state-owned company *Energía Provincial Sociedad del Estado*. The original idea was to develop the whole production chain for the generation of solar electric power, by building an integrated factory for the manufacture of panels, *while importing cells and their components for assembly*. *What we cannot manufacture yet is solar-grade silicon*; *this has been relegated due to a matter of logistics and costs that cannot be viable in San Juan* (Reference: EPSE, personal conversation on April 2021).

That factory accounts for 100% of the machines purchased. Civil works were executed by a private UTE (two local companies forming a temporary union of companies) that was awarded a public tender. During the construction process, they had problems due to changes in the exchange rate and others related to customs that had nothing to do with EPSE or the province. The funding came from the Government of the Province of San Juan. The province-owned company (EPSE), organized under a consortium format (following INVAP model[5]), will be in charge of the management, since for the government *it is difficult to buy inputs, and calling for international bids would result in time delays and complicated logistics to ship the supplies to the plant*. The products developed in the factory will supply the solar parks in San Juan (such as the one located in Tocota[6]) and progressively in other parks. *This is a comprehensive project. The final product is not the panel, but the production of energy. So the project is financed and it makes sense when panels are incorporated into solar parks* (Reference: EPSE, 2021).

At present, EPSE operates three solar parks and provides advice and authorization for works. It has entered a collaboration agreement with IMPSA for the development of national manufactured inverters. IMPSA is one of the largest metalworking companies in the country and is located in the Province of Mendoza. This company manufactures wind turbines for the wind industry, among other major products as well as hydro and oil megaprojects. Both stakeholders participate in the recently created National Renewable Cluster.[7]

The construction and operation of Solar Parks in the Province of Mendoza had public and private participation. PASIP Solar Park emerged from a long and expensive construction process involving several stakeholders through a round of RenovAr Program, the provincial government, and local energy distributors. Later, the experience of the associated Smart Grid project was added. This project was carried out within the framework of a sectorial development program promoted by the Ministry of Science, Technology and Productive Innovation in 2015. A work group consisting of professionals from the National Technological University (UTN) *together with EDESTE and EMESA companies installed five thousand meters in the town of San Martín to manage distributed energy. PASIP produces and injects electric power into a medium voltage line belonging to EDESTE and EDESTE is in charge of the distribution*. The purpose is to test *the effect, mode, and impact of the injection into the grid of photovoltaic generation* (Reference: UTN, 2020). This group project seeks to improve data collection of distribution centers in medium- and low-voltage stations.

Two other privately managed parks, Parque Santa Rosa and Helios, were developed by companies settled in the Province of Mendoza: EDESTE, ENERGE, and Tassarolli S.A. These parks have equipment that combine domestic

[5]INVAP is a state-owned company of the Province of Río Negro (Argentina), began with the creation of nuclear equipment, and became a model of technology management, manufacture of satellites, and the aerospace industry.

[6]Tocota is the name of the town in the Province of San Juan, where a transformer station was built in 2018. It has 12,000 hectares (approximately 29,600 acres) and a power line with access to the Argentine Interconnection System (SADI).

[7]Public and private body consisting of domestic manufacturing companies in a number of provinces that manufacture goods produce technologies and services associated with the generation of power from renewable sources: SAPEM Arauco Wind Farm (Province of La Rioja); EPSE (Province of San Juan); EMESA and IMPSA (Province of Mendoza); SAPEM Energía de Catamarca (Province of Catamarca); Neuquén Investment Agency (Province of Neuquén); and Eólica Rionegrina Sociedad Anónima (ERSA) (Province of Río Negro).

production and imported components and reach a capacity of approximately 5–6 MW.

EDESTE is in charge of power distribution in the east of the province and is the company responsible for managing the operation and maintenance of the parks.

ENERGE emerged from a business pool in the National University of Cuyo; its founders were fellows of the National Council for Scientific and Technical Research. Within the environment of the development of renewable energies at a national level, ENERGE is one of the largest manufacturers and marketers of solar energy generation systems and equipment. It began with prototypes of thermal solar tanks (next section) and in 2014 ventured into photovoltaic solar generation projects, such as the park built in Santa Rosa, Mendoza, through MATER. The process of its execution went through several setbacks, finishing its construction in 2020.

Tassarolli is a metalworking construction company located in the Department of San Rafael, in Mendoza; it began its activities in 1953 and is involved in the fields of hydroelectric, mining, oil, and renewables industries. Tassarolli has a presence in Chile, Colombia, and Brazil, in addition to Argentina.

Helios was awarded in the third round of RenovaAr program. Although the investment is private, it was financed by the province government (Mendoza Activa Program and the Fund for Transformation and Growth) and a grace period of 12 months. *The park is connected to the distribution company network, EDESTE, so the electric power will go directly to the national interconnected system, that is, it will not feed specific consumption. The power purchase and sale agreement is subscribed with CAMMESA* (project reference, 2021). The park features bifacial panels and a weather station reports data to the facility administrator to forecast generation and possible intermittencies.

Other stakeholders involved in the productive system are independent professionals or small companies that provide advice, design, and installation services. This includes engineering, production, and installation, commissioning of a plant or photovoltaic installation. In general, they do not just market panels or accessories but offer a comprehensive service for residential and industrial customers. Among the works carried out, installations have been made to feed pumping equipment in agricultural areas, a 200-kilowatt plant in the province of Buenos Aires; home installations in a number of places; a project named *A Tiempo* (emergency care services); and provision of both photovoltaic panels and solar collectors in buildings under construction, in partnership with national manufacturers (Reference: Evergy Solar, 2020).

The working process *to install a system or equipment consists of a visit to the place, to advice about the capacity required*, and then make a specific estimate for each piece of work. Each installation has its own requirements, and it will be necessary in the first place to determine how to do it and where (floor, ceiling, wall), as well as the material and value of the structure and to know the available budget (see Table 14.3) (Reference: Evergy Solar, 2020).

In practice, inputs, materials, and technology adapted to each project/piece of work are characterized by a combination and adequacy of domestic and imported products. Among the main components of a solar park, photovoltaic panels and power inverters (that convert direct into alternating current) are imported from China and Europe. The structures on which the panels are mounted may be manufactured locally (e.g., IDERO) and compete with international components (from Spain or the United States) for assembling a solar park.

Stakeholder configuration involved in each project will define the type and origin of the technology and inputs that will be used. At Solar San Juan project and in some of the solar parks awarded under RenovAr Program, domestic products have been prioritized (e.g., PASIP), in accordance with policies requirements (as provided in Law 27,191). In turn, at works managed by private stakeholders, and built by international EPC contractors, the final cost is taken more into consideration than the origin of the components.

From the point of view of the stakeholders, the value ratio between domestically manufactured

Table 14.3 Case study highlights (I)

Cases	Infrastructure and technology	Inputs and materials	Solar power generation and electric power transformation	Grid connection and consumption
San Juan Solar Project/EPSE	Local manufacturing and development	Local and imported combination	Photovoltaic insertion in SADI	Grid connection, it involves large distributors, and CAMMESA is in charge of the administration
Solar Parks in Mendoza: PASIP Santa Rosa HELIOS	Local technology is prioritized complemented with imported components	Priority is given to local materials	Photovoltaic insertion in SADI	Grid connection, it involves large distributors, and CAMMESA is in charge of the administration
Smart Grid San Martín/Distributed Generation	Local development experience: dual meters test including tracking technology	Various places of origin, adapted to local power network	Operation in electric power distribution chain	Connection already established to the grid
ENERGE	Local manufacturing and development in combination with imported components	Local and imported combination	Photovoltaic and thermal Equipment is provided	Specific projects, equipment for self-consumption
Independent professionals, small companies	Design and installation of local and imported generation systems, adapted to users	Local and imported combination	Systems and equipment are adapted to each project/user	Generally for industrial and residential self-consumption

and imported products is detrimental to the former, not only because of the cost of the components but also because of the combination of stakeholders involved in the construction process. During the first construction projects of parks and works, the use of domestic products implied a process that consisted in bringing together manufacturers, installers, and service providers. From the perspective of the development of productive structures, this was an auspicious process. The construction of civil works, the manufacture of metallic structures, the transportation of equipment and components, the extraction of minerals and processing them to the required degree, the design and installation of electrical equipment, and the distribution of electrical energy can be mentioned as the main related industrial activities.

A further problem, in addition to the cost of the components, is the exchange rate fluctuation along the time projects are presented, approved, and executed. Budgets presented and approved upon the basis of a certain peso-dollar parity underwent considerable variations at the time of executing the works and consequently altered the value of the final product. *The main problem with our projects is that money reserve is in pesos, but we buy everything in dollars* (Smart Grid case, Reference: UTN, 2020).

Access to and types of financing are other element to take into consideration for the development of works. Economic valuation relations (who sells, how much, and to whom) are tied to the value of the final price of energy of each project. In the case of power generation in solar parks, price guidelines included in the bidding process, via RenovAr or MATER programs, have been decisive for guaranteeing the return of the investment. The role played by CAMMESA in this aspect is favorable to obtain profitability (and capital for investments) for the private stakeholders involved.

14.3.2 Local Manufacturing: Diversification of Processes and Products

Based on data from the solar thermal census (INTI 2020), percentages applied to solar thermal installations carried out in 2019 (Sabre et al., 2021: 10) were as follows:

- 61% for domestic hot water
- 16% for swimming pool heating
- 10% for heating
- 9% for industrial processes
- 4% for commercial premises

In Argentina, there are two types of solar thermal collector technologies: flat plate (grill and sandwich) and vacuum tubes. The first named is most popular at local level, domestic manufacturers accounting for 22% of the total market. This production coexists with the commercialization of imported products (78%), mostly including vacuum tube technology (INTI 2020).

Both the annual domestic production capacity and the amount of solar equipment manufactured in the country had an increase from 2017 to 2019 (85% and 37%, respectively) so did the amount of equipment marketed by importers during 2019 (71%). Eighty-one percent of the importing companies operate from China. Other countries of origin include Brazil, the United States, Greece, Australia, Spain, and Mexico (Sabre et al., 2019, 2021).

We also find a large number of service providers engaged in installation, maintenance, project design, and training. The number of installation companies increased by 61% with respect to those surveyed in 2015. Of these, 8% have INTI certification. *Although most of the installations surveyed were carried out by service companies (34% in 2017, 29% in 2019), a high percentage of manufacturers perform installations (26%), followed by distribution companies (23%) and importers (22%).* In that aspect, value chain shows a low degree of segmentation (Sabre et al., 2019, 2021).

It is worth noting here the high percentage of service companies devoted to project design (90%) and training (49%) (Sabre et al., 2021: 23).

Distributors work with manufacturers, importers, and service providers, accounting for 31% of the stakeholders involved in the production and value chain. In connection with sales channels, *importers make greater use of the distribution chain than manufacturers do, who have a higher percentage of direct sales to users*. In the latest survey, this percentage was reduced and was mainly through distributors (62% and 67% of importers and manufacturers sales); there were also sales to public purchases (12% and 4%, respectively) and retail chains (1%) (massive sale in hypermarkets and home appliance stores). Although this last-named marketing channel is the least used, there has also been a significant use of sales via the Internet, especially by importers. The percentage of products exported by manufacturers in 2017 was low (5%), and in 2019 no operations of this type were recorded (Sabre et al., 2019, 2021).

The number of people working in the power generation field shows a significant share of jobs in the service provision sector. Typically, the companies that develop this activity are small-sized (three workers on average), while manufacturers represent the highest mean number of employees (nine workers per company on average).

The service provision phase involves independent professionals who provide advice, design, and adapt renewable energy generation systems based on the characteristics of sites and users. This group of stakeholders has an incipient[8] field of development. Architects, engineers, urban developers, and bio-climatologists work, in gen-

[8] For instance, the Master Degree Studies in Sustainable Development of Human Habitat (UTN) in charge of researchers from CLIOPE and INAHE are oriented to the professional formation field in this area.

eral, at municipal and residential levels, in public works and buildings.

With regard to manufacturing companies, the case of ENERGE stands out. This company emerged from a joint work with the National University of Cuyo Region and other stakeholders of the local industry. The first prototypes of solar water heaters were manufactured by metal-mechanic industries in the Province of Mendoza, which put into practice the equipment, experience, and design of the company's first products. The association with other manufacturers through the National Institute of Industrial Technology (INTI) meant also a significant contribution. The intention of reaching a consensus on certain production processes and sustaining demand resulted in consolidating a certain productive structure and participating in projects including several manufacturers. ENERGE has positioned itself as one of the main manufacturers at national level, combining domestic and imported inputs and components in its production process (particularly in solar photovoltaic technology). It undertook two projects with associated industries that did not last, but which resulted in lessons learned for the production and commercialization process and in being recognized in the country. One of the projects was with the household appliance company Longvie and a development attempt with YPF Gas that was unsuccessful.

In connection with the diversification of processes, inputs and promotion of solar energy consumption, the work developed by CLIOPE Research Group under the National Technological University (UTN), the Institute of Environment, Habitat and Energy (INAHE) under the National Council of Scientific and Technical Research (CONICET), the Institute of Energy (IDE) under the National University of Cuyo, and the National Institute of Agricultural Technology (INTA), deserve a specific mention. These bodies are involved in research and development activities in the field of sustainable energies, generation devices, and optimized capture and use of energy from solar sources. They also deal with the spreading information about how to accede to the production of devices, generation, and consumption of this type of energy. In general, they work through public or private universities, in study centers, and research teams, interacting with productive stakeholders and residents of areas far from urban centers.

The National Institute of Industrial Technology (INTI), as seen from data above, is playing a central role in the development of the solar thermal energy production complex. The survey of stakeholders not only provides key information but also brings together several operations that have an impact on the productive environment. The certification of installers, on the one hand, consolidates this segment of the production complex, favoring the diversification of the participating stakeholders. On the other hand, the register of manufacturers provides a catalog of companies that develop equipment, including technical details and geographical location. Moreover, the articulation with housing construction programs in the provinces consolidates not only the incorporation of solar energy generation systems but also the strengthening of these production networks (manufacturers, distributors, and installers).

The municipalities, as minor territorial jurisdictions, enable the diffusion of renewable energies as sources of energy supply. This occurs in terms of communication, training in different trades, and in further building regulations. However, there are still technical and economic limitations in facilitating the incorporation of solar power generation, particularly regarding residential equipment (see Table 14.4).

Solar thermal energy in the world of renewable energies has a particular added value in terms of the technology needed to generate it. National production is that value. As for manufacture, it does not require large production plants and so can be carried out in different locations across the country and enables the creation of productive structures, generating direct and indirect employment. Among the related industries, as mentioned above, are metal mechanics, transportation, logistics, packaging, marketing chains of household appliances and household products, hardware stores, and marketing and communication services.

Table 14.4 Case study highlights (II)

Cases	Activity	Inputs and materials	Distribution/scope	Service provision
ENERGE	Local manufacturing and development	Domestic and imported (stainless steel, equipment, components)	Own sales establishments, franchises/Argentina	Technical advisory, design, equipment provision, and installation for self-consumption
Independent professionals	Design and installation of generation systems and equipment, adaptation to each user	Domestic and imported (equipment, components)	By demand/Cuyo Region, Córdoba, and Buenos Aires	Technical advisory, design, and equipment installation for industrial and residential generation and self-consumption
CLIOPE UTN/ INAHE CONICET/IDE UNCuyo/INTA	Technical developments, promotion of projects in partnership with private and public actors	National origin priority	By project developed/ Cuyo Region, and Argentina	Technical support and advisory
INTI	Technical developments, registration of actors, and promotion of partnership	National origin priority	By project developed/Argentina	Technical advisory, promotion of equipment development, and quality control
Municipalities (RAMCC-ActionLAC)	Promotion and incorporation of solar generation	National origin priority	By project developed/Argentina	Training in trades, installation permits, promotion of use/ consumption in public buildings

However, among the components of the manufactured products, stainless steel is the most used raw material. This component is imported and has an impact on the cost structure of manufacturing companies.

14.3.3 Solar Energy Generation Process: Economic-Political Relations

The network of stakeholders described in the various productive processes, including construction and operation of solar parks, manufacturing, and local services for the incorporation of photovoltaic and thermal solar energy generation systems, is made up on the basis of particular relationships. In each case, the strategies of the stakeholders will be understood when seen from a structural standpoint, as a crystallization of capitalist social relations of production in the country, and from a process standpoint, in the interaction between applicable promotion policies and concrete practices of the stakeholders.

The composition of energy supply sources in Argentina and its recent transformation with the growing addition of renewable energy sources, mainly wind and solar, account for the impact experienced on the expansion of the production complex across the territory. We have noticed through the case studies the operation of specific executed projects and how a productive structure was formed as a result of said projects and of certain incentives under the national energy policy.

We need to make a differentiation in connection with the economic-political relations involved in the solar parks built in Cuyo region. The differentiation has to do with the definition of actions aimed at completing the local manufacture of components and the construction of the solar parks, as opposed to the operation of private enterprises, where ownership and control are primarily about the economic value of the product. In both cases, there is a key stakeholder that commands the distribution and valorization process. The Wholesale Electricity Market Management Company (CAMMESA) grants certain stakeholders access to electric power and to participate in power generation and consumption. The assignment of a priority order to inject power into the electric grid, the destination of the consumption of the various types of electric power, and the establishment of a predefined value for each project become especially relevant, considering that the price is lower than the energy produced through conventional sources and that it ensures the return of the generation projects. This exercise defines, in relational terms, who produces, who consumes, and who appropriates the production value of this type of energy.

The execution of generation projects of a certain size and capacity follow a series of procedures and mechanisms that will result in the decision of who ultimately be the involved stakeholders. Province-owned power generation companies, local manufacturers, developers, and investors all form a heterogeneous network within each project, but with a certain practice (and productive economic support or productive capacity) for their execution. On the other hand, market conditions and promotional policies show a concrete incidence in the development of each generation project.

In the case of San Juan Solar Project, *the production process first requires low energy and logistics costs, neither of which conditions are currently being met in Argentina. Energy is expensive for the industry, and living in San Juan is the same as living in the last place of…we do not have trains; we do not have access to the facilities; access by road is poor and expensive.* Second, in order to be able to manufacture, you need a license through a patent: Siemens or Monsanto Electronics. *China produces through a process called modified Siemens (a copy of Siemens), and it currently has about 30% of the world market. To find a solution to this issue, one must resort to an international court or be prepared for a trade war. If we were China, we could have chosen a similar solution, but in our case, there is no way that we can use a patent without paying for it* (Reference: EPSE, 2021).

Difficulties to go further or deeper into a solar panel manufacturing project have been somewhat solved in order to consolidate the whole production complex. The project works when solar parks are built and connected to the national power grid. The investment and startup of the whole production process (Sect. 2.1) makes sense when electric power is produced as a final product.

On the other hand, the development of solar parks in the Province of Mendoza arises from the economic motivation of taking advantage of available electricity networks that are no longer in use due to reduced agricultural activity plus the availability of acres of uncultivated land. Having access to the networks through the MATER Program, the initial investment was made by various investors not necessarily linked to the activity. The regulations implemented to increase the use of renewable energy supply by the industries, together with the facility provided by the agreements entered with CAMMESA, helped to foster the investment. *The companies that opted to take advantage of this, instead of generating 8%, generated 35% because renewable energy is cheaper* (Reference: ENERGE, 2020). This is the way to encourage these development projects.

However, in the end, CAMMESA *will lose money because it has bought at a higher price, and then it will have to sell cheaper because of subsidies*. As a managing company, CAMMESA buys energy (off-taker), facilitates the agreements with other private companies to be able to develop renewable energy projects (solar park or wind farm, biomass, biodiesel, or small hydro projects) and is in charge of priority dispatch (Reference: EPC contractor, 2020).

CAMMESA's willingness to let energy be injected, the price at which it takes said energy and to whom it sells it seems to be discretionary as to which stakeholders benefit from it. This happens with the pattern of consumption of energy from renewable sources by companies that reach a certain demand (large users regulated by Law 27,191). In terms of socioeconomic relations, *you could buy energy from another renewable generator, the energy was considered as yours, it was self-generated. For instance, I get together with three or four companies, buy a piece of land, and generate renewable energy. Since the plot is not close to my location, I cannot lay a cable to my place; instead I sell power to a distributor, and with the proceeds of that sale, I generate/buy the quota of renewable energy as stipulated by the law* (Reference: UTN, 2020).

With regard to socioeconomic relations among local manufacturers of solar thermal collectors (such as ENERGE and those in the registry kept by INTI), and of those who adapt technologies, materials, and components of generation systems, competition with importers is what defines some of the strategies deployed. From the perspective of the developments, there is a need for upgrading or making equipment suitable to local generation conditions. In this aspect, technological proposals, the study of materials, and technical adjustments to each region have an expansive potential in products and in the professional standards of designers and installers. Another aspect is related to the challenge in the matter of costs and price formation within the valorization process. Imported products, mostly of Chinese origin, have an artificially low value in terms of product composition (incorporated technology and labor force required). In fact, claims have been filed to complaint about this situation (Murphy & Elimä, 2021).

In the cases under study, the performance of the national industry, either as direct manufacturers or as partners in the production chain, are experiencing difficulties that reflect similar problems to those of industrial development in our economies. Market conditions of solar products are detrimental to domestic manufacturers, in terms of competition and prices. In addition, developers and consumers have their preferences for certain technologies over others. For instance, vacuum tubes versus flat plates. Solar park structures also depict this. The involvement of foreign stakeholders directly in the construction (EPC contractors) or their association with local stakeholders also determines the proportion in which local products are present. The incidence of requirements in public work tenders (photovoltaic or housing projects) is a major incentive for the development of domestic products, although this does not result into budget savings for each project.

Macroeconomic conditions and the conditions of social relations of production determine the margin of competition or collaboration of the local stakeholders, the continuity of their compromise, and the capital invested in these projects. In the territory, energy-production policies and the associated incentives become necessary articulations, but they require to be anchored in the potential profitability obtained from the undertaken projects. When the incorporation of energy generation systems by renewable sources is encouraged, incentive policies for intensive capital investments favor the insertion of certain stakeholders (EPC contractors, investors) and products over others. In Argentina, the implication or orientation of these policies would mean to sponsor national industry, based on manufacture by diversified local stakeholders and users of different sizes/types (residential, industrial, agricultural).

Notwithstanding, the combination that ultimately gives form to this productive structure also results from the dynamics consisting of financing the development of projects, assigning a budget (cost structure) and the times associated with the mechanisms of project allocation, permits, and capital disbursement. With regard to our country, we should especially consider the variations in our macroeconomic policy, particularly in relation to a monetary framework, the relationship with the exchange rate, and the regulations and policies on international trade and capital movements.

14.4 Conclusions

Making a sociological reading of the economy, it is possible to discern, within the productive structure of solar energy, that there are economically profitable sectors and others that require assistance for their development. While the profitable sectors progress, the others are subject to oriented policies. Making a relational reading of the production complex considered as an economic sector, we find that it needs the same support and it undergoes the same ups and downs of macroeconomic dynamics in relation to the movements of the international market of equipment and components. Looking in depth the development of works, projects, and specific territory where solar energy generation systems are incorporated, it is possible to see the convergence of local productive forces, with a certain autonomy of action. Such autonomy is subject to inputs, materials, and components of the generation systems which, although they can be adapted or reproduced, and even improved in the domestic industry, must face difficulties with regard to their economic operability. The relationship between domestic and imported components, more developed (standardized) or "handcrafted" (small scale of production) technologies, price formation, and special features connected to the use of one or another product could reflect the same constraints as any other production and valorization process (product).

The difference lies in the type of product and the transformation involved in its use. By understanding the production complex as an integral part of a larger process, energy diversification, as well as the actions and practices aimed at overcoming the abovementioned difficulties, can be channeled under other parameters that exceed the exclusive economic operability.

In other words, the logics of reproduction of capitalist social relations of production apply equally to other production complexes. The differentiation is the particular and progressive association between the expanded incorporation of renewable energy generation systems (and their alternative forms of production) and their productive use (residential, industrial, agricultural). The mutation of the technological-productive paradigm will be achieved through a transition to types of energy that reduce the production and consumption of fossil fuels. The productive structure of regional economies is key in the configuration of alternative forms of production and consumption, that is, in the manufacture and incorporation of materials and equipment for the completion of the whole generation process.

From the analysis, we can identify some issues to be addressed in order to strengthen energy diversification processes with the incorporation of local developments. The conjunction of public policies aimed at the energy transition to replace fossil fuels with the existing productive, scientific, and technological development networks and the economic actors themselves in the territory is indispensable. The time required for the incorporation and use of alternative energy generation systems depends on the type of actors involved. This also defines the type of development that takes place: multiple actors of diverse origins act together in the configuration of the solar energy complex. This diversity implies challenges in the concrete processes of energy diversification: different practices of the actors involved (and interested) participate/proceed/are part of diverse structures (interweaving) (global economic-political networks, national and regional-subnational production, and value chains) as spaces of practices and interaction of diverse actors, with diverse subjectivities and interests.

The analytical perspective moves through different levels and contributes by pointing out the direction of articulating/consensualizing practices of diverse actors (in terms of origin, size, incorporated capital), not without conflicts. The social relations of capital production are visible, operate, and become imperative: the profitability of the projects involved in the processes of energy diversification and those that arise in articulation with the structures and dynamics of production (and valorization) in each specific territory proliferate. Learning from this is planning for the introduction of renewable energies into the energy composition of a country taking into consideration the territorial level and the configuration (profile, features, and practices) of the stakeholders involved. The macroeconomic conditions that accompany or difficult the investment processes in mostly capital-intensive projects in countries of Argentina's characteristics, with differentiated subnational spaces, and the sustainability over time of those of greater magnitude mark the current concrete features of the possible energy transition.

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15 Uncertainties About the Transport Planning in Brazil in the Context of Climate Change: Tradition (Biofuels) or Innovation (Electric Mobility)?

Carolina Grangeia and Luan Santos

15.1 Introduction

Climate change is one of the greatest economic and political challenges faced by the world economies today (IPCC, 2014). It implies the need to reconcile the global nature of the problem with actions at regional, national, and/or local levels (Santos, 2018; Schütze et al., 2017). The impacts of climate change are increasingly taking center stage in political, economic, social, and environmental discussions, as countries, in signaling the transition to a low-carbon development model, are seeking technically and economically feasible solutions and mechanisms to reduce emissions of greenhouse gases (GHG).

The increase in climate action and net-zero commitments around the world is notable. In this scenario, the Brazilian government presented its Nationally Determined Contribution (NDC) at the 21st Conference of the Parties (COP 21) in 2015, whose main result was the establishment of the Paris Agreement. Through this document, Brazil indicated the intention of reducing GHG emissions by 37% below 2005 levels by 2025, with a subsequent indicative contribution to reduce emissions by 43% below 2005 levels by 2030. After the first NDC revision in 2020, this subsequent indicative contribution became official. The target levels were not established in terms of sectorial commitments; however, for internal purposes, it indicates the expected effort from each sector, considering planning objectives and the feasibility of the mitigation effort (Brazil, 2015a, b), varying from reforestation to the increase of the bioenergy and renewable energy shares in the Brazilian energy system. Unfortunately, after the first review, such details were removed from the Brazilian NDC.

The fact is that Brazil is one of the best well-positioned countries when it refers to renewable resources in the world, given that its energy matrix has 51.6% of its share represented by the oil and gas industry and 48.4% with the participation of renewable sources, mainly marked by the increase in the supply of biomass and expansion of wind and solar sources in energy generation (BEN, 2021). From the perspective of the Brazilian oil and gas market, there are interesting opportunities within the scope of the decarbonization of the energy matrix, given the maturity and complementarity of the bioenergy with greater use of biomass and instrumentalization of sectoral decarbonization credits (e.g., carbon reduction credits – CBIO that will be explained and detailed in the next section); the possibility

C. Grangeia (✉)
Production Engineering Program, The Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
e-mail: carolinagrangeia@ufrj.br

L. Santos
Faculty of Business Administration and Accounting Sciences, The Federal University of Rio de Janeiro, Rio de Janeiro, Brazil
e-mail: luan.santos@pep.ufrj.br

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of refineries becoming biorefineries or offering hydrogen through natural gas; greater plurality of agents and market opening with Petrobras' divestments; the development of carbon, capture, utilization, and storage (CCUS) technologies; the growth of renewable energies such as solar and wind; and the O&G industry's own experience in offshore projects that can leverage offshore wind generation technologies (CEBRI, 2021).

Particularly in the Brazilian transportation sector, whose mobility technologies are highly locked-in to fossil fuel use (Pietzcker et al., 2014), decarbonization becomes even more complex – the automotive industry represented c.a 5% of the gross domestic product (GDP), and it was responsible for c.a 20% of the industrial GDP, generating approximately 1.3 million direct and indirect jobs (ANFAVEA, 2020). Furthermore, the Brazilian economy growth has been accompanied by the increase of demand for energy (Baran & Legey, 2013). This way, to guarantee the reduction of climate change impacts from transportation, it is important not only to promote cleaner vehicle technologies but also to increase the use of more sustainable transportation modes (Silva et al., 2021; Schäfer et al., 2009). From the supply side, for instance, current efforts to decarbonize the transportation sector find it necessary to increase engine efficiency and promote the use of low-carbon fuels (Silva et al., 2020). From the demand side, it is also important, for example, to establish an equalization between total cost of ownership and consumer's affordability, besides promoting mobility in scale, from micromobility to electric buses or other cleaner technologies, given the social dynamic (e.g., income level, educational level, age, aversion to the initial outlay, among others). In other words, even when the new technology is competitive, its dissemination is not immediate, as it depends on socioeconomic and behavioral characteristics (EPE, 2018).

In Brazil, the transport sector responded to approximately 33% of the total energy consumption in 2019, and it was responsible for 190.5 $MtCO_2e$ – 45.4% of total emissions from the energy sector (BEN, 2021). Also, the domestic production of oil increased by 7.8% in 2019, reaching an average of 2.79 million barrels per day (BEN, 2021). In this context, it is important to highlight that in Brazil, transport has oil as its primary source of energy, notably a large emitter of polluting gases and whose domestic price has fluctuated in the face of the international scenario and national policies (Grangeia & Santos, 2020b).

Furthermore, Brazil is highly dependent on road transport (Baran & Legey, 2013), and the vehicle fleet accounted for 46.9 million units, including cars, light commercial trucks, and buses in March 2021 (Sindipeças, 2021). By the end of 2020, flex vehicles represented 71.4% of the country's fleet and gasoline vehicles, 17.4%. The share of diesel vehicles remained around 11%. Hybrid and electric vehicles (EVs) in turn registered 37500 units, representing almost 0.1% of the total fleet. However, the releases and imports carried out each year and the decision of some automakers to phase out combustion vehicle will progressively increase the presence of hybrid and EVs vehicles in the fleet (SINDIPEÇAS, 2021).

Several studies have investigated how to pursue decarbonization in transportation worldwide. Bataille et al. (2020) designed net-zero deep decarbonization pathways in Latin America, and they concluded that decarbonization is reached in the transportation sector through a mix of urban planning, mode shifting, electrification of buses and passenger vehicles, and alternative net-zero liquid fuels (e.g., sustainable biodiesel and ethanol). The same approach for China concluded that carbon intensity improvements toward cleaner alternative fuels, such as renewable electricity, biofuels, and hydrogen, are mainly responsible for mitigation efforts in the country (Pan et al., 2018). For the 28 countries of the European Union (pre-Brexit), Haasz et al. (2018) studied methods to decarbonize the transportation sector and found that electrification will play a key role, especially after 2030. In Brazil, Goes et al. (2020) found that investments in electromobility and infrastructure to decarbonize transportation are more cost-effective than biofuels.

Giving this context and the relevance of the transport sector in Brazil for the decarbonization of the country, this chapter aims to analyze the energy and fuel policy in Brazil in the context of Sustainable Development Goals (SDGs) and possible impacts from Brazilian decisions related to climate change. To this end, an extensive analysis of the main government plans, as well as the political directions on the biofuels and electric mobility agenda, will be carried out in order to understand the current state of energy and transport planning in the country, so as to foster the development of public policies for the sector.

15.2 Technological Route of Biofuels and the Consolidated Brazilian Experience

In the last few years, fossil fuels are facing criticism due to the high utilization by the dense population, urbanization of various geographical areas, and industrialization which directly affect the global climate and economy. Thus, with the expansion of fossil fuels and their hazards, fuels from biological origin such as ethanol, vegetable oil, and various biomasses are gaining attention. In this regard, biofuel's environmental benefits are widely touted among renewable fuels' advocates to reduce pollution and climate-altering GHG emissions worldwide (Benites-Lazaro et al., 2017; Sandesh & Ujwal, 2021).

Sorda et al. (2010) review governmental policies and national strategic plans for biofuels in different countries, and their expansion is basically justified by government interventions such as financial incentives, blending mandates, and feedstock use, sustained by environmental strategies. These strategies combined with intensive development of biofuels are based on the assumptions, for example, that the production of ethanol from sugarcane and sugar beet could cut emissions between 60% and 90%. Meanwhile, production of biodiesel, maize and palm oil, and rapeseed turn out to reduce emission by 35%, 80%, and 60%, respectively (Subramaniam & Masron, 2021).

The growth of flex fuel vehicles can be justified after the first oil crisis in 1973 and the introduction of the National Alcohol Program (PROALCOOL). In the 1970s, the Brazilian Government began mechanisms to encourage vehicles powered by alcohol, such as the Tax on Industrialized Products (IPI) specific for alcohol-powered cars, in addition, automakers developed gasoline-powered cars, with the addition of a percentage of anhydrous alcohol (Junior, 2011). After the second oil crisis, the production of vehicles powered by alcohol reached its peak, accounting for 90% of new vehicles sold in the country (Teixeira, 2005). Only at the end of the 1980s, with the supply crisis caused by the combination of the good remuneration of sugar in the international market and the disincentive to alcohol production, in addition to the reduction of subsidies, did hydrated alcohol lose its competitiveness against gasoline. In the 1990s, the Brazilian automobile industry was exposed to global competition, and from that moment, the Brazilian market turned to the production of flex fuel vehicles, with tax benefits for its expansion (Junior, 2011). Notwithstanding this success, flex fuel engines are less energy efficient than engines that run on one fuel only (Figueiredo, 2005), and there is no policy to develop and accelerate the entrance of hybrid and electric vehicles in Brazil (Baran & Legey, 2013).

The technological route of biofuels has been notably standing out in Brazil since the PROALCOOL in the 1970s, until the current National Biofuels Policy (RenovaBio), established by Law Nº. 13.576/2017. The National Biofuels Policy was launched in December 2017, with the aim of supporting the Nationally Determined Contribution (NDC) commitments under the Paris Agreement. This policy includes Life Cycle Assessment (LCA) and financial instruments, supporting national energy security and reducing GHG emissions. It focuses on increasing the consumption of biofuels and expanding it in the Brazilian energy matrix, encouraging producers and creating an open market for carbon-reduction credits called CBIO (Lazaro & Thomaz, 2021; Gonçalves et al., 2021; Grassi & Pereira, 2019; Grangeia & Santos, 2020a, 2021a). In brief, RenovaBio's main purpose is to increase biofuel consumption and its expansion in the Brazilian energy matrix based on a solid decarbonizing policy, giving incentives to producers, and creating an open market of carbon-reduction credits called biofuel Decarbonization Credit (CBIO) (Gonçalves et al., 2021; MME, 2017).

The emission reduction targets for the fuel matrix were defined for the period from 2019 to 2029 by CNPE Resolution No. 15, of June 24, 2019 (Brazil, 2019a). These targets will be broken down annually into mandatory individual targets for fuel distributors, according to their participation in the fossil fuel market, under the terms of ANP Resolution No. 791/2019, of June 12, 2019 (Brazil, 2019b). Through the certification of biofuel production, different grades will be assigned to each biofuel producer and importer, in a value inversely proportional to the carbon intensity of the biofuel produced (MME, 2017). The note will accurately reflect the individual contribution of each producing agent to mitigate a specific amount of GHG in relation to its fossil substitute (in terms of tons of CO_2 equivalent-CO_2e).

Biofuel producers and importers who wish to join the program will hire certifying firms accredited by the ANP to carry out the Biofuel Certification and validate the Energy-Environmental Efficiency Rating (NEEA). The Certificate of Efficient Production of Biofuels will be valid for 3 years, counting from the date of its approval by the ANP, and can only be issued by the inspecting firm after the approval of the process by the ANP (Grassi & Pereira, 2019; Klein et al., 2019).

To achieve its objectives, RenovaBio is designed to introduce market mechanisms to recognize the capacity of each biofuel to reduce emissions, individually, per production unit. Basically, there are two main instruments (MME, 2017; Brazil, 2019a, b):

1. Establishment of national emission reduction targets for the fuel matrix, defined for a period of 10 years. The goals are important to bring predictability, in terms of the volumetric need for fuels (fossil and renewable) in this time horizon, and thus allow private agents to make their investment planning and analysis in an environment with less uncertainty.
2. Certification of the production of biofuels, assigning different grades for each producer (higher grades will be given for the producer that produces the greatest amount of net energy, with the lowest CO_2 emissions, in the life cycle). The note accurately reflects the individual contribution of each producing agent to mitigate a specific amount of GHG in relation to its fossil substitute (in terms of tons of CO_2e).

The connection of these two instruments occurs with the creation of the CBIO, which is equivalent to one ton of carbon, and it is a fundamental component of the RenovaBio program (MME, 2017). This is an asset, traded on a stock exchange, issued by the biofuel producer, from commercialization (invoice). Fuel distributors will meet the target by demonstrating ownership of CBIOs in their portfolio. Its commercialization is an incentive for biofuel producers to expand their production and a way to attract new investments, inducing a greater participation of biofuels in the matrix and contributing to the reduction of GHG emissions.

The annual mandatory target represents the volume of carbon dioxide that must not be emitted to the atmosphere by a renewable fuel or emitted by a fossil fuel, as one ton of carbon dioxide corresponds to one CBIO. To issue a CBIO, biofuel producers/importers must be certified by an inspection company, which will give them an energy efficiency grade calculated using RenovaCalc, a specific calculator that considers, beyond other aspects, the production route, the way of production, and biomass eligibility criteria (Gonçalves et al., 2021).

Considering the annual target for each year, it will be divided into individual targets and applied to all fuel distributors proportionately to their market share in fossil fuel sales in the previous year. The distributor is obligated to acquire CBIO; otherwise there is a fine that can reach R$ 50 million (approximately US 9.2 million), and the CBIO nonacquired will take part into the target the year forward (MME, 2017). It should be noted, however, that, given the current pandemic context of the new coronavirus (Covid-19) and the oscillation of fuel consumption, many questions regarding the volume of CBIOs appear, as well as their estimated price.

So far, more than 200 producers have already been admitted to RenovaBio. In order to guarantee the credibility of the CBIO, it is registered by financial institutions and traded on the Stock Exchange. CBIO, in practice, constitutes an element of pricing for carbon reduction. Distributors will have the obligation to purchase CBIOs to meet their goals that will be issued by producers/importers of biofuels, duly certified by a certifying company, in an amount proportional to the respective volumes sold of these products and to NEEA. Thus, the program is a market-driven scheme with no subsidies, and it drives to sustainable bioenergy production (Gonçalves et al., 2021; MME, 2017; Grassi & Pereira, 2019; Klein et al., 2019).

The biofuel producers/importers will have up to 60 days to issue the CBIO after its sale, and the primary issuance of CBIO will be made in book-entry form – contracting a bookkeeper. The negotiation of decarbonization credits will be carried out in organized markets, and the bookkeeper will be responsible for maintaining the business records that occurred during the period in which the credits were registered. Then, the CBIO will be traded on an exchange by bookkeeper or broker and can be acquired by distributors, investors, hedge funds, and other market players. By the end of the day, the final negotiations will be shown by the stock exchange (Grangeia & Santos, 2020b; MME, 2017).

Furthermore, the Federal Government launched the Fuel of Future Program in 2021 in order to increase the use of low-carbon intensity fuels and decarbonize transport matrix by proposing measures such as the complete evaluation of energy-environmental efficiency through the analysis of the LCA. Also, it aims to integrate public policies in the automotive and fuel sectors, such as the National Biofuels Policy (RenovaBio), Brazil's National Biodiesel Program, Program for the Control of Air Pollution from Automotive Vehicle – PROCONVE (Brazil, 2021; Grangeia & Santos, 2021b).

The Fuel of Future Program highlights fuels with high octane and low-carbon emissions from the Otto Cycle (gasoline and ethanol), promotes the use of second-generation ethanol, and encourages the promotion of the ethanol fuel cell. Also, in the Diesel Cycle, it aims to enhance the use of biomethane, natural gas, green diesel, biodiesel, and other synthetic fuels. Consequently, the program brings guidelines to promote the development of advanced technological routes; however, the electric vehicles have a sluggish participation in this context (Grangeia & Santos, 2021a, b).

Finally, the influence of the biofuels industry on the economy, on the occupational dynamics and on the generation of employment and income in the country, is remarkable. However, all this apparatus of sectoral programs and plans, until then, do not clearly demonstrate the strategies and mechanisms of verification of the social impacts of biofuels. Thus, a proposal for the RenovaBio Social Seal (SRS) was presented, structured around four themes – employee's rights, impacts on the community, responsibility with customers, and health and safety – with principles and criteria, framed in the basic, intermediate, and advanced levels. In this way, the seal, still under debate, seeks to bring the theme of social justice and strengthen the argument of the sugar-energy sector on social and economic inclusion, using the legal framework well-established by the Law 13.576/2017 (BEP, 2022).

15.3 Electric Mobility Growth, Its Benefits, and the Recent Brazilian Experience

Among the decarbonization alternatives sought from the supply side, electrification has gained terrain for two reasons: first, electric motors are much more efficient than internal combustion engines (García-Olivares et al., 2018); therefore, overall energy efficiency of fleet usage would increase because of a switch to EVs. Second, renewable electricity as an energy source can substantially reduce transportation's carbon footprint. Indeed, Dominković et al. (2018) conducted a literature review to assess the contributions of biofuels, hydrogen, synthetic fuels, electrofuels (produced from CO_2 and water electrolysis), and electricity to the transition to renewable transportation. They concluded that electrification showed the greatest benefits and should be the focus of the transport transition. Moreover, higher fleet efficiency leads to lower final energy demand in the transportation sector.

Several other authors have studied the role of electrification in decarbonizing the transportation sector, especially in passenger transportation. Teske et al. (2018) studied the implications of high renewable energy penetration for urban energy and transport systems and found that, in such a scenario, transport energy demand would be lower due to a drastic shift to electric mobility, accompanied by a phasing out of combustion engines and a modal shift in favor of urban public transport. A study by Zhang et al. (2018) analyzed how several low-carbon transport policies, such as electric vehicles, speed regulation, pedestrian-friendly design, and bicycle-oriented development, contributed to decarbonization and concluded that EVs have the most significant emissions reduction. Lorenzi and Baptista (2018) performed a scenario analysis to assess the promotion of renewable energy sources in the transportation sector in Portugal and found that EVs would substantially reduce total energy consumption and GHG emissions. Furthermore, Brozynski and Leibowicz (2018) studied how to decarbonize power and transportation at the urban level and discovered that the optimal decarbonization pathway has two stages: reducing carbon intensity in the power sector, followed by electrifying transportation. Further, Glitman et al. (2019) assessed the role of EVs in a decarbonized economy and concluded that with proper integration with the power sector; EVs can be useful tools in such an economy.

Regarding technology comparison, Ahmadi (2019) conducted a life cycle emission and cost comparison among different powertrains of EVs to assess their contribution to the decarbonization of transportation. The conclusion was that fuel cell electric vehicles (FCEVs) and full battery electric vehicles (BEVs) are "the most environmentally benign" options. Paulino et al. (2018) evaluated alternatives for the passenger road transport sector in Europe and found that compressed natural gas (CNG), biofuels, and EVs show the greatest reduction in climate change. Finally, Hannula and Reiner (2019) studied the role of biofuels, electrofuels, and BEVs in decarbonizing road transport and found that such technologies would require carbon and oil prices higher than USD 130/t CO_2 and USD 100/bbl, respectively, to become commercially viable relative to petroleum. Economies of scale in deployment and production, however, will potentially reduce these figures, as well as access to low-cost renewable electricity. Therefore, electrification of light-duty passenger vehicles appears to be an important measure to reduce emissions in the transportation sector.

In fact, the cost of electric powertrains has been falling in the past few years. Increased interest from both the demand and supply sides has contributed to a growth in the uptake of light-duty electric vehicles (LDEVs) and to a decrease in their acquisition cost. In the past decade, the cost of batteries – the main contributor to the price of LDEVs – has fallen by 87% (BNEF, 2019), and it is expected that economies of scale in battery production will push this figure even further down in the future.

Consequently, with growing concerns about the impacts of climate change and energy security, policy support for the electric vehicle (EV) industry was strengthened to reduce GHG emissions. During COP 21, in 2015, the Paris Declaration on Electro-Mobility and Climate Change and Call to Action were established, which set the global goal of reaching 100 million EVs and 400 million EVs from two or three wheels by 2030 (UNFCCC, 2015).

According to data from the World Energy Outlook 2020 (IEA, 2020), there was a 40% increase in the global inventory of passenger EVs from 2018 to 2019, reaching 7.2 million units. About 47% of this world fleet was in China, 25% in Europe, and 20% in the United States. However, despite recent international, governmental, and national targets, many regulatory and institutional barriers still challenge the expansion of EVs, as well as companies entering the EV industry and still need to define profitable business models that address these barriers and ensure sustainable growth (Grangeia & Santos, 2020b; Bohnsack et al., 2014; Kley et al., 2011). In this sense, the regulatory structure and public policies play a fundamental role in uniting the various players in the EV market, bringing the public sector closer to the private sector, and providing legal certainty for the construction of instruments that allow greater receptivity of national and international investments (Wady & Consoni, 2020).

This transition is still taking place slowly in Brazil. However, over the past few years, EVs have been growing, especially considering the need to reduce GHG emissions. Significant capital and investment in EV development are bringing a range of products from the paper design and prototyping phase into commercial production. In addition, from the 2000s onward, with the significant increase in the price of oil, directly impacting the price of derived fuels, even more alternative vehicle technologies were promoted (Slowik et al., 2018). Currently, the total fleet of EVs in Brazil, in 2020, totaled around 30,092 licensed units, and around 25% of these units were battery-powered electric vehicles or plug-in vehicles. Most of these vehicles are concentrated in the south-southeast region, which presents a more intense freight and passenger logistics activity (ANFAVEA, 2020). This same pattern of geographic development is observed in the growth of public charging infrastructure.

The EVs have not been given as much attention in Brazil as other countries such as China, India, and the United States (Baran & Legey, 2013), as the growing presence of EVs in these countries is due largely to a series of policies which include subsidies for the purchase of EV, tax reductions, regulatory measures limiting gas emissions, exemption from parking fees, and circulation limitation in some areas with circulation and incentives for the installation of public charging stations. Also, these countries and automobile companies installed in these countries assumed ambitious goals providing incentives for low-emission vehicles (Wunterberg, 2020).

Meanwhile, it is notable that Brazil has a great potential for the manufacture of EVs, mainly because the country is one of the main automotive markets in the world. However, there is a detachment between the initiatives and stakeholders involved, as well as punctual government incentives and policies to turn electric vehicles a democratic product (Barassa, 2019; PNME, 2021). Among the national programs, we can highlight the Incentive Program for Technological Innovation and Densification of the Automotive Vehicle Production Chain (InovarAuto), till 2017, and Rota 2030, which is still in course. The latter seeks to "support technological development, competitiveness, innovation, vehicle safety, environmental protection, energy efficiency and the quality of cars, trucks, buses, chassis with engines and auto parts." In addition, state and municipal climate plan initiatives with net-zero commitments are configured as policy levers aimed at local low-emission transport (IEMA, 2021).

Another relevant point is the potential of electric vehicles to reduce CO_2 emissions, especially in countries with an energy matrix composed mainly by clean sources. In this sense, Brazil has an advantage in terms of share of electricity from low-carbon sources. In other words, 65.2% of its electrical matrix comes from hydropower, followed by 9.1% biomass, 8.8% wind, and 1.7% solar energy (BEN, 2021). However, it is observed that there is still no national consensus on EVs, as well as an absence of development plans in this regard. Also, the expansion of electric vehicles in Brazil is still moving slowly, while the country announces new policies for the advancement of biofuels (Grangeia & Santos, 2021b).

15.4 Brazilian Transport Planning: Current Status and Future Perspectives

The climate agenda and environmental pressures on the oil and gas sectors have highlighted the strategic role of the biofuels industry.

Furthermore, the energy transition and security are opening a range of opportunities for this industry, especially in Brazil, a country that seeks to keep the leadership in this sector. In this context, the National Biofuels Policy (RenovaBio) was recently launched, creating an instrument called CBIO and providing a new trade market. As discussed in Sect. 15.1, such policy includes mechanisms for LCA, commercialization and predictability of the fuel market, in addition to increasing the use of biofuels, supporting national energy security, and reducing GHG emissions as the policy meets Brazil's commitments under the Paris Agreement.

However, in the face of so many economic uncertainties, market fluctuations, and the socio-economic scenario, there is a trigger to review the policies associated with biofuels in Brazil – such as RenovaBio, Biodiesel Auction, Resolutions from the Brazilian Petroleum, Natural Gas and Biofuels Agency (ANP), taxation, and financing, among others. Despite the challenges imposed to this new public policy in the energy sector, RenovaBio stimulates the increase of biofuels in a country that is a reference in bioenergy and supports the achievement of the Brazilian NDC's goals. So far, the program has not yet been implemented with full effectiveness, even with 14.5 million tons of carbon dioxide avoided by the transport sector as a result of 2019/2020 target (Unica, 2021). However, it is expected that the government addresses some of RenovaBio's gaps in order to guarantee Brazilian climate's ambitions.

It is also verified that the transition to electric mobility is still slow, mainly due to the highlight and advances of biofuels, which have traditionally stood out since PROALCOOL until the launch of the Fuel of the Future Program, which seeks to integrate public policies such as RenovaBio, the National Program of Biodiesel Production and Use, Program of Air Pollution Control by Motor Vehicles (PROCONVE), Rota 2030 Program, Brazilian Vehicular Labeling Program, and CONPET (energy efficiency seal) (Grangeia & Santos, 2021a).

Therefore, the Fuel of the Future Program does not bring as a priority agenda incentives to electromobility, going in the opposite direction of other countries that have assumed electrification targets. In this sense, Brazil has a strategic role in relation to electric mobility and GHG emissions reduction, with opportunities within the production chain and new businesses. However, decisions such as the majority focus on biofuels route can contributes to the unclear position of Brazil in relation to other technological transition (Barassa, 2019; Grangeia & Santos, 2021b; Wunterberg, 2020).

Despite the international, national, and city-wide targets toward net-zero achievement, many regulatory and institutional barriers challenge the expansion of EVs (Kley et al., 2011; Bohnsack et al., 2014). In this sense, the regulatory structure plays a fundamental role joining different players from the EV market, bringing the public sector closer to the private sector, and providing legal certainty for the construction of instruments that make national and international investments more receptive (Wady & Consoni, 2020). At this point, Adner and Kapoor (2016) argue that it is necessary to assess the "ecosystem" in a broader way, looking at complementary technologies, services, standards, regulation, and infrastructure, among others, so as to have a better understanding between the "new" and old ecosystems – not just the technology itself – and thus better predict the timing of entry of the "new" technology.

In this context, the penetration of EVs in Brazil could be enhanced by the establishment of standards, zero-emission mandates, regulations, and good practices such as low-carbon zones and exclusive parking space. In addition, other factors also influence, such as financing models, accessible EV infrastructure, incentives such as tax exemptions, training, and knowledge management of different sectors for the construction of the necessary framework and the most appropriate business model to a given place (D'Agosto et al., 2020; PNME, 2021).

Even with no specific plans for electric mobility, according to the new rules, tax on an industrialized product (in Portuguese abbreviation, IPI) that is levied on EVs ranges 7–18%, depending on energy efficiency and vehicle weight (Brazil, 2018a, b). Also, at the federal level, the import tax changed in 2015 from 35% to 0% for EVs (Bitencourt et al., 2021). The Law 13.755/2018 also establishes IPI and the Brazilian tax on financial operations (in Portuguese abbreviation, IOF) exemptions (Brazil, 2018b). Moreover, the Program of Social Integration (PIS) and the Contribution for the Financing of Social Security (COFINS) tax on new vehicles is 9.25% (Bitencourt et al., 2021). Lastly, all 26 states and the Federal District are exempt from the tax on the circulation of goods and transportation and communication services (in Portuguese abbreviation, ICMS) solar energy (micro- or mini-generation), under the Agreement 16/2015 (Confaz, 2017). The exception is the states of Santa Catarina and Parana, where they are exempt for up to 48 months.

On a state/local level, some states exempt electric vehicles from the Property Tax on Motor Vehicles (in Portuguese abbreviation, IPVA). An example is the state of São Paulo, where the Law 15.997/2014 establishes the devolution of 50% of the IPVA and provides exemption from the municipal car rotation system in order to stimulate the purchase of EVs (Bitencourt et al., 2021). Besides, São Paulo state recently announced the reduction of ICMS, from 18% to 14.5%, starting in January of 2022 (Forbes, 2021).

To assist the global transition challenge, the International Energy Agency (IEA) emphasizes that for the countries' commitments and ambitions to be achieved, it is necessary to make the transition resilient to crises, aiming mainly at: (i) inclusion, reduction of inequalities, and, consequently, the mitigation of resistance to the process; (ii) the search for an integrated vision, encompassing energy demanders and suppliers in a complementary way, with policies aimed at both sides; and (iii) guaranteeing the necessary financing for the productive restructuring of the industrial-energy system (CEBRI, 2021).

In addition, the Institute of Energy and Environment (IEMA, Portuguese acronym) alerts that if the trajectory of the Brazilian industry and digital transformation are not managed and guided with sustainable goals consisting especially in inclusive urban mobility and the reduction of socioeconomic inequalities, the tendency is for setbacks. Among them are the risks of job loss, continuity of production of polluting automobiles, external dependence for the supply of EVs, greater elitism of vehicles as consumer goods, and the widespread failure of the public transport system and the possible return of clandestine transport (IEMA, 2021).

Finally, Brazil already has a legal and technical framework to encourage the development of technological innovations in transports, such as the National Policy on Urban Mobility (PNMU, Portuguese acronym) and the National Policy on Climate Change. However, only social demand can drive such structural and innovative changes. Still, without an industrial rearrangement, the country runs the risk of becoming an EV importer, and for that not to happen, another political and institutional context, with private and civil society support, will be necessary and in accordance with the principles of sustainable development, where social and universal rights prevail, subsidizing a fair energy transition.

15.5 Conclusion

The theme of sustainability has become inevitable for the formulation of public policies, becoming essential for disruptive technologies to overcome barriers and initial resistances and strengthen themselves. In addition, it is essential that decision-makers include the implications of these new technologies for society, in order to democratize their access. In this regard, the global pressure for decarbonization in the transport sector goes hand in hand with the transformations in the automobile industry, with regulatory support and targets to ban combustion vehicles, in addition to the expansion of agendas such as the Paris Agreement, the Sustainable Development Goals (SDGs), and ESG (environmental, social, and governance) practices.

Despite Brazil being one of the pioneers in the bioenergy sector, global pressures governed by electrification targets of other countries and the strategic redirection of major vehicle manufacturers generate concerns about a possible isolation of the national production chain facing a global market where electric vehicles predominate. It is necessary to more clearly understand the Brazilian position in relation to electric mobility since the absence of a National Plan on this theme is observed. Therefore, it is necessary to give light to the different mobility alternatives and seek political support for electric mobility.

For a long time, the EV market in Brazil had a marginal role in the composition of actions and policies, either at governmental, institutional, or private sector level. Currently, it is observed the growth of discussions about the business model to be implemented, which involves the public to be reached, the costs and which models (light or heavy vehicles) would be more efficient to the Brazilian reality. It is also highlighted that there is much to be done in relation to urban planning adequacies, such as recharging infrastructure and waste management, such as batteries.

Therefore, mainly aiming at improving the competitive position of the national automotive industry, it is necessary to deepen technical-economic feasibility studies, normative and regulatory aspects, formulation of legal framework and business and financing model, rearrangement of the productive chain, and technological improvement. Thus, it is important an agenda that incorporates more efficient and clean propulsion technologies, supporting in the construction of models that give scale to the EVs market and that foster a healthy competition and cooperation with biofuels and their technological routes, identifying innovative opportunities of coexistence within the production chain, generating facilities and offering new choices for the Brazilian consumer.

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16 Factors That Contribute to Diffusion of Solar PV Energy: Evidence from Holambra in São Paulo Macrometropolis, Brazil

Raiana Schirmer Soares, Lira Luz Benites Lazaro, and Celio Bermann

16.1 Introduction

Energy transitions are crucial for the achievement of Agenda 2030's goals, not only because renewable energies can contribute to the reduction of fossil fuel consumption (Villavicencio Calzadilla & Mauger, 2018; Güney, 2022) but also because energy access is foundational for human and economic development (Shyu, 2021; Goldenberg et al., 1987; Bermann, 2002). In this regard, especially in contexts such as the Latin American one, where there is a significant trade-off concerning people's right to energy and the climate issue, renewable energies provide the possibility to increase energy production while also mitigating greenhouse gases (GHG) and alleviating the negative effects of climate change.

Among renewable sources, solar energy is considered by many the most ideal renewable one for increasing low-carbon energy production given that, besides being abundant, it is also cost-free, inexhaustible, and flexible (de Paulo & Porto, 2018; Vinod et al., 2018; Awasthi et al., 2020; Güney, 2022). Solar energy PV can also favor the development of employment at the local level (Çetin & Eĝrican, 2011), which is vital in terms of the 2030 Agenda efforts to support new economic and labor initiatives that ensure universal access to modern energy services, improve energy performance, and increase the use of renewable sources. It also gives opportunities to put people at the center of climate solutions so that homeowners can make a tangible contribution to the fight against climate change.

These are some of the reasons that explain why solar photovoltaic (PV) is one of the fastest-growing renewable energy technologies that can play a major role in the future global electricity generation mix (IEA, 2020). According to the IEA report, Solar PV generation had a record 179 TWh (up 22%) in 2021 to exceed 1000 TWh. Thus, it proved to be the second largest absolute generation growth of all renewable technologies in 2021, after wind, and is expected to further increase over 8% in 2022, reaching almost 320 GW (IEA, 2022). IRENA's REmap analysis shows that solar PV power installations could

R. S. Soares (✉)
Institute of Energy and Environment, University of São Paulo, São Paulo, Brazil
e-mail: raianaschirmer@usp.br

L. L. B. Lazaro
Department of Environmental Health, School of Public Health, University of São Paulo, São Paulo, Brazil

Durham Energy Institute and Department of Anthropology, Durham University, Durham, UK

C. Bermann
Institute of Energy and Environment, University of São Paulo, São Paulo, Brazil

Energy and Environment Institute, University of São Paulo, São Paulo, Brazil

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grow almost sixfold over the next 10 years, reaching a cumulative capacity of 2840 GW globally by 2030 and rising to 8519 GW by 2050. This implies a total installed capacity in 2050 almost 18 times higher than in 2018 (IRENA, 2019, 21).

Despite this favorable scenario and the abundance of solar radiation, Latin American countries have to yet to experience the expected boom of solar PV diffusion, given that it represents only about 0.002% of its installed capacity to generate electricity (OLADE, 2021). The high cost of solar panels is not the only reason for their limited adoption (Zhang et al., 2012; Ohunakin et al., 2014; Liu, 2018); many authors have demonstrated different barriers that affect the deployment of PV energy in the cities, and they range from physical potential to sociotechnical and socioeconomic structures (Freitas et al., 2015; Izquierdo et al., 2008; Heiskanen & Matschoss, 2017). The latter considers not only the technical characteristics of the equipment used for the conversion of energy but also sociotechnical and socioeconomic structures' perspectives concerning the viability and the social acceptance of the adoption of the systems (Karakaya & Sriwannawit, 2015; Jung et al., 2016). In addition, there are concerns about the social foundations of harvesting renewable energy in relation to the scale of facilities and the availability of options for fostering decentralized power supply; further questions arise on whether markets should be free to provide these services (Wüstenhagen et al., 2007).

Insights from studies on innovation and the theory of sociotechnical transitions suggest that the vision of allowing markets to be free to provide energy services is wrong at best (Karakaya & Sriwannawit, 2015; Byrne et al., 2012; Smith et al., 2014). The innovation studies indicate that an enabling environment is certainly important but not enough. Such studies also reveal that the development benefits associated with innovation can only be fully exploited if innovative capabilities are built, including innovation systems. A sociotechnical understanding of innovation tells us that the context matters and that innovation processes are molded interactively with political, social, and environmental forces as well as with those actors who possess economic and institutional power (Ockwell et al., 2010; Smith et al., 2014).

To understand the development of an innovation system capable to provide a suitable environment for PV distribution is important that we understand what the main drivers and barriers of this diffusion are. Also, targeting the expansion at a more distributed generation, closer to the consumption hot spots, more efficient, cleaner, and less dependent of large-scale stations, one should consider the role of the cities to overcome barriers to enable greater penetration of solar PV. In this regard, it should be noted that PV systems can play a key role in urban environments, given that decentralized systems can provide electricity closer to where it is consumed (Mah et al., 2018; Byrne et al., 2015; Collaço et al., 2020).

However, understanding how energy innovations evolve in Latin American cities is still a rather underexplored topic. Therefore, in this study, considering solar energy generation an innovation in the energy system, this chapter aims to provide a better understanding on what drives people in harvesting this market at a particular stage where costs are still high, and doubts are yet to be over. Considering our motivation to analyze urban phenomena and understand how cities can become protagonists of energy transitions, we used the city of Holambra as a case study, given its noted protagonist role in terms of installed PV units per residence in the most important Brazilian urban region, the Macrometropolis.

The Sao Paulo Macrometropolis (MMP hereafter) has been chosen as object for this exercise not only because of its major importance in Brazilian economy but also because of its great challenge to be self-sufficient in what comes to its energetic demands. Even though its territory represents less than 1% of the national one, MMP is a very demanding region: around 22% of all electricity consumption in Brazil results from the Macrometropolis' demand, and the power plants within this region's territory cater only for ~16% of its total consumption (Soares, 2020). Given the fact that the Brazilian electricity supply is provided through an interconnected grid, enhancing the distributed production of solar PV power within the MMP territory would be a reasonable means to expand the production of renewable energy, while avoiding overcharging other regions due to the burden of responding to such a high and particular demand. In other words, the distributed generation of solar PVs could be an ally to produce and increase the consumption of clean energy in the MMP region, which can be interpreted as a step toward a more sustainable energy system.

Besides that, even though considered Brazil's epicenter in the patterns of diffusion of general consumption, the diffusion of solar PV in the MMP region does not seem to be flourishing as one would expect. In 2019, a total of 11,306 units of solar PV systems were installed in the region, which is less than 7% of the total units installed in Brazil (171,783 units) in the same year (ANEEL, 2020b). It is important to consider that in 2019 the share of solar energy in the Brazilian national energy mix was only 0.4% (MME, 2020). As illustrated in Fig. 16.1, in 2018, Holambra was the municipality with the highest concentration of PV installations in Brazilian Macrometropolis. In order to better understand the concentration of PV systems in Holambra, Table 16.1 illustrates a comparison of all municipalities (in the MMP region) for which the concentration was higher than the standard deviation of the average calculated for all 174 cities that comprise MMP. Holambra occupies the first position with regard to the concentration of PV installations; and its concentration highly differs from that observed in the other cities in the top ten best-case scenarios (ANEEL, 2020b).

Thus, in order to discuss ways through which cities can actively incentive PV decentralized systems' penetration, aiming to unfold the reasons behind the adoption in a city considered a role model in an early stage of the PV adoption in Brazil (2018), this chapter presents the results of interviews carried out with people who installed solar PV units at their residents in the city of Holambra, SP, Brazil.

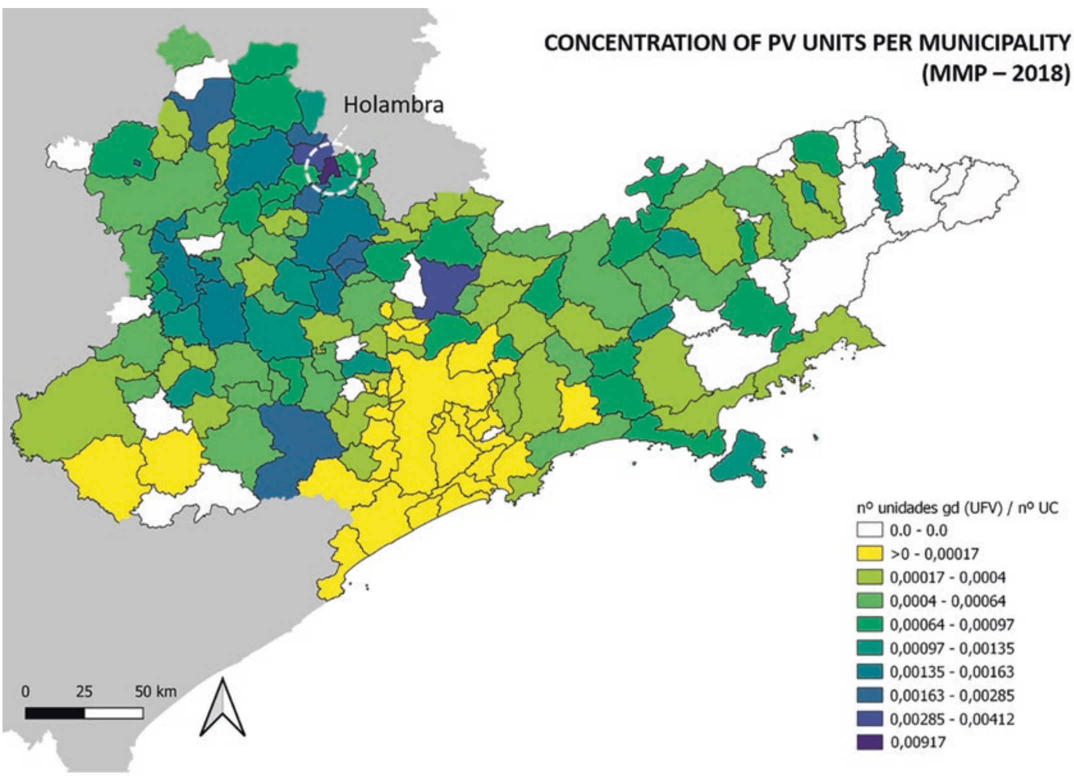

Fig. 16.1 Concentration of distributed PV systems per Municipality. (Source: Adapted from ANEEL, 2020b). Notes: the unit is: number of PV system per households in the city connected to the grid

Table 16.1 Concentration of PV installations in São Paulo's municipalities until the end of 2018

Municipality	Concentration (number of properties with PV installations/number of properties connected to the grid)	Number of standard deviations above the average
Holambra	0.009172	13.59
ArturNogueira	0.004125	5.29
Atibaia	0.003773	4.71
Vinhedo	0.002855	3.20
Rio Claro	0.002019	1.82
Engenheiro Coelho	0.001922	1.66
Valinhos	0.001891	1.61
Paulínia	0.001885	1.60
Ibiúna	0.001816	1.49
Águas de São Pedro	0.001812	1.48

Source: Adapted from ANEEL (2020b)

16.2 Distributed Solar-PV Generation: A Key to Energy Transition and Sustainable Development in the Cities

The expansion of distributed generation and the expansion of clean energy supply in Brazil are related phenomena thanks to political efforts to include the sustainability agenda in the redesign of the energy distribution system. Such redesign includes widening the system by introducing prosumers (final consumers elevated to the rank of micro- or minigenerators) in the distribution network. In Brazil, the regulatory milestone for distributed generation was the publication of Normative Resolution 482, later amended by Normative Resolution 687, which established the general conditions for the access of distributed microgeneration and minigeneration to the electricity distribution systems (ANEEL, 2012). Among the prerogatives adopted, the resolution allows consumers to generate their own energy as long as minimum technical standards are respected – and this is precisely the reason why distributed generation in Brazil is key for sustainable cities (Pavanelli et al., 2022). Some of these criteria concern the energy source employed, since only solar, wind, hydro energy, or qualified cogeneration are eligible for distributed generation (ANEEL, 2012).

Since the publishing of the resolution, distributed generation has changed the arena for solar energy production. In fact, in Brazil, 99% of distributed generation spots (17,1783, base year 2019) were photovoltaic projects (ANEEL, 2020b). Considering solar energy's positive effects on mainly centralized energy services, it is reasonable to infer that distributed generation is, therefore, responsible for the transformation of Brazilian energy system into a cleaner, more responsive, more modern, and smarter one (Brown et al., 2021). It therefore represents an important tool in building an energy transition agenda, especially as it combines rapid technological enhancements in the energy field with growing social and market interest (Saikku et al., 2017). However, the social dimension of this new sociotechnical arrangements should not be underestimated, and one should consider that in this new energy territories, social injustice persists (and may even be highlighted) (Lampis & Bermann, 2022; Lampis et al., 2022).

One interesting exercise to bring forward the social dimensions of solar PV sociotechnical arrangements is to analyze energy transitions from a geographical lens. Even though more emphasis has been put on the *temporal* dimension of energy transitions (e.g., when we are going to meet the each and every sustainable development goal), they can also be read as a spatial and geographic process (Bridge et al., 2013; Lazaro et al., 2022). Under the latter, we unfold and exercise the notion that energy systems are constituted in space as an outcome of the many linking of networks connected to provide energy from a territory to another territory, allowing them (and their communities) to enjoy and perform power in the energy system or to increase their dependence.

Perceiving the energy transition as sensitive to the different geographies of energy systems implies, therefore, understanding it by means of deeper contextual analyses – which encompass contrasting the complex relationships architected by the most diverse (and unequal) societies in relation to their different energy uses. Taking this into account, it is important to contextualize the role of cities regarding the externalities of their development – an exercise that, according to

Rutherford and Coutard (2014), is still in need of further attention. By considering the geographical dimension of energy transitions, one may question the relativism of sustainable development goals in respect to the inner-geographies within countries, for examples. In other words, aside from targeting *when* the transition will take place, it is important to define *how* this transition will take place and *where*.

Analyzing distributed generation under this notion, therefore, implies realizing that its diffusion will depend on the sociotechnical experimentations of the various geographic contexts in which it is analyzed, given that its penetration depends on numerous factors that are territorialized – such as differences in the economic incentives of the policies adopted, the level (and quality) of the infrastructure available, the perception of its institutions and market players, and the cultural practices developed and performed within this social arrangements (Huang & Castán Broto, 2018; McLellan et al., 2016; Coenen et al., 2012).

That is, there is not one single and most ideal path for the energy transition, but different alternatives that are more or less sustainable and feasible according to the different contexts and the conjunctures in which they take place. Considering that in order to offer alternatives that adapt to its unique urban morphology and make its development more sustainable, less dependent on exogenous resources, and less costly for Brazil as a whole, distributed generation should be encouraged and fostered in a region such as the MMP (Pavanelli et al., 2022).

16.3 Why Do People Invest in PV? Factors Related to the Diffusion of Solar PV (Photovoltaic) Distributed Energy Systems

Rogers' (2003) diffusion of innovations theory was used as a reference in numerous studies exploring how the diffusion of solar PV technologies occurs. This theory is divided into five main steps: knowledge, persuasion, decision, implementation, and confirmation. For the purposes of this chapter, we focus on the knowledge and persuasion first steps, given that we are willing to understand how to foster investment in PV technology. The main difference between knowledge and the persuasion is that, in the first, although one is becoming aware of the innovation, they have yet formed no attitude (positive or negative) toward it, while in the second, one does (Vasseur & Kemp, 2015). In each of these steps, different factors may be addressed (as and when relevant) for the diffusion of decentralized solar PV systems. Through a consistent literature review of the theme, it was possible to identify three main determinants that needed to be incorporated in this study: context, perspective, and level of information.

As for the contextual factors, income is a relevant indicator to be considered, especially in contexts where the technology is still incipient and where there is a considerable number of economically vulnerable people – both cases being present in the MMP region. In other words, although one can understand the eventual economic benefits of their investments, they may not be able to purchase a product due to economic restrictions. Schaeffer and Brun (2015) indicate, for example, that a private household's willingness to invest in solar PV products is directly proportional to the per capita income of their region's population given that, despite the decreasing investment cost in PV technologies, it is still inaccessible to a majority. The authors (Schaffer & Brun, 2015) also discuss the crucial role of middle actors, understood by the authors as a sociotechnical factor, indicating that these factors can be game changers once they possess both the willingness and the capacity to invest in the solar technology.

According to Saikku et al. (2017), solar energy poses an important challenge to existing sociotechnical systems, mainly because these are mostly dependent on centralized systems. Taken as political processes, sociotechnical transitions may probably face resistance, but with the proper alignment of the network of actors and a well-designed project, they may be implemented successfully (Saikku et al., 2017). It is inferable, then, that political and regulatory frameworks should also be considered as relevant contextual factors. For example, Dong and Wiser (2013) demonstrated that differences in the level of access permission (to the grid) affect the investment cost of residential PV systems.

As for the level of information factors, Farhar and Coburn (2000) demonstrated through their findings in Colorado (USA) that residents are not willing to install PV systems unless they know more about it and that people who already owned PV systems were among the highest-rated sources of PV information. Endorsing this understanding, Sommerfeld et al. (2017) demonstrated, through qualitative research in Queensland (AU), that most respondents received information before investing in residential PV systems and that the most relevant sources of information were people and marketing from companies who have already invested in the PV energy sector.

Neighborhoods can also be an important direct or indirect source of information for new purchasers. For example, Rai and Robinson (Rai et al., 2016) verified in their study in Texas that customers who adopted PV systems were influenced by their neighbors, both actively and passively, that is, they were influenced by exchanging information with their neighbors who had already invested in PV systems and were also persuaded by the simple visualization of the modules installed in their homes. The middle actors (referred to priorly) are mentioned in some papers as important sources of information as well. For example, the results of Owen et al. (2014; Owens & Driffill, 2008) suggest that these agents (middle actors) have had, in the past, a high impact on the final decision of customers in the UK.

Regarding the perception factors, Zhai and Williams (2012) present an important contribution. Using two questionnaires in Phoenix, one for adopters and another for non-adopters, the authors observed that while environmental benefits were the most important factor for the adopters, the cost of the PV system was the most relevant barrier for non-adopters. In Queensland, however, according to the results presented by Sommerfeld and his colleagues (2017), the environmental factor was not observed among adopters as an important motivator, whereas economic perception on the investment risk had a fundamental effect on the diffusion of residential photovoltaic systems in the studied area. The differences observed in the studies by Zhai and Williams (2012) and Sommerfeld et al. (2017) illustrate the range of variables involved in people's perceptions with regard the decision-making process. In such a context, out of these discrepancies, one can infer that in order to assess the facilitators or barriers associated with the diffusion of innovative technologies, such as the PV system, it is necessary to understand the surrounding environment's particularities; this is because the replicability of results obtained in different locations may not properly explain the case under study.

16.4 Methodology

This study applied nonparametric statistics to analyze the diffusion of PV systems in Holambra city. Such a method is often applied in social sciences, given that it does not assume a normal distribution of the variables under study. Statistically, the nonparametric statistic is weaker (Savage, 1957), but it can be more reliable when addressing human behaviors because inferring normal distribution is complex when addressing personal values, preferences, and cultural inclinations.

To contact the investors, the company that was responsible for the majority of PV projects in the city was contacted. This company provided us contact with 32 investors, representing 85% of the total projects in the municipality. The surveys were carried out using Google Forms and sent to the investors via email. Consent was obtained from all interviewees to make the results public. Figure 16.2 illustrates the premises used to create the survey questions. Table 16.2 presents the operational variables created to address the independent variables in the study, which culminated in the elaboration of the final questions. The survey used structured questions, and to investigate the investors' perceptions, a Likert scale was used. To verify whether the semantic classes of the survey and the sequence of questions were

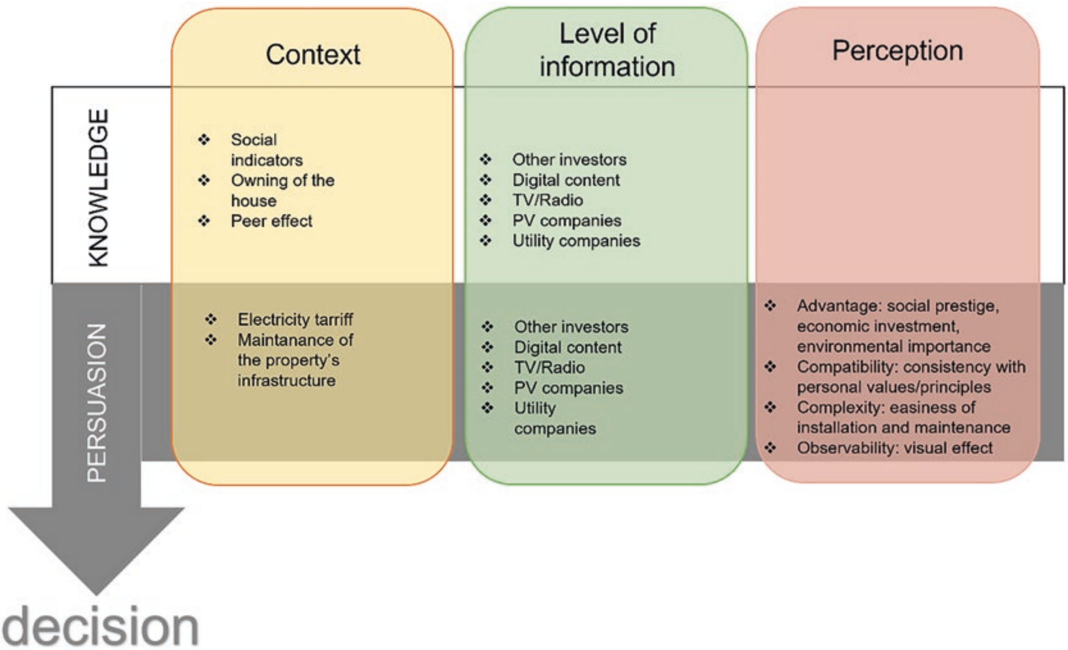

Fig. 16.2 Independent variables under study

appropriated, all questions were pretested with two investigators and with a businessperson who worked in the PV sector.

The applied Likert scale was a five-point scale; therefore, the questions with final median under three were considered rejection of the statement. There is always an option for a neutral statement, and considering the potential implications of such neutral answers over the final comprehension of the results of the survey, all medians equal or higher than three were tested. The medians underwent a signal test, with the neutral position in the Likert scale representing zero; those statements lower than three, as negative signals; and those higher, as positive ones. Subsequently, the frequency of the less frequent signal was compared with the critical value (at determined levels of significance) (tested for up to 10%). If the frequency was lower or equal to the critical value, the null hypothesis was rejected; if the frequency was higher than the critical value, the null hypothesis was accepted.

16.5 Results

Fourteen people, representing 43% of the contacted investors, agreed to answer the survey. Table 16.3 presents the social indicators of the interviewees. Fifty percent of these investors have high school completion and 50% undergraduate. The age group of 50% was older than 60. The class of electricity consumption of the majority of the respondents was residential.

Table 16.4 presents the answers of the interviewee concerning the events that made them aware of the possibility of investing in solar PV. The interviewees were presented with a range of options and were instructed to choose only one option, given the premise that you only get to know and become aware of something once.

Concerning the question "once aware of this possibility, which events led you to be interested in the investment?" which issued to investigate the factors in the persuasion step of the diffusion

Table 16.2 Operational variables

Steps	Independent variables	Operational variables
Knowledge	Social indicators	Level of education
		Age range
		Location of the property
		Classification of the property
	Owning of the property	Whether the property is owned or not
	Visualization impact	Seeing installed panels in the city/neighborhood was or was not the way how one became aware of the possibility
	Contact with other investors	Contact with other investors was or was not the way how one became aware of the possibility
	Online information	Online information was or was not how one became aware of the possibility
	TV/radio information	TV or radio information was or was not how one became aware of the possibility
	Contact with PV companies	Contact with PV companies was or was not how one became aware of the possibility
	Contact with utility company	Contact with the utility was or was not how one became aware of the possibility
Persuasion	Electricity tariff	Level of influence of tariff price over one's increase of interest
	Maintenance of the property's infrastructure	Level of influence of maintenance of property's infrastructure over one's increase of interest
	Contact with other investors	Level of influence of contact with other investors over one's increase in interest; level of importance of contact with other investors over one's final decision-making
	Online information	Level of influence of online information over one's increase in interest; level of importance of online information over one's final decision-making
	Contact with PV companies	Level of influence of contact with PV companies over one's increase in interest; level of importance of contact with PV companies over one's final decision-making
	Contact with utility	Level of influence of contact with utility over one's increase in interest; level of importance of contact with utility over one's final decision-making
	Perception of relative advantage	Level of agreement with the statement: "Investing in solar PV provides social prestige"
		Level of agreement with the statement: "Investing in solar PV is economically advantageous"
		Level of agreement with the statement: "Investing in solar PV is important for the environment"
	Perception of compatibility	Level of agreement with the statement: "Investing in solar PV is consistent to my personal values/beliefs/principles/ideas"
	Perception of complexity	Level of agreement with the statement: "The process of installation of solar PV is easy/practical"
		Level of agreement with the statement: "Maintaining the PV system is easy/practical"
	Perception of trialability	Level of agreement with the statement: "If necessary, the PV system can be modified, improved, or broadened after installed"
	Perception of observability	Level of agreement with the statement: "After investing, I encourage people to invest in solar PV"
		Level of agreement with the statement: "The installed modules impart a positive visual effect to the property"

Table 16.3 Main characteristics of the interviewee

Level of education (%)	
No formal education up to third grade (elementary school)	0
Elementary – complete	0
High school – complete	50
Undergraduate – complete	50
Age group (%)	
From 18 to 25 years old	0
From 26 to 35 years old	0
From 36 to 45 years old	28.6
From 46 to 59 years old	21.4
Older than 60	50
Possession of the property (%)	
Owns	92.9
Does not own	7.1
Locality of the property (%)	
Downtown	21.4
Near downtown	50
Rural area	28.6
Periphery	0
Residential condominium (%)	
In a condominium	35.7
Out of a condominium	64.3
Class of electricity consumption (%)	
Rural	7.1
Commercial	14.3
Residential	78.6

Table 16.4 Interviewee's awareness of the possibility of investing in solar PV

Through seeing panels installed within the neighborhood or city	0%
Through conversations with people who had already installed PV systems	43%
Through online information	21%
Through TV or radio information	14%
Through information made available by the utility provider	0%
Through marketing of companies associated to PV sector (installation, project design, and selling)	7%
Others	14%

Table 16.5 Level of influence of factors in initial interest and sources of information in final decision-making

Factors that led to the initial interest	Median
Energy price	Much influence
Planning/restructuring building	No influence
Seeing installed panels in the neighborhood or city	No influence
Talking to family and friends about it	Moderate influence
Talking to companies of the sector	Much influence
Marketing in TV or radio	No influence
Direct marketing of companies of the sector	Moderate influence
Influence of sources of information important in final decision-making	Median
Contact with other investors	Few influence
Contact with the local utility provider	No influence
Contact with companies of the sector	Much influence
Online information	Few influence
Radio or TV information	No influence

process, Table 16.5 presents the median observed for the answers of each factor. The test results of the medians, presented in the Appendix A, illustrate that only "energy price" and "talking to companies of the sector" could have influenced the interviewee to become interested in the investment; this is because they are the only factors whose null hypothesis could be rejected within a level of significance of 2% and 10%, respectively.

With regard to the sources of information critical for the final decision-making in the step of persuasion by investors, Table 16.5 presents the medians of investors' answers. The test of medians (Appendix B) confirms that the only relevant source of information for the interviewee, with respect to the final decision-making, was "contact with companies of the sector."

Finally, concerning the interviewees' personal perceptions relevant to the understanding of the diffusion process of solar PV in Holambra, Table 16.6 presents the medians of their agreements to the statements. As shown in Appendix C, these medians were tested in such a way that all null hypotheses could be rejected, but the ones from the statements "Investing in solar PV provides social prestige" and "The installed modules impart a positive visual effect to the property."

Table 16.6 Perceptions of the interviewee

Perceptions of the interviewee	Median
Investing in solar PV provides social prestige	Partially disagree
Investing in solar PV is economically advantageous	Fully agree
Investing in solar PV is important for the environment	Fully agree
Investing in solar PV is consistent to my personal values/beliefs/principles/ideas	Fully agree
The process of installation of solar PV is easy/practical	Partially agree
Maintaining active the PV system is easy/practical	Partially agree
If necessary, the PV system can be modified, improved, or broadened after being installed	Partially agree
After investing, I encourage people to invest in solar PV	Fully agree
The installed modules impart a positive visual effect to the property	Partially agree

To analyze whether the number of companies in each municipality in the MMP could explain the expansion of the PV sector, a correlation study was proposed using the number of units of PV generation and the number of companies established in each of the 174 cities up to the end of 2019 (Portal Solar, 2020). The cities with the highest number of PV installations are also the ones that have more companies in the sector set up within their territory. Figure 16.3 illustrates such correlation, and Table 16.6 summarizes the premises used to apply the student's t-test to observe that the null hypothesis (indicating that the variables do not correlate) could be rejected and that the possibility that the relationship between the variables occurs at random is lower than 0.1%.

16.6 Discussion

16.6.1 Importance of Middle Actors in Diffusion of Information and in Persuading Purchasers

Considering the contact with companies of the PV sector was important in both imparting the information and persuading the people who invested in Holambra, it is clear that these middle actors play an important role in the diffusion of PV systems in the city. This, along with the fact that almost all the projects in the city were developed by a single company, helped us to deduce that the establishment of this particular company in the city was foundational for the expansion of the sector.

It is worth mentioning that during meetings (with the contact person responsible for the company's participation in the study), it was easy to observe that the company maintained a close "after-sales" relationship with their customers. Even after installing the panels, for example, they maintained the meter reading to verify any possible dysfunction. In addition, the single fact that the company accepted to participate in an academic study to help to understand the reasons behind their customers' investment is notable, mostly because it demonstrates how interested and engaged the company is in expanding its business by understanding the social acceptance of their products.

Figure 16.3 and Table 16.7 demonstrate that such behavior could also be observed in the MMP region. Based on a correlation analysis, there was a strong positive correlation between the diffusion of PV systems and the diffusion of companies in the sector throughout the territory. Karakaya and Sriwannawit (2015) discussed how weak and neglected after-sales services and inappropriate company business portfolios could serve as barriers to the diffusion of solar PV systems. The cases of Holambra and MMP illustrate the importance of PV companies in the diffusion of PV systems, overcoming possible barriers by their performance.

Understanding the reasons for the early adoption of innovations is a key factor for understanding its diffusion; similarly, understanding early business investors' motivations and perspectives is imperative. As early adopters do, they also invest in a risky, unknown, and sometimes poorly regulated business model. Considering the solar market is still growing in Brazil, one may wonder whether at some point the market will be saturated, or whether the new companies incorporated would be less committed to the diffusion and possibly less trained.

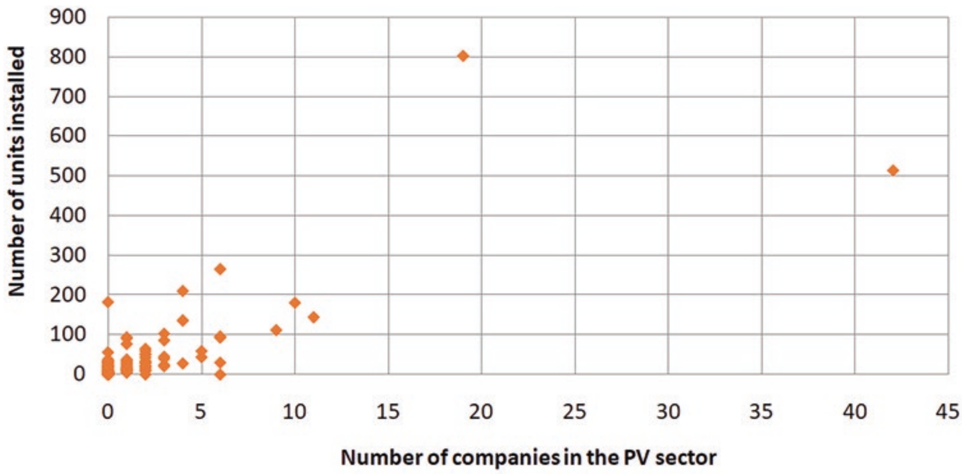

Fig. 16.3 Number of companies operating in the solar PV sector versus the number of units installed in cities in the MMP region. (Source: Adapted from ANEEL, 2020b)

Table 16.7 Student's t-test

Number of PV units (average)	29.5
Number of PV companies (average)	1.2
Pearson coefficient	0.79
T-test	17.85

Source: Adapted from ANEEL (2020b)
Note: If Student's t-test is > critical value, null hypothesis can be rejected

16.6.2 Adopters' Perceptions

According to Karakaya and Sriwannawit (2015), the quality of photovoltaic systems is of vital importance for their diffusion, given that low performance or possible faults in the systems can discourage future adoptions. The survey in Holambra demonstrated that people who adopted PV systems were satisfied with the working of their systems as long as the maintenance of the active PV system is easy/practical and that, if necessary, the PV system could be modified, improved, or broadened after installation and that the process of installation of solar PV is easy/practical. Such findings may be a result of the services provided by the company responsible for the installation and maintenance of PV systems along with the standard of quality of the technology.

In Brazil, Decree 357 (Inmetro, 2014) outlined a number of requirements for PV systems and photovoltaic energy equipment. According to the Normative Resolution No. 482 (April 17, 2012) (ANEEL, 2012) in order for one to be considered a generator within the distribution grid, one has to present a project that satisfies such standards. Therefore, in Brazil, the standards for PV technology are high, and the inspection of their compliance is a prerequisite. It is expected, conversely, that this may have an impact in the final cost of the systems, because, usually, the higher the standards, the higher the price associated with the technology.

Soares (2020) estimated that the technology cost has decreased by approximately 40% for systems of 4 kWp (which represents the average installed capacity of the residential sector in the MMP region) and 35% for systems of 18 kWp (which represents the average installed capacity of the commercial sector in the MMP region) from 2016 to 2019 in the MMP. In 2019, this cost was around R$ 12,500.00 (equivalent to 2220.56 US dollars in October 2020) for the residential sector and R$ 45,720.00 (equivalent to 8118.62 US dollars in October 2020) for the commercial sector (apart from the cost related to installation). Even though these numbers demonstrate a rapid decline in technology costs, it is important to note that the total investment is still high, considering the income levels in the MMP region. Such considerations allow us to infer that in the absence of proper funding, PV adoption is still restricted to a small segment of the population.

Many authors have discussed the role of early adopters in the diffusion of PV systems (Faiers & Neame, 2006; Vasseur & Kemp, 2015; Mundaca & Samahita, 2020; Palm, 2016). Their particular interest has understood the reasons behind their investment in an incipient business model, which, therefore, was riskier and more extensive. In the case of Holambra, even though the interviewee did not agree that they had been influenced by other investors to adopt a PV system, they agree that after investing, they encourage people to invest in solar PV systems. Therefore, under Rogers' (2003) ideas, and the fact that the total number of PV systems is still very low in Holambra, we could infer that those who were interviewed can be considered early adopters. Under such an assumption, the fact that the interviewees were aware of the importance of their investment for the environment, and that the investment (besides being economically advantageous) was consistent with their personal values, principles, beliefs, and ideas, makes it possible to expect that their encouragement may lead others to share similar principles and adopt solar PV systems. Besides, it is critical to consider that the costs associated with the power tariffs were major incentives for people who had invested in PV distributed systems in Holambra. Considering that up to 2019, the tariff applied in the city was the lowest in the Brazilian southwest (ANEEL, 2020a), it is possible to infer that other energy systems will have an even greater inclination for adoption under such an incentive.

16.6.3 Contributions for Construction of Political Agenda to Foster PV Diffusion in MMP Region

In 2012, ANEEL launched the Normative Resolution No. 482 (ANEEL, 2012), which established the general conditions for micro- and minigeneration of electricity within the distributed systems. The resolution also established an energy compensation system known as a net-metering system, under which a consumer would only pay for the amount of energy consumed and that the eventual surplus generated would be compensated in future tariffs as credit. Resolution No. 482 was later amended by Normative Resolution No. 687 (November 24, 2015) (ANEEL, 2015), which increased the maximum capacity allowed per final consumer to 5 MW.

Even though the institutional framework has been developed in Brazil, as demonstrated by Karakaya and Sriwannawit (2015), an important barrier for diffusion is the economical one. As already discussed, the costs associated with the initial investment are still high in the MMP region; therefore, financial schemes are instrumental for low-income markets. As for the financial schemes directed to foster PV adoption, in Brazil, there is still several emerging alternatives, as demonstrated by Luna et al. (2019), Soares (2020), and Vilaça et al. (2018) who added private schemes in the analysis. Therefore, one feasible way to overcome the economic barriers in the diffusion of PV systems in the MMP region is increasing the number of financial schemes through direct credit and tax deduction.

Considering the particular case of the MMP region for discussion, it is important to assess the relevance that distributed generation may represent to understand the level of incentives required. Even though it only represents a small share of the national territory (around 1%), it is responsible for 22% of the total national consumption of electricity. However, the generation within its boundary accounts for only about 16% of its consumption (Soares, 2020). Therefore, one important debate for the sustainability agenda of the region is seeking greater energy independence. Under such consideration, distributed photovoltaic generation represents an important alternative to be considered when it comes to increasing electricity supply in the territory, especially considering these are private investments, which generally do not require land and can be implemented using only rooftop space.

Decentralization is a process that implies, for enhanced effectiveness, local empowerment (World Bank, 2020). It would then be up to public policymakers to encourage distributed photovoltaic generation in the MMP region to reduce the costs associated with the installation of PV systems. This would bolster the sector economically and make the systems more accessible to different social classes, making the access to the investment less unequal. Even though it does not have political authority to regulate the distributed energy under its territory, MMP could, through municipal action, provide economic incentives to new adopters. In addition, each municipality could take the lead in such an adoption curve by investing in PV systems itself. This could be an effective way to foster the knowledge step over people through the visualization of modules or their installation and to boost the businesses of companies within their surroundings. In addition, to properly decentralize the sector and allow the proper diffusion of new companies throughout the territory, governments must engage new actors as a means of properly understanding the barriers in the diffusion of PV systems. Taking action and investing in PV technologies would be a feasible means to start a dialogue with these actors.

16.7 Conclusion

The study analyzed the urban initiatives toward solar PV energy integration; we collected data through a survey with 14 adopters of solar PV in Holambra to assess factors influencing their adoption and the policy implications. Our findings suggest that associated middle actors, such as companies in the PV sector, government, and adopters, play an important role in steering the diffusion of PV systems. São Paulo's MMP is an economically important urban region with a high demand for natural resources and electricity. Considering the need to diversify its energy sources and establish a more independent energy system, the distributed PV generation represents an important alternative to be considered with regard to increasing electricity supply in this urban territory.

A key result of this study is that middle actors, such as PV companies, could have had a relevant impact on PV technology diffusion, considering they foster the sector by making people aware of the potential advantages and persuading them to purchase the systems. Our results also show that the key driver in solar energy PV diffusion in Holambra is an economic factor associated with the high cost of energy and that the implementation of such systems would imply reductions in energy consumption bills. Investors who catalyze investment in the region understand the relevance of the technology in terms of its economic advantage and to the environment. In addition, distributed PV generation presents itself as a possible path toward energy transition, but it lacks incentives and clear regulation with respect to the investments.

Regarding technology adoption, given the barriers posed by different actors as explained by Karakaya and Sriwannawit (2015), and the social acceptance perspective discussed by Wüstenhagen et al. (2007), it is important to consider that social acceptance is also related to the political manifestation of social and market acceptance. Therefore, for PV distributed generation to be considered a feasible step toward a more sustainable energy system (for the MMP region), collaborative decision-making should be carried out while fostering frameworks that enhance market and social acceptance.

Despite the apparent way that solar power contributes to the SDG by providing "clean and affordable energy." Solar energy can also contribute to other SDGs, for example, SDG 1 poverty reduction, SDG 5 gender equality, SDG 10 reducing inequalities, and SDG 13 tackling climate change. Our study reveals that when cities at the local level such as in the case of Holambra access a renewable energy source, they gain social and economic benefits by providing opportunities for more economic activities, which are essential in eliminating poverty.

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Appendices

Appendix A

Factor A	Energy price
Factor B	Planning/restructuring building
Factor C	Seeing installed panels in the neighborhood or city
Factor D	Talking to family and friends about it
Factor E	Talking to companies of the sector
Factor F	Marketing in TV or radio
Factor G	Direct marketing of companies of the sector

Factors that led to the initial interest							
Interviewee	Factor A	Factor B	Factor C	Factor D	Factor E	Factor F	Factor G
Respondent 1	4	2	5	3	4	1	3
Respondent 2	4	1	1	2	1	1	1
Respondent 3	2	1	1	1	4	3	4
Respondent 4	4	3	1	3	5	1	5
Respondent 5	3	1	1	2	1	1	1
Respondent 6	5	5	3	3	5	4	4
Respondent 7	5	3	4	4	5	2	2
Respondent 8	5	1	5	5	5	1	1
Respondent 9	3	1	1	1	1	1	1
Respondent 10	5	1	1	5	5	2	5
Respondent 11	3	1	1	5	4	3	3
Respondent 12	4	3	1	4	4	3	3
Respondent 13	3	1	1	5	4	3	3
Respondent 14	5	1	1	1	4	1	1
Median	4	1	1	3	4	1	3
(+) signals	9			6	11		4
(−) signals	1			5	3		6
Freq. Less frequent signal	1			5	3		4
Number of signals	10			11	14		10
VC ($\alpha = 1\%$)	0			0	1		0
VC ($\alpha = 2\%$)	1			1	2		0
VC ($\alpha = 5\%$)	1			1	2		1
VC ($\alpha = 10\%$)	1			2	3		1
Reject null hypothesis	Yes ($\alpha = 2\%$)	No	No	No	Yes ($\alpha = 10\%$)	No	No

Appendix B

Factor A	Contact with other investors
Factor B	Contact with the local utility
Factor C	Contact with companies of the sector
Factor D	Online information
Factor E	Radio or TV information

Influence of the sources of information important in the final decision-making					
Interviewee	Factor A	Factor B	Factor C	Factor D	Factor E
Respondent 1	4	2	4	2	1
Respondent 2	2	1	4	4	1
Respondent 3	2	1	4	4	3
Respondent 4	1	5	5	3	1
Respondent 5	2	1	1	1	1
Respondent 6	3	3	5	5	4
Respondent 7	2	5	3	1	1
Respondent 8	5	1	5	1	1
Respondent 9	1	1	3	2	1
Respondent 10	4	1	5	1	1
Respondent 11	5	3	4	2	2
Respondent 12	4	2	4	1	4
Respondent 13	5	3	4	2	2
Respondent 14	1	1	3	3	1
Median	2	1	4	2	1
(+) signals			10		
(−) signals			1		
Freq. less frequent signal			1		
Number of signals			11		
VC (α = 1%)			0		
VC (α = 2%)			1		
VC (α = 5%)			1		
Reject null hypothesis	No	No	Yes (α = 5%)	No	No

Appendix C

Factor A	Investing in solar PV provides social prestige
Factor B	Investing in solar PV is economically advantageous
Factor C	Investing in solar PV is much important for the environment
Factor D	Investing in solar PV is consistent to my personal values/beliefs/principles/ideas
Factor E	The process of installation of solar PV is easy/practical
Factor F	Maintaining active the PC system is easy/practical
Factor G	If necessary, the PV system can be modified, improved, or broaden after installed
Factor H	After investing, I encourage people to invest in solar PV
Factor I	The installed modules result in a positive visual effect in the property

Perceptions of the interviewee									
Interviewee	Factor A	Factor B	Factor C	Factor D	Factor E	Factor F	Factor G	Factor H	Factor I
Respondent 1	3	5	5	5	4	4	3	5	4
Respondent 2	1	4	5	5	4	4	4	3	3
Respondent 3	1	5	5	5	5	5	5	5	4
Respondent 4	1	4	5	5	5	4	4	4	3
Respondent 5	1	3	5	5	4	5	5	5	1
Respondent 6	3	3	5	5	5	5	5	5	2
Respondent 7	3	5	5	5	5	3	3	3	3
Respondent 8	5	5	5	5	5	5	5	5	4
Respondent 9	1	4	5	5	4	4	4	5	3
Respondent 10	4	4	5	5	4	4	5	5	4
Respondent 11	2	5	5	5	4	4	4	5	5
Respondent 12	3	5	5	4	5	5	3	5	4
Respondent 13	2	5	5	5	4	4	4	5	5
Respondent 14	2	5	5	5	5	5	4	4	5
Median	2	5	5	5	4,5	4	4	5	4
(+) signals		12	14	14	14	13	11	12	8
(−) signals		0	0	0	0	0	0	0	2
Freq. less frequent signal		0	0	0	0	0	0	0	2
Number of signals		12	14	14	14	13	11	12	10
VC (α = 1%)		1	1	1	1	1	0	1	0
VC (α = 2%)		1	2	2	2	1	1	1	0
VC (α = 5%)		2	2	2	2	2	1	2	1
VC (α = 10%)		2	3	3	3	3	2	2	1
Reject null hypothesis	No	Yes (α = 1%)	Yes (α = 1%)	Y (α = 1%)	Yes (α = 1%)	Yes (α = 1%)	Yes (α = 1%)	Yes (α = 1%)	No

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Part IV

Energy Services: Access, Energy Poverty, Decentralization, and Democratization

17 Shifting Powers Toward Decentralized Energy Generation: A Comparative Perspective Between Argentina, Chile, and Uruguay

Martín Ariel Kazimierski

17.1 Introduction

The way electricity is currently produced and consumed is not sustainable. Over the last century, electrical systems have been strengthened by the exploitation of their most affordable and profitable fossil resources, supported by a process of centralization and concentration of electricity generation and distribution, not only in its technical but also in its economic and political aspects and those related to property (Goldthau, 2014; Bridge et al., 2013; van der Vleuten, 1998). However, as the energy transition progresses, new political actors appear on the scene (Brisbois, 2020; Hess, 2013). The results obtained from this have been diverse: from companies and business associations, public entities, networks of workers and users to community-based organizations (Avelino & Rotmans, 2009; Bermejo, 2013). In 2019, the European Union recognized the Renewable Energy Communities (REC) as entities with rights and with a leading role to play in the energy transition and decarbonization (Ríos, 2020).

The formation of this diverse universe of actors responds to the opportunities offered by a ductile energy technology that can be adapted to different scales and territories (Geels & Raven, 2006; Loorbach, 2010). Particularly, the expansion of the so-called distributed renewable energy generation (DREG) is one of the most revealing examples. The real exploitation of energy from winds, rivers, solar radiation, and biomass residues enabled us to think of local models of energy management, which are connected exclusively to the low-voltage distribution network, opposite to what is happening today with megawind and/or photovoltaic farms, which respond to a rather centralized logic and a generation scale similar to the thermoelectric or nuclear ones. This model is not at all new, but, on the contrary, it was the norm at the beginning of the electrical industry. In Europe, the centralization and interconnection of the electric system did not begin until the 1950s (van der Vleuten, 1998), and until then a large number of small suppliers provided electricity to the regional network (Lehtonen & Nye, 2009). On the other hand, municipalities and small agricultural cooperatives in countries such as Germany, the Netherlands, or Denmark are today the predominant agents in the electricity market (Morthorst et al., 2006), which have persisted despite the onslaught of large corporations.

The growing competitiveness of wind and photovoltaic generation technologies has turned the DREG into a global phenomenon that is considerably transforming the concepts of transmission and distribution, eroding the conventional centralized and concentrated electricity model

M. A. Kazimierski (✉)
Institute for Latin American and Caribbean Studies (IEALC), Buenos Aires, Argentina
e-mail: martin.kazimierski@uba.ar

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(Bermejo, 2013). The International Energy Agency (IEA, 2021) estimates that between 2017 and 2020, 179 GW were added globally in solar photovoltaic energy alone, and it projects that this will quadruple to reach 633 GW by the end of this decade.

One of the keys to the expansion of this model lies in the incentive schemes. Although there are numerous experiences, the most accepted instruments can be summed up into three: the most efficient with respect to the rapid disclosure of these energies, due to cost reduction and the incentives it offers to investors, is the *feed-in tariff* (FiT) instrument, where the consumer-generator receives an extra incentive for each kWh injected. Its particularity is that the remuneration received guarantees a return on investment in a shorter period according to the amount assigned to the energy generated. The second is *net metering*, where the payment is deducted from the difference between what has been produced and what has been consumed from the network in an equitable manner. And, finally, the *net billing* scheme, which differs from net metering in that the energy injected by an individual and that purchased from the network have different prices, established by the wholesale seasonal price that distributors must pay to the system and the retail prices paid by captive consumers, respectively.

National and municipal states have reacted differently to these regimes. For example, the South Korean government had to abandon its FiT policy in 2017 due to the heavy financial burden – a situation like that of Spain, which 5 years earlier had to impose a "sun tax" given that the fiscal stimulus affected the viability of the system (Dong, 2012; Sergent, 2018). On the other hand, Germany and the United Kingdom carry out continuous monitoring to manage rate increases and reflect market changes (Muhammad-Sukki et al., 2013). Other financial mechanisms have had a significant degree of development: in the United States, credit systems called *property assessed clean energy* (PACE) have prevailed, as instruments to finance energy efficiency upgrades through mortgages or specific encumbrances, where the consumer is the owner of the generator or consortium (Coley & Hess, 2012). The *third-party financing model* has also been expanded, which corresponds to companies or individuals that manage the DREG systems on the property of a third party, mainly roofs in residential areas (Drury et al., 2012). In Europe, the *cooperative model* has prevailed, functioning as nonprofit consumer organizations that share a generation unit (Bauwens et al., 2016; Hess, 2013; Ríos, 2020).

However, the implementation of these recipes in other regions of the world has had a relative development, demonstrating the impossibility of applying universal mechanisms (Dong, 2012). In certain cases, the strengthening of the generation options closest to consumption has allowed the deployment of multiple experiences of a social nature, and this allowed the change from a passive to an active societal dimension with which respect to energy (Geels & Raven, 2006; Loorbach, 2010; Hess, 2013). On the contrary, in other cases, the market has been captured by companies that have found a parallel business to their core business, to the detriment of the role of the State and regulatory entities (Brisbois, 2020). In this sense, the DREG necessarily transforms the typical operation of public services, enabling greater autonomy for consumers, which could contribute to a certain redistribution of the benefits of the electricity sector or, on the contrary, reinforce the liberalized scheme that today contributes to markedly asymmetric power forces.

The main objective of this work is to analyze the development of the DREG market in the region known as the Southern Cone of South America, made up of Argentina, Chile, and Uruguay, where the adaptation of their regulatory frameworks in the last decade and the implementation of incentives schemes have had disparate and ambivalent results. The main question is what kind of decentralization promoted these new energies. The article seeks to characterize the main political transformations that the national electricity systems have undergone, as well as the incipient opportunities that their future expansion entails.

Through the analytical framework given by the *multilevel perspective* (MLP) (Bridge et al., 2013; Avelino & Rotmans, 2009), electrical systems are approached within a particular energy regime determined by the context and its actors at multiple scales, and energy – as well as the different energy technologies – weighted not only in its physical or economic component but also as a social fact, an object of power and therefore of conflict (Brisbois, 2020; Bertinat et al., 2014). The study begins by carrying out a theoretical-analytical construction of the prevailing energy transition processes, followed by a characterization of the regional electricity sector, its public-private socio-economic frameworks, to finally explore the strategies and transformations that the expansion of the DREG electricity market has had in each country.

17.2 Theoretical Approach

Technological evolution in the production, management, and consumption of energy has been at the base of energy transitions. Since the 1990s, studies on socio-technical transitions have been proposing an MLP (Bridge et al., 2013; Avelino & Rotmans, 2009), made up of three fundamental levels: the first one refers to the *socio-technical regime*, made up of the set of norms and practices established for the actors that make up the system; the second, associated with the *socio-technical niches*, which make up protected spaces for experimentation in immature models with potential for changes in the regime; and lastly, the *socio-technical landscape*, which includes the set of exogenous factors, which might be political, economic, ideological, etc. The socio-technical regime is studied mainly because transitions are defined as the change from one regime to another; therefore, the niche and the landscape level are derived from concepts that are defined in relation to the regime.

Although there is a wide bibliography for historical revisionism, in recent years, interest has increased in the contribution of its prescriptive elements to think about the design of public policies toward more sustainable regimes from the economic and environmental point of view (Smith & Stirling, 2010). The pressures of the landscape given by geopolitics, macroeconomics, or climate policy caused a growing instability of the fossil regime, which extended analytical proposals such as *Strategic Niche Management* (Geels & Raven, 2006) or *Transition Management* (Loorbach, 2010), installing new debates on power relations and energy governance at local, regional, and global levels (Brisbois, 2020; Avelino & Rotmans, 2009).

A weak point of these analyses has been their marked inclination toward the implementation of innovation economy models, which prioritize commercial logic and where technological applications such as the DREG depend exclusively on their profitability compared to the competition (Garrido, 2019). As an alternative, authors such as Seyfang and Smith (2007) explore bottom-up solutions such as social innovations developed at the community level, which are less risk-averse. It is within the framework of these experiences, which the authors call *grassroots innovation*, that technologies are co-constructed by multi-stakeholders in local niches, with rules and incentives that differ from those imposed by the markets.

The purpose of the MLP is to bridge the distinction in the social sciences between materialist theories – prices, capital, investment, resources, and competition – and idealistic theories, interpretations, visions, and debates. Regarding these aspects, the actors are placed in a form of limited rationality (Geels & Raven, 2006). Therefore, it is necessary to place greater emphasis on rationality and power relations to study the interaction between institutions and their action pattern (Brisbois, 2020). In the case of the DREG systems, their main mechanisms for implementation were incubated in the central countries and then spread around the globe, so that they arrived in South America as models to imitate (Garrido, 2019). Consequently, the adoption of these technological packages is leading to gradual but important systemic transformations, with different problem areas that will be developed below.

17.3 The Electrical Regime in the Southern Cone

The legislation adopted in the South American region at the end of the last century was marked by neoliberal reforms of the state apparatus, which, in line with the directives of the Washington Consensus, established its functionality towards the most concentrated capital, relegating strategic planning in favor of large economic groups (Azpiazu, 2002). In particular, the electricity sector became one of the most dynamic cores of the accumulation model.

In Chile, the military dictatorship privatized the system in 1982, segmenting it between generation, distribution, and commercialization, a structure that has been maintained until today. It created three basic markets: distribution concessionaires which are subject to price calculation for regulated clients; large users who can opt for freely contracted prices; and *spot market*, where the marginal cost is defined hourly by the National Electrical Coordinator (Serra, 2002). Among other things, the companies have absolute control over the technology to be used, the size of the power plants, location, date of entry, etc., while the State plays a supervisory/regulatory role.

In Argentina, the enactment of Public-Law 24,065 in 1991 privatized almost the entire electric system, which was segmented as usual. As it happened with the Chilean market, the generation was submitted to competition under two modalities, a *spot market*, coordinated by the Wholesale Electricity Market Administrative Company (CAMMESA), and a *futures market*, in which the price of energy is agreed between large consumers and a particular generator (Azpiazu, 2002). The difference with Chile lies in the fact that, within this scheme, a series of instances were left out of the privatization wave: in the field of generation, nuclear energy and the two large binational dams (Salto Grande and Yacyretá), and in the field of distribution 9 provincial companies and more than 500 cooperatives (Garrido et al., 2013).

On this end, in Uruguay the ownership of the electrical area, until not long ago, was entirely public, controlled by the National Administration of Power Plants and Transmissions (UTE). The Regulatory Framework of the Electricity Sector Public-Law 16,832, enacted in 1997, eliminated the state monopoly of generation and enabled the opportunity for a generation to be privatized, therefore creating a competitive market (Bertoni, 2011). Thus, the Electricity Market Administration (ADME) was created as a non-state public entity that would manage the market; the public company UTE was authorized to associate with private firms, national or foreign; and a regulatory entity – the Electric Power Regulatory Unit (UREE) – was established to separate the "business" and regulatory function from the State.

In this framework, both the Argentine and Chilean electric systems were consolidated under a private scheme strongly concentrated in a small number of companies that throughout this century would deploy both vertical and horizontal integration strategies, acquiring powers to establish the conditions in power generation and influence its transport and control distribution. Strictly speaking, Azpiazu (2002) defines three main strategies: *concentration*, the firms increased their participation in sectors in which they were already inserted; *integration*, they monopolized more than one activity of the system; and *conglomeration*, they diversified their participation toward other sectors of the energy chain such as gas or oil. The case of Uruguay is different, where the National Administration of Power Plants and Electric Transmissions (UTE) is a central actor, with a solid track record and financial capacity, being the main agent in generation and owner of the transmission networks (Bermúdez & D'Espada, 2014). Added to this, the University of the Republic, also public and co-governed by teachers, students, and graduates, has researchers in the field of social sciences that support the current management model. The electrical union Association of State Power Plants and Electric Transmission Employees (AUTE) is also a spearhead for the public control of energy. It was the political consensus between parties, unions, and universities that allowed defining the 2005–2030 Energy Policy in the country.

Although, both in Argentina and Chile, the private landing in recent decades contrasts sharply with the undeniable State presence in Uruguay, the incorporation of renewable energies and the different degrees of progress of the DREG in the region have disrupted the national scenarios or are able to do so. Below you will find a specific analysis of the progress of the DREG and the level of underlying transformation within the three countries.

17.4 Uruguay: The Threat to the State Monopoly

Traditionally, Uruguay has been an energy-importing country. Its centrality in the national economy is such that it constituted the basis of the external restriction to growth throughout the twentieth century (Bertoni, 2011). For this reason, in 2008, the Ministry of Industry, Energy and Mining (MIEM) presented to the Executive Branch a long-term proposal aimed at reducing energy dependence on neighboring countries, minimizing generation costs, committing to the environment, and lowering electricity rates. The framework given by Public-Law 16,832, which establishes that energy generation can be carried out by any agent, pushed the materialization of regulatory signs favorable to private investment in renewable generation plants (Bermúdez & D'Espada, 2014). Among the different legal provisions, Decree 173 was passed in 2010, making Uruguay a pioneer country in South America in allowing low-voltage consumers to generate their own energy and sell it to the electric grid. The legislation set the commercial conditions for the purchase of surpluses through a net-metering regime and ensured a 10-year contract period. Later, in 2012, Decree 158 enabled industrial consumers who generated wind power to celebrate sales contracts with the UTE.

In this way, despite the possible union between the actors that participate in the energy field and the social consensus about the benefit originated in the State controlling the energy, Uruguay has designed a multiparty policy to promote private investment. Particularly, the growth of the DREG market has bad press, either from the union point of view or for the members of the MIEM and the University. This is due to, on the one hand, the loss of generating power of UTE as a result of photovoltaic, wind, and biomass low-power and self-consumption installations and, on the other hand, to the fact that this segment today faces a lobby to increase "market freedom" and sell energy outside the UTE channels, directly to private consumers (PIT-CNT, 2016). These actors highlight the entrepreneurial and "free" nature of self-generation and sale of energy, in a sort of economic-energy liberalism that promotes diminishing the central role of the public firm.

While in 2012 only 5% of renewable electricity came from private generators – basically biomass from the pulp mill of the firm UPM in Fray Bentos; in 2017 this figure climbed to 40%, where wind power represented 72% of the total (see Fig. 17.1). In this sense, the DREG would be nothing other than the way in which the country acquired the partial privatization of that segment. In 2017, the person in charge of the wind generation area of the UTE warned: "If this system became generalized, it would not be economically sustainable for the State" (Energía Estratégica, 2017a). This refers to the tariff regime established by Decree 173, which guarantees a subsidy for the first 100 kWh per month to residential consumers, which constitutes more expensive energy than that which the user traditionally pays to the company.

An important fact to note is that the sale of energy in the spot market gave meager results for investors in renewables, currently being an almost nonexistent market in the country. These sectors expressly encourage the sale of energy outside the UTE: "From Ventus they assure that they can offer a price reduction of 25% to 35% (for the energy sold by UTE to the industrial sector)" (Energía Estratégica, 2017b), while they affirm that they have a presence in 50% of the

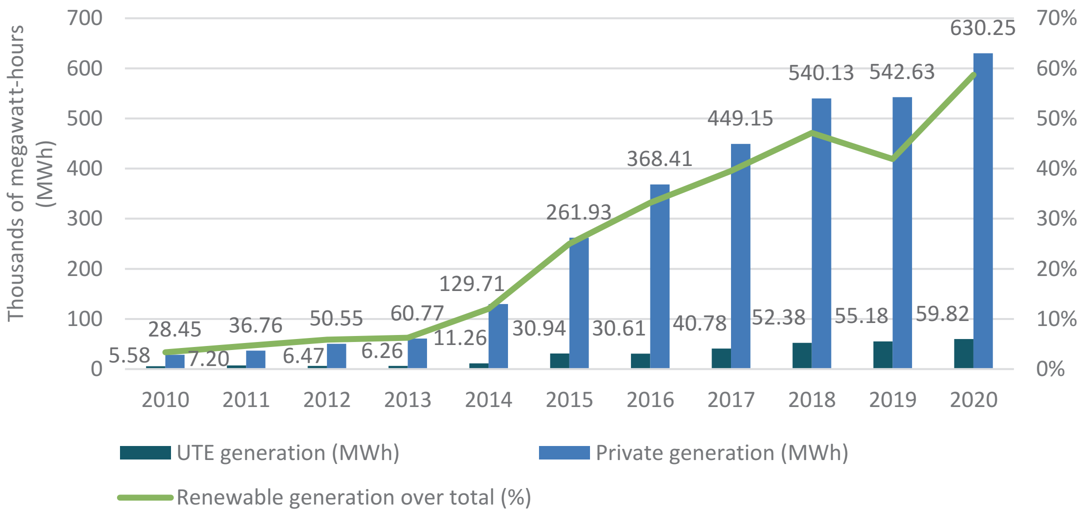

Fig. 17.1 Renewable generation by property (MWh) and participation (%) in Uruguay. (Source: Developed by author, based on National Directorate of Energy, 2021)

DREG projects. In this way, it is argued that the expansion of the market has guaranteed private firms a substantial part of the energy income, which the State thus loses. According to Esponda and Molinari (2017), if the investment had been made directly by the UTE, it would have entailed a significant indebtedness for the company; even so, this model implied an exponential increase in liabilities "for service concessions," reaching almost 40% of the total in 2015.

When thinking about a DREG with a public-social foundation, it should be noted that in Uruguay there are not many local user organizations that have energy as one of their priority axes of work. This is due, in large part, to the fact that the provision of the UTE is practically a total of 99.80% of the population, and for the remaining percentage, AUTE has promoted the action of *solidarity squads* for the realization of electrification programs and subsidized rate, to guarantee access to energy. For their part, the networks or public institutes that support the community projects of the DREG are framed within the universities and the technical teams of the same UTE. These favor the DREG and the constitution of intelligent networks of social base, as a mode of organic adoption of the working intelligence and the civil society. In fact, Uruguay plans to incorporate 300,000 smart meters for a total of 1.5 million consumers. Also, starting in 2008, the Energy Sector Fund was created under the scope of the National Research and Innovation Agency (ANII), which annually launches calls to support research, development, and innovation projects in the energy area.

In this framework, the DREG opens a field of debate in this country, basically because it is not a priority for the UTE, nor for the MIEM, much less for the AUTE union, which associates it with private injection and the loss of classic predominance of the state-owned company. In turn, the DREG is usually linked to the asymmetry that its implementation entails in self-regulated spaces of sectors with extensive resources, such as a condominium, or interference in private areas through intelligent networks. In this sense, the space of private actors is fed by large companies that can potentially become large generators or by large corporations that, depending on market conditions, prefer to become self-sufficient or enter a special energy purchase contract with other non-state actors, which has become more common in recent years. However, its weight is still relative, basically because the UTE still controls the entire network and more than half of the generation.

17.5 Chile: Opening Up and Dispute Over Private Income

Unlike what has been explained about the Uruguayan case, the existence in Chile of a system strongly privatized makes the DREG a potentially democratizing option. This alternative was launched in 2012 with the enactment of Public-Law 20,571 under the net billing model, where the consumers receive approximately 60% of the cost they pay for their consumption. This less attractive regime is compensated by higher energy prices that Chilean consumers must pay: the price in 2019 was US$0.18 per kWh in contrast to the US$0.15 world average.[1] In addition, unlike its neighboring countries, Chile does not have any type of social rate or electricity subsidy.

Until 2018, the DREG application was not fruitful, on the one hand, because the approval procedures were far from diligent; an approximate delay of 1 year ended up discouraging its implementation. By that year only 1776 units – 6.61 MW – had carried it out including those of public institutions (Ministry of Energy, 2020). On the other hand, its application aimed to satisfy self-consumption; therefore the distributor indicated the installed capacity allowed in the unit. In other words, no one ever thought of microgeneration with a unit capable of making a profit. The maximum admitted power of 100 kW also limited the participation of regulated customers of a commercial and/or industrial nature, causing huge roof surfaces from shopping centers, factories, or industries not to be used for generation purposes.

However, the law was modified at the end of 2018, triggering exponential growth in this market: in 2020, the DREG reached 73 MW of power (see Fig. 17.2), and in a trend scenario for 2030, it was projected at 2000 MW, 13% of renewable power (Ministry of Energy, 2020). Among the main changes to the Law was the extension of authorized power from 100 to 300 kW, in addition to extending the range of admissible projects to community and jointly owned systems (Herrera, 2019), allowing the creation of energy cooperatives. In the central and southern part of the country, there is a set of concessionaire cooperatives for the distribution service. Grouped in the Federation of Electric Cooperatives (Fenacopel), they have a total of 148,100 clients and 63,086 members. Likewise, in recent times a series of cooperative initiatives have emerged in practically all regions, under the impulse of strong citizen participation, but they have not yet been able to enter the field of generation. The particularity they have is that not all users are partners and that it is possible to take profits; thus, the legal framework does not differentiate it from a private company for profit. The new provisions also allow *virtual net metering* for energy harvesting for those who lack the place to install it, which makes the DREG a viable option in large urban centers (Vargas, 2018; Sánchez Molina, 2018).

This model is the one prioritized by the incoming government of Gabriel Boric (2022–2026), whose decarbonization plan includes installing 500 MW in nonconventional renewable energy self-generation systems, both residential and community. It foresees the decentralization of generation through local companies and cooperatives, within the framework of the implementation of local development policies that will seek "a green productive transformation that allows extractivism to be overcome and move towards a new development model" (Rodríguez Nazer, 2021).

However, in Chile there are conditions to demand the opening-up of the market to obtain moderately disruptive elements; in fact, the possibility of producing its own energy does not contradict the basic postulates of the liberalism that prevails in the country. The DREG presents a challenge for utilities on how to transform the conventional flow of energy into a bidirectional one. The tensions here are played out with the omnipresent skeleton of private energy management, which naturally does not favor the slightest inconsistency that could undermine its

[1] Information provided by the International Energy Agency (IEA), available at https://www.eia.gov/international/overview/world

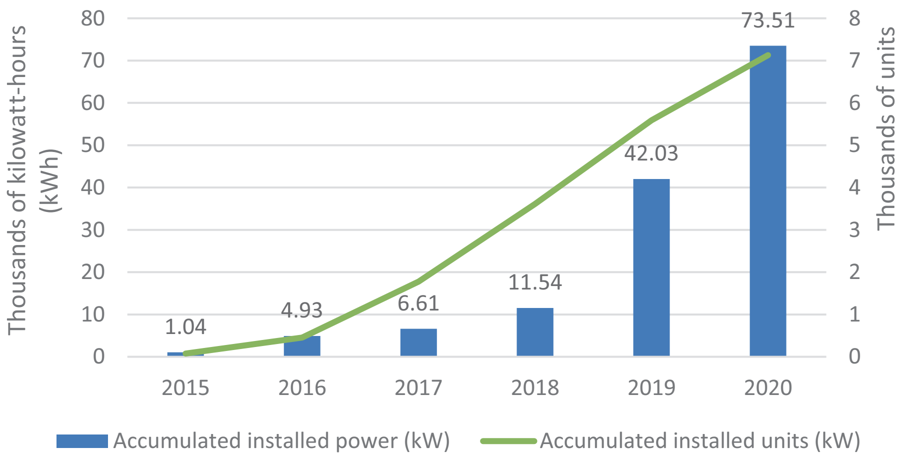

Fig. 17.2 Quantity and installed power (kW) of the DREG in Chile. (Source: Ministry of Energy, 2020)

operations. Examples of these controversies are the statements of the Minister of Energy at that time, Máximo Pacheco, in relation to a discussion in 2019: "It seems serious to me that a public policy first identifies an investment opportunity for private parties, then makes it mandatory for all Chileans and finally guarantees by law the profitability of that investment" (Sepúlveda, 2019). With this comment, he referred to the fact that the Bachelet government had approved, with force of congressional law, the installation of smart meters at a cost of US$1000 million that would be paid by the consumers themselves, which aroused a strong public discussion to the point that the president Piñera had to go out and reaffirm "consumers pay for everything." But the onslaught that followed led to the revision of this measure. In fact, Enel, a multinational that supplies more than 1.8 million consumers in the Metropolitan Region of Santiago, bought the installed meters from its Italian subsidiary E-distribuzione, which was supposed to be a round deal: the firm made a purchase from itself and the cost was paid by the users. Finally, the distributors "accepted" to give in and offered to pay consumers $10,000 for the old meters (Orellana, 2019).

From this experience, a national debate was uncovered around not only the installation of smart meters but also the high profits obtained by distributors protected by the General Electric Services Law. The legislation guarantees the private monopoly of the sector and a minimum annual return of 10% before taxes, a percentage much higher than those established by the European and North American regulations, which are between 5% and 7%. In 2017 alone, Enel Chile reported $349 billion in profits, followed by Compañía General de Electricidad (CGE), the firm responsible for 40% of the distribution infrastructure, with US$179 billion. In total, the distribution segment obtained profits of almost US$600 billion in that year, a figure higher than the annual profit of the six pension fund managers operating in the country (Sepúlveda, 2019). Faced with this, Pacheco himself affirmed that "the State cannot guarantee round business for companies" and sentenced: "Rules imposed 30 years ago that favor them disproportionately must be reviewed now."

According to Sara Larrain, a member of the Parliamentary Technical Citizen Commission for the Energy Matrix (CCTP), residential consumers allow a profitability of around 60% if bills include "fixed charge, single charge for use of the trunk system and base energy, and divide said sum by the kWh consumed throughout the month" (Larraín, 2011). A study carried out by the consulting firm Bonilla y Asociados for the National Energy Commission (2017) assured that a rate of profitability consistent with these times should not exceed 6.5%, which would generate a noticeable drop in electricity bills. Furthermore, the Commission proposed to radically change the current operation of the electric system toward deregulated energy marketing models, such as the European one, where the distributors would oversee the *cable business* – the distribution infrastructure – while electricity marketing would be opened to the so-called retail market.

Although the competing initiatives are attractive to think about greater public intervention, the truth is that the Chilean experience is especially fruitful for advocating conservative innovations of a mercantile nature. Therefore, the opening up of the electricity market and the technical possibilities offered by the DREG are aspects that open a window of opportunity for the decentralization and even the democratization of the national energy system. In contrast to the current regime that proposes the construction of extensive transmission lines, the DREG promotes regionalization and local supply. In particular, the cooperative movement is undergoing a resurgence, in which an opportunity is seen to carry out energy projects that consolidate service cooperatives, although not only that but also work cooperatives, where the technical design and installation of the DREG systems constitute a source of employment of relevance.

17.6 Argentina: Autarchy and Asymmetric Growth

In Argentina, the sanction of Public-Law 27,424 and its regulation toward the end of 2018, constituted the first national regulatory step toward the DREG. This establishes the legal and contractual conditions for the residential consumers of the network to generate their own energy and oblige distributors to facilitate said injection, ensuring free access to the network. It also creates the figure of the *consumer-generator*, which includes both individuals and association of co-owners of horizontal property or real estate groups, and expressly excludes large consumers. Similarly, it creates a trust called the Fund for the Development of Distributed Generation (FODIS), intended for the granting of loans, incentives, guarantees, the making of capital contributions, and the acquisition of other financial instruments, with the national State as the enforcement authority.

The development of this market has been gradual, and by mid-2021 only 5.7 MW of power were connected to the grid. Of that power, 70% corresponds to industrial and commercial consumers, and only 21% to residential consumers. In other words, this technology has not been able to consolidate itself as a profitable alternative for small captive consumers; in any case it has been used by those who have large consumptions and have the capital to make the investment. The most significant barriers are based on the lack of financing at reasonable rates, subsidies for conventional electricity rates, together with a net billing rate model that does not include the payment of a differential rate. Another important point is the regulatory framework given by Public-Law 15,336 and the distribution of powers between the Federal State and the Provincial States over public services. This establishes that, unlike the transmission lines and the generation connected to it, the distribution and collection of electricity corresponds to the provincial jurisdiction. Therefore, for Public-Law 27,424 to be effective in each jurisdiction, it must be signed by the provincial States, which has aroused certain debates within the country.

From various political sectors, it is argued that some of the provisions established by the National Law exceed the federal jurisdiction, in particular the incentive rate and the connection authorization (Porcelli & Martínez, 2018). This has led to the fact that, to date, only 15 of the 24 jurisdictions fully adhere: Buenos Aires, Catamarca, Chaco, Chubut, City of Buenos Aires, Córdoba, Corrientes, Entre Ríos, La Pampa, La Rioja, Río Negro, San Juan, San Luis, Tierra del Fuego, and Tucumán (see Fig. 17.3).

Due to this federal framework, the transformation capacity of the DREG lies mainly in the intermediate and local scales, actors with the capacity for effective action. Indeed, the most advanced provinces are those that have established local legislation. A paradigmatic case

Fig. 17.3 Provincial regulatory framework regarding Public-Law 27,424. (Source: Developed by author)

is the province of Santa Fe, which was a pioneer in enabling the connection to the network of residential systems in 2013, and between 2016 and 2020 carried out its own incentive program called *Prosumidores*. This program sought to promote the adoption of DREG photovoltaic solutions for clients of the Provincial Energy Company (EPE) and the electric cooperatives in charge of distribution. What proves interest in this option is that this experience was followed by numerous provinces, although under different structures and regulatory conditions: Mendoza, Public-Law 7822; Salta, Public-Law 7824; Neuquén, Public-Law 3006; Misiones, Public-Law 118; and Jujuy, Public-Law 6023.

The technical and administrative guidelines established by Public-Law 27,424 are not only politically controversial points but also economic. While the national law adopted a net billing rate scheme, some provincial regimes opted for net metering; Santa Fe and Salta oriented their strategy toward a FiT system; and the Neuquén legislation authorized the Enforcement Authority to establish differential prices during different periods (Sosa, 2017). These regimes are crucial for the development of the market and cannot be dissociated from energy costs and grid parity in each province, that is, from the possibility that a DREG installation has to amortize the investment in a short period of time. For example, a study by Sergent (2018) states that a net-metering regulation in Buenos Aires could be amortized in 21 years, compared to an average useful life of the equipment of 20 years. In the case of a user from Santa Fe, who benefits from slightly more radiation than Buenos Aires, this amortization drops to 12 years. This difference is explained by two main reasons: the type of rate applied and the strong disparity that persists in electricity rates between provinces. Santa Fe prosumers benefit from a FiT model that allows them to save on network energy consumption, which is more expensive than that of their peers in Buenos Aires.

However, from different regulatory bodies and distributors, it is argued that an exaggerated amount of monetary incentives means that captive consumers subsidize part of the distribution cost to microgenerator consumers, leading to what in the sector jargon is called a *death spiral* (Gubinelli, 2018), that is, when the necessary costs to operate and maintain the networks are spread over a shrinking base of consumers and a smaller number of consumed kWh. Regarding the case of Santa Fe, a large part of the FiT program was fed by a derisory fixed tax in Argentinian pesos that, in accordance with the provisions of Provincial Law 12,692, all users in the province pay equally, without differentiating between small and large consumers. This limited the program's available resources and had an impact on its scope, limiting the benefit to only 100 projects per year for sectors with available capital.

Beyond the questions of a political, economic, legal, and technical nature, it should be noted that today there is an open debate in Argentina about the DREG, in some cases related to a strong political decision. Even though the National Law proposes a highly conservative goal of 1000 MW of installed power by 2030, the contribution of this technology in the provinces is incipient, and the degree of citizen participation will necessarily be the result of effective dissemination at all management levels: federal, provincial, and municipal, especially if one takes into account that only a smaller portion of the population has the savings capacity to invest autonomously in it. Provinces such as Mendoza and Córdoba have advanced in community-distributed generation (CDG) programs, which give the possibility of adding individual investments to associate in a medium-scale generation project (Medinilla, 2021). Furthermore, the cooperatives have been promoting, since 2007, the Electric Generation of Integrated Cooperatives (GECI) project, which seeks to take advantage of regional energy resources; and they are studying the possibility of entering the future market, that is, selling clean energy to large consumers.

On the DREG rests the possibility of opening the citizen and/or community generation, or closing it based on specifications that end up benefiting large companies, inhibiting their moderately disruptive potential. The work with provincial state-owned companies, municipal governments, and more than 500 electric cooperatives that operate the local distribution service are otherwise encouraging. Cooperatives represent 11.64% of national consumption, 30% of the market if the agglomeration of Buenos Aires is not taken into account, and 58% taking only rural areas (Garrido et al., 2013). The logic is that, in the medium term, automatically when economic possibilities facilitate it, DREG is incorporated into the local matrix. In this way, the profit from the generation of large generators is transferred to territorial actors; even these entities have the potential to generate income that today is only outsourced. The consumer, the cooperative, the municipality will win, all under the same territorial roots, the same proximity.

17.7 Conclusions

As we have seen, the preeminence of large energy corporations is significant in the region. Particularly in Argentina and Chile, the neoliberal corset implemented at the end of the last century led to the creation of an energy regime that was deregulated and strongly concentrated in private actors (Azpiazu, 2002; Serra, 2002). However, while the debate about the DREG in Chile enabled the incorporation of a group of consumers to the generation market, it also triggered a public discussion about the extraordinary profits obtained by electricity distributors, which opened the doors to question the entrenched legislation that protects their interests. If treated based on its most transformative edges, the DREG opens a field of social action in the country that today seems suffocating when it comes to the predominance of private profit. In the case of cooperatives, the possibilities in this regard are promising, boosted by legislation that offers the conditions to be able to carry out disruptive projects.

In Argentina, the diversity of social subsystems calls for the need to deploy an articulated transition between local and national processes and between political and economic logics of action. Even though Public-Law 27,424 helps to close a legal gap that Argentina had regarding its neighboring countries, there is still opacity in the system that blocks the possibility of a greater transformation. Therefore, innovative ideas are needed to decisively incorporate environmental problems and the deconcentration of the system. Even when the distribution of energy is within power of the provinces, a consensual national regulation is necessary to consolidate common technical and administrative guidelines that integrate long-term energy policies with a strategic objective.

The most convincing case of structural transformation, without a doubt, has occurred in Uruguay, where the private landing from the expansion of the DREG is particularly problematic. Even so, the weight of the "public thing" is so great that the commercial dynamic has not had enough strength to unfold, although it has generated a certain appropriate legality in the nineties. The problem, of course, is whether this technological option is going to mean a consolidation of private actors and their accumulation, or the creation of a broad social base dedicated to energy production to become a channel for redistribution. The question, in this case, is how decentralization does not undermine the direction of the energy policy of public actors.

Sooner rather than later, the DREG will be a component that will tend to become more acute, constituting a central element in the reorganization of electrical systems at a global level, a kind of strong trend direction and at the same time a window of opportunity. Its success will depend on the design of a long-term sustainable remuneration model. To do this, innovative ideas are necessary, whether they come from political society or civil society, which fully incorporate the deconcentration of the system. Special attention should be paid to the evolution of installation costs, as well as the applicable rate table. But particularly in the Southern Cone, the realities of electrical systems require thinking further, toward structural issues such as the articulation among income, private company and public sector, even among subsidy policies, tariffs, and fiscal activity as a basic mode of redistribution.

The main question lies in whether decentralization maintains the scheme of concentration in generation and the privilege of the large players in the electric system or if, on the contrary, public-social experiences are enhanced. The latter requires the implementation of vernacular technological niches, which direct a transition toward conceptions of energy as a right, where the great majorities have access not only to its use but also to its management.

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18

Unfolding the Relationship Between Poverty and Energy Consumption in Brazil: A First Step Toward the Energy Poverty Debate

Raiana Schirmer Soares, Andrea Lampis, Lira Luz Benites Lazaro, and Celio Bermann

18.1 Introduction

The concept and measurement of energy poverty, much like income and multidimensional poverty, is inherently normative, and our definition of energy poverty and its related conditions shapes our understanding of which groups are affected. As we will discuss later in this text, the definition of poverty is not static and can change based on the context in which it is applied. Nevertheless, one thing is certain: there is a significant inequality in access to energy and energy-related services, and this can have profound implications for the well-being and quality of life of individuals and communities.

Energy has an undeniable importance in the environment, as it affects both the impacts of climate change and the possible mitigation actions related to its control (IEA, 2021; IPCC, 2014). However, energy is also key for human development and is recognized as such through SDG 7, which aims "to ensure access to affordable, reliable, sustainable, and modern energy for all" (United Nations, 2022). Despite this, and the fact that Agenda 2030 has as a core objective to end poverty and leave no one behind (Kharas et al., 2019), some significant features of energy transition related to social injustices have not yet been fully comprehended or considered (Dunlap, 2017; Kopnina, 2016; Löfquist, 2020; McCauley & Heffron, 2018; Villavicencio Calzadilla & Mauger, 2018).

The concept of energy poverty has gained the attention of academics and policymakers, although with a considerable degree of controversy. Bouzarovski (2018) stated that "the nexus between energy and poverty has historically been riddled with conceptual discord. For a long time, politicians and scientists alike failed to recognize that a unique set of issues existed at the intersection of these two domains." The concept ties together the synergies and trade-offs between energy access and poverty to enable the claimed energy transitions to be transformative in terms of social justice. Energy poverty does not have a universal definition because the issues surrounding poverty and energy are deeply grounded in

R. S. Soares (✉) · A. Lampis
Energy and Environment Institute, University of São Paulo, São Paulo, Brazil
e-mail: raianaschirmer@usp.br

L. L. B. Lazaro
Department of Environmental Health, School of Public Health, University of São Paulo, São Paulo, Brazil

Durham Energy Institute and Department of Anthropology, Durham University, Durham, UK

C. Bermann
Institute of Energy and Environment, University of São Paulo, São Paulo, Brazil

Energy and Environment Institute, University of São Paulo, São Paulo, Brazil

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historical, geographical, technical, political, and regulatory factors. Therefore, energy poverty occurs because of poverty and social exclusion.

Thus, through the lens of energy poverty, this study explores the differences in the way people experience poverty and how they relate to the ability to access energy and the quality of energy services. By using a multidimensional poverty indicator that combines elements from both the biophysical and monetary approaches to poverty measurement, we adopted a three-pronged classification, whereby the different categories of poverty (recent, inertial, and chronic) unfold according to specific time frames when certain communities and socioeconomic groups experience forms of energy deprivation and vulnerability.

We also presented relevant data that question the narrative of the universal access to energy provision under Agenda 2030 while discussing the largely unchallenged assumption of adequate electricity services in Brazil. In addition, we analyzed the access to clean cooking fuel, whereby previous data has demonstrated that there is a lack of statistical correspondence between access to clean cooking fuels and their exclusive use that is based on social dimensions. Indeed, our results indicate that tens of thousands of households rely on contaminated, polluted, and hazardous cooking fuels, such as wood or charcoal, either to complement LPG or other cleaner sources or to replace them completely during periods of crisis.

Energy poverty in Brazil has not been recognized by policy or broadly discussed by academics; therefore, an evidence-based initial analysis of the relationship between energy consumption and poverty is necessary. Thus, instead of measuring energy poverty, this study analyzes how energy expenditure impinges on the economic situation of low-income people in Brazil. This will contribute to the energy poverty debate in Brazil by shedding light on the intimate relationship between energy consumption and poverty in the country.

18.2 Why Should We Discuss Poverty in Association with Energy Poverty?

This section serves two purposes: (i) to present an overview of the core debates on poverty from approximately the 1990s to the present and (ii) to unveil the connections to the current debates and approaches to conceptualize and measure energy poverty. It does not present an exhaustive account of the debates on poverty but identifies the various factors that affect any discourse on poverty and its determinants. Accordingly, the purpose of this section is to offer a contribution to the discussion on energy poverty, its nature, and related implications. In view of this objective, it is relevant to bear in mind that "measurements and operational models are never neutral. They reflect philosophical and political convictions and believes" (Lampis, 2009, p. 232).[1]

Although there are considerable studies on energy poverty (EP), the historical aspects of poverty in the conceptual and methodological debates have been largely ignored. Debates on poverty can best be represented as a sequence of adjustments in relation to the politics and knowledge of this area. Instead, mainstream contributions to EP tend to overlook these historical factors (Bouzarovski & Simcock, 2017; Sareen et al., 2019).

We contend that EP approaches are primarily borne out of policy- and measurement-oriented debates. The first debates on energy poverty occurred after the oil crises of 1973 and 1979, although the contemporary debate began subsequent to the 2008–2009 financial crisis, whereby many European countries endured severe material deprivation that altered the poverty debate beyond that of the relative poverty focus in the 1980s to the early 2000s (Hantrais & Mangen, 1996; Kangas & Ritakallio, 2007; O'Brien & Penna, 2008; Sen, 1983). This greater emphasis on measurement continues to be a gray area in

[1] After Sen (1976) and several of his other writings.

Table 18.1 Poverty debates as families of approaches

Biophysical approaches conceptualize poverty as a matter of survival and are generally limited to inadequate access to nutrition and shelter
Monetary approaches are a set of techniques and methodologies adopted mostly by economists, based on the identification of poverty using a monetary indicator and an "objective" derivation of a poverty line[a]
Multidimensional approaches include the aspects of physical survival or the ability to buy necessary goods and services. Accordingly, based on a renewed humanist approach that re-conceptualizes human well-being (e.g., the capability approach), they embark on what can still be read as unrestricted issue an open-ended journey (see, e.g., the Sustainable Development Goals).
Representational approaches reflect a critical interest in the discursive and political representation of poverty, particularly in "modern" (post WWII) poverty analyses. They tend to share a common concern that is mainly derived from post-developmental critiques of poverty analyses. That is, they place politically and ethically driven factors at the center of the debate to question the cultural and representational narratives of poverty and low-income individuals in Western thinking

[a]See Ruggeri Laderchi (2000) for a formal discussion

the debate on EP. In Brazil and other Latin American countries, decolonial perspectives (Fuchs, 2011; Lander & Castro-Gómez, 2000; Quijano & Clímaco, 2014; Santos, 2010) have increasingly challenged the validity of the European and Western viewpoints and the measurement tools for other latitudes and economic conditions, and it is from this perspective that we critically approached this debate.

Hence, we hereby explore the relationship between energy and poverty in Brazil to critically assess the poverty debate in the country, orient it toward the poverty eradication mission, and increase the awareness of the relationship between social vulnerability and socio-technical relations. In order to do so, we synthesized a vast body of literature into four categories, to which we suggest that all major approaches to poverty can be allocated as families of approaches: (a) biophysical, (b) monetary, (c) multidimensional, and (d) representational (see Table 18.1). Borrowing the term from qualitative analyses, the category we chose to cluster the approaches is that of the family. That is, the long-standing tradition of debates on poverty can be reframed as clustered around or within *families* of approaches,[2] which are not mutually exclusive, and have some conceptual or methodological overlaps.

This section develops this fourfold categorization, whereby parallels are provided among each family of poverty approaches and comparisons are made with the core insights from current mainstream energy poverty approaches. Our aim here was to analyze hidden or explicit contact points between poverty and energy poverty and to unveil their underlying assumptions, whether epistemological, methodological, theoretical, conceptual, or political.[3]

(A) *Biophysical Approaches*

Biophysical approaches have evolved since the first studies on poverty in England between the end of the nineteenth and the beginning of the twentieth century and have become effective tools for identifying social vulnerabilities (Sibrian, 2009). Biophysical approaches have also been employed to address energy poverty. The notion of energy poverty is historically a re-elaboration of the unmet basic needs approach, specifically, the need for thermal comfort (warming and cooling). When this cannot be fulfilled, a household is defined as experiencing energy poverty, and this creates debates on the economic conditions causing the shortfall and the impact on the health of the individuals involved.

In 1991, under the assumption that access to energy affects the capacity to meet basic physical needs, Boardman (1991) introduced the first broadly reproduced operative measurement of fuel poverty, the "10% income threshold," whereby a household is in a condition of fuel poverty when its fuel expenditure exceeds 10% of its income. From an operational point of view, this indicator is useful, since it is easily measured, and the results are clearly understood.

[2]This analytical approach is adapted from Lampis (2009) and provides the analytical structure of the entire section.

[3]This section is based on a yet unpublished but already submitted document.

However, this approach presents two main limitations: the selection of the 10% threshold is arbitrary, and the income distributions of households are not considered. In other words, it does not accomplish a key postulate for a robust measure of poverty where the approach should be sensitive to variations in the income distribution to capture deprivation and inequality simultaneously (Sen, 1976).[4]

Although less cited, prior to Boardman's (1991) attempts, some authors have also proposed energy poverty indicators based on the biophysical aspects of poverty, by calculating the minimum consumption required in physical terms (kWh) to satisfy critical energy needs. One of the most important of these studies was that of Goldenberg et al. (1987), who, more inclined to discuss the human development relationship with energy consumption, concluded that the minimum consumption per person was 500 kWh. This indicator assumes a methodological premise very similar to that of the minimum nutritional intake indicator, since both use a defined quantitative threshold, whereby levels below this threshold would be considered inadequate.

Townsend (1993) presented a powerful synthesis of the limitations of the minimum consumption method on at least three grounds, which also questioned the required energy threshold. That study stated that to transform an abstract requirement in terms of nutrients (or kWh) and their prices and quantities, one must determine the availability of the resource. Similar to any social habit, food (and energy) is socialized. As such, it depends on cultural arrangements and factors that vary among countries or regions. Thus, the fact that individuals, households, and communities have different patterns of real consumption must be considered (Townsend, 1993). This also applies to minimum required energy levels, as the preferred energy source, available resources, and patterns of use vary depending on the different climates, regions, cultures, and available resources.

(B) *Monetary Approaches*

Although monetary approaches are the most used methods to measure poverty because they are readily implemented and intuitive, they do not incorporate a clear definition of poverty (Ruggeri Laderchi, 2000). As such, income- and consumption-based approaches are unable to explain the control that individuals, households, groups, and communities have over assets, their access to different kinds of resources, and their reasons for using certain resources according to context-specific situations (Moser, 2010; Ruggeri Laderchi et al., 2003). Furthermore, money-centric approaches to poverty tend to focus on the effects of poverty ("how much" and "where") without considering the "why" and "how" issues that are key when attempting to explain poverty dynamics.

An interesting comparison can be established between the minimum income standard (MIS) and low-income high-cost (LIHC) approaches to EP measurement. The MIS is defined as an energy-poor household whose available income (the amount remaining after the basic expenses have been deducted) cannot meet the required energy costs. Although it is a robust approach, as it addresses the problem from its economic roots of affordability, it fails to define energy poverty and its causes, and most of all, it does not offer a solid conceptual base to establish a correlation among income poverty, basic needs, and energy poverty (Romero et al., 2018).

In turn, the LIHC approach considers households to be energy poor if (i) their "expenditure on fuels" is above the national (regional, municipal, etc.) median, and (ii) spending that amount would leave them "with a residual income below the official poverty line." However, this approach does not discuss the parallel relationship between poverty and energy poverty. Furthermore,

[4] In his work, Sen demonstrated how any poverty measurement that attempts to overcome the limitation of monodimensionality (measuring only one aspect of poverty) should be capable of describing not only the depth of poverty but be sufficiently sensitive to identify changes within the incomes of low-income groups as well as between these groups and the rest of society. He formulated a set of axioms the represent a mathematical formalization of his conceptualization in "Poverty: An Ordinal Approach to Measurement" (Sen, 1976).

although it corrects the weakness of the 10% income threshold indicator by considering not only the expenditure on energy but also the income threshold, it is difficult to identify the households that are able to reduce their energy expenditure to move out of the energy-poor category. This is mostly due to the failure to relate poverty and energy poverty with variation in income inequality. A general decrease or increase in median fuel expenditure within society, or variations in non-energy goods and services may still leave a household in an EP condition.

(C) *Multidimensional Approaches*

Both biophysical and income-based approaches to poverty tend to be mono-dimensional and overlook the critical role of social and psychological needs. Within poverty debates, this limitation is at the root of several studies that have sought to achieve a broader comprehension of poverty, both in conceptual and methodological terms.

As mentioned in the previous section, in one of his early works, Sen indicated that any poverty measurement should reflect the possibility of not only describing the depth of poverty but also have sufficient sensitivity to identify changes within incomes of low-income individuals as well as those between these individuals and the rest of society (Sen, 1976). He also suggested that any poverty measurement should be conceptually meaningful and capable of informing us of both the extent of material deprivation and the implications in terms of inequalities. Therefore, it is important to consider that capability and vulnerability approaches are important milestones within the family of multidimensional approaches to poverty.

Martín-Consuegra et al. (2020) researched the relationship between multidimensional poverty and its spatialization to build a multidimensional index that conceptualizes deprived neighborhoods as places characterized by the accumulation of multiple forms of sociodemographic, economic, residential, and infrastructural inadequacies That is, they applied some of the core ideas regarding the vulnerability approach to EP. Petrova explored EP affecting young adults in the UK by developing the "energy precarity" to uncover the governance practices and material conditions that cause the inability of households to secure socially and materially necessary levels of energy services (Petrova, 2018).

In Latin America, several scholars have been dedicated to the study of energy deprivation and energy poverty (Giannini Pereira et al., 2011; Pellicer-Sifres, 2016), and as illustrated in a study by García Ochoa, most of these approaches use a multidimensional EP by embedding access to several energy services in their models to determine whether a household experiences moderate or severe deprivation (García Ochoa et al., 2021). Nevertheless, they do not define what EP is, but discuss how it could best be measured, while maintaining the conceptual overlap between electrification and EP (see Alkire et al., 2021).

(D) *Representational Approaches*

Post-developmental critiques of poverty are highly diverse. Nonetheless, there are some core elements that connect the different positions, thus forming a common thread. Taking stock of Foucauldian inheritance and Foucault's analysis of the power of narratives and discourses in shaping policy and politics (Foucault, 2008), several authors have indicated that, ultimately, all concepts of poverty are social constructs, as suggested by Escobar with the "regimes of representation" (Escobar, 1995; Shaffer, 2012). This is the case of poverty as a concept that is functional to developmental projects, as deconstructed by Escobar. Using a logic like Escobar but broadening the perspective using additional elements, development as a result of neo-colonial domination represents poverty as a state of decline and a constant need for aid (financial and technical cooperation).

Representational approaches have had a noticeable echo in those on energy justice (EJ) discussions. Scholars such as De Souza et al. have argued that the concepts and theories developed by postcolonialist scholars to criticize the culture and knowledge of power between Europe and its former colonies can be expanded to analyze the failure of international energy cooperation projects such as the Mediterranean Solar Plan (MSP) and Desertec (de Souza et al., 2018). Debates on the distributional, procedural, and, more recently, the representational aspects of EJ have also been indicated (Gillard et al., 2017; Jenkins et al., 2021; Martínez & Castillo, 2016; Pellegrini-Masini et al., 2020), with interesting implications for EP debate as they relate the process of access to energy to broader issues closely related to the dominant role played by Western institutions and developmental models.

18.3 Methodology

In recent research with an impressive worldwide breadth, Alkire and colleagues presented a new perspective to the debate using global data, regarding the conceptual complexities of considering EP as the ultimate analytical goal of their work on poverty. Those authors stated that electricity deprivation could serve as a proxy for multidimensional poverty. This could address some of the issues regarding EP, which we highlighted in Sect. 18.1. Although it is not explicitly spelled out in the questions put forward by Alkire's group, a very central debate on which they indirectly touch upon is whether electricity deprivation affects human capability. This is similar to the case for key dimensions of human deprivation, such as health and education, which is largely debated in the literature on human development (Fukuda-Parr et al., 2005), except that Alkire et al. replace those classic dimensions with electricity deprivation. We quote the questions they posed below, as they are representative of a research agenda on the multidimensional relationship of both electricity deprivation and EP, with poverty as a social condition in need of an urgent reflection on the materiality of energy consumption for human development, while the attached socio-technical configuration is undergoing rapid transformations.

> Whether electricity deprivation can be considered a good proxy for multidimensional poverty needs to further analysed and best approached through a step-by-step analysis that answers the following questions: i. What is the relationship between a lack of electricity and other aspects of multidimensional poverty?; ii. What are the most common simultaneous deprivations the electricity deprived face?; iii. Among the poor, how many are deprived in electricity?; iv. How are these people distinctive?; v. What is the association between electricity and economic development?; vi. What is the poverty intensity among those MPI poor and deprived in electricity?; vii. What is the association between electricity and multidimensional poverty over time? (Alkire et al., 2021, p. 9)

Considering this reflective proposition, the debate on energy poverty should intersect the panorama of actual poverty debates to understand how they are intertwined. Therefore, the posed questions lead us to a more specific set of core questions that articulate the research presented in this study. They are to be answered by considering the Sustainable Development Goals: (*1*) *What is the relationship between poverty and energy access in Brazil?* (*2*) *What does this exercise teach us about energy poverty in the country?*

To answer these questions, we defined a method to identify people living in poverty. Considering the prior discussions on the different conceptual approaches to addressing poverty, we chose to work with a multidimensional indicator to capture the multifaceted and complex relationship between poverty and energy. The chosen method combines biophysical and monetary approaches. Such an exercise allowed us to identify three different expressions of poverty: recent, inertial, and chronic.

The indicator used in this study from a biophysical approach was unmet basic needs (UBN), which has traditionally been used by Latin Americans as a poverty threshold (Alkire & Foster, 2011). It is an objective indicator that "involves focusing on the fulfillment of certain minimum human needs" (Stewart, 1985, p. 2). In summary, the UBN indicator verifies whether the household lacks access to any critical need. If so, the household is categorized as in poverty. Table 18.2 illustrates some of the traditional dimensions considered as basic requirements in Latin America.

The monetary approach used in this study is the World Bank income poverty for upper-

Table 18.2 UBN dimension

Basic need	Dimension
Housing quality	Overcrowding
Infrastructure that will guarantee minimum sanitary standards	Availability of drinking water Type of system for the elimination of human wastes
Access to education	Attendance of school-age children at an educational Establishment
Economic capacity	Probability of insufficient household income

Source: Feres and Mancero (2001)

middle-income countries (such as Brazil). The World Bank indicators are now the most widely used in official poverty measurements in Latin America. However, as briefly discussed in Sect. 18.1, they are not exempt from criticism. In their article "How not to count the Poor," Reddy and Pogge (2005) described the World Bank's poverty line[5] as "meaningless" and "arbitrary" given the fact that its definition is not anchored in a human needs approach and because it is highly dependent on the monetary conversion required to compare the realities of different countries. However, as suggested by Sen (1979), income perspectives (such as that of the World Bank indicator) allow for the analysis of the ability of individuals to meet their needs, regardless of their intention or willingness to do so. Even though that author suggested that direct approaches to the measurement of deprivation relate to human needs and are sounder than income approaches, he also suggested that although the two measurements are different; they are also interrelated in terms of identifying those individuals who are not having their needs met.

Sen (1979) was not the only researcher to highlight the complementarity of the two approaches. In fact, different authors have implemented an integrated bidimensional approach using both perspectives (Kaztman, 1989; Reyes Moyano, 1996). Considering the different levels of family income, monetary indicators reflect a

[5]Which at that point was 1 USD per day per capita.

Table 18.3 Clustered poverty from the bidimensional lens

	Income below the poverty line	Income equal or above the poverty line
At least one critical shortfall (UBN)	Households in situation of chronic energy poverty	Households with inertial poverty – vulnerable due to social deprivation
No critical shortfalls (UBN)	Households in a situation of recent poverty – economically vulnerable	Households out of poverty

Source: Kaztman (1989) and CONEVAL (2008)

conjunctural aspect of poverty, since they articulate people's participation in the productive process, while the indicators related to access to basic services emphasize the structural aspects of poverty, which depend not only on the family income level but also on specific policies for inclusion (Feres & Mancero, 2001). Kaztman (1989) integrated both approaches, as shown in Table 18.3, indicating different conceptions of poverty through the different interactions between the indicators.

1. According to this bidimensional perspective, households whose income is equal to or above the poverty line and have no critical shortages are "out of poverty," meaning they are not in poverty nor are they vulnerable to entering poverty. This ultimately means that their living conditions are dignified (Kaztman, 1989). Our first hypothesis (H1) is that households in this situation will also be out of the energy poverty zone. If this hypothesis is correct, it confirms that indicators related to energy access in Brazil may be a good proxy for poverty measurements. In this regard, it is relevant to bear in mind that acknowledging the proven relationship between energy consumption and human development in this conceptual context leads us to suggest that, if energy access is not properly and equitably balanced among these social groups, inequality will increase in the future.
2. Households with no critical shortages but whose income is below the poverty line are

economically vulnerable (CONEVAL, 2008), or, in Kaztman's words, "recently poor" (Kaztman, 1989). The rationale behind this categorization is that the mismatch between insufficient income to cover a certain lifestyle and the absence of critical needs would result in downward social movement and impoverishment of these households. Their vulnerability here is less connected to social structure historical fragilities and more related to situational living conditions. Feres and Mancero (2001, p. 29) stated that "it is plausible to assume that an increasing reduction of income in these households will translate into lower current consumption, and not into an immediate deterioration of the achievements in terms of satisfaction of basic needs." The second hypothesis of the present study (H2) is that people in this situation are more likely to face other difficulties to pay for energy services than to be deprived in terms of access to energy. This result may appear obvious, but it highlights an important consideration when measuring energy poverty: access and affordability approaches used to measure EP will identify different realities of poverty and, thus, choosing one need over another could lead to the neglect of certain needs.

3. Households whose income is above the poverty line but does not satisfy all basic needs are vulnerable due to social deprivation (CONEVAL, 2008), such as households with inertial poverty. In contrast to recent poverty, the mismatch between the presence of critical needs and economic sufficiency in these households would reveal a structural condition much more connected to social history, the successes and failures of people in previous efforts to accumulate material wealth or human resources, and the marginalization of some social groups (Feres & Mancero, 2001; Kaztman, 1989). These households are protagonists of the social conditions related to inherited poverty, a remnant of the previous poverty situation. According to Kaztman (1989), overcoming inertial poverty is related to the time required to adjust access to essential services according to consumption patterns. Thus, our third hypothesis (H3) is that households in a situation of inertial poverty are more likely to be deprived of access to energy than to face difficulties paying for energy services. If confirmed, this demonstrates an important bias of energy poverty indicators that implies that there is an expenditure threshold below which people are not energy-poor, such as the 10% income threshold already explained. The fact that people do not spend more than 10% of their income on energy, in this sense, could also mean that they do not consume sufficient energy to guarantee all required energy services (for communication, water heating, illumination, etc.) are assessed.
4. Finally, households that are both economically and socially vulnerable, that is, where income per capita is below the poverty line and where critical needs are not met, are called "chronically poor." These households are affected by both structuring conditions related to inherited poverty and conditioning situations related to monetary poverty (Kaztman, 1989). In other words, they are subjected to a cycle of poverty and impoverishment that is difficult to break without external actions. Our fourth hypothesis is that people in chronic poverty may not only have difficulty accessing energy but also paying for their energy services. If confirmed, considering the positive relationship between human development and energy consumption, it highlights a pessimistic perspective for the future of these families and the urgency of implementing policies that ensure that this cycle of impoverishment can be interrupted, which could be achieved by providing access and securing energy consumption.

18.4 Poverty in Brazil

In this section, we present the results of the exercise to identify individuals in poverty in Brazil, using the methodology described in Sect. 18.2. Brazil does not have an official poverty line as other Latin American countries do, and the official report Synthesis of Social Indicators (2019) (2019) from the Brazilian Institute of Geography and Statistics (IBGE) uses two indicators from the World Bank (World Bank, 2020): the first one defines that people who live under USD 1.90 PPP per day are extremely poor and the second, which is directed at countries with upper-middle-income, that people living with less than USD 5.50 PPP per day are poor. The premises used in this exercise are presented below.

- Income threshold: USD 5.50 PPP per day per capita (World Bank, 2020)
- Critical Needs (Feres & Mancero, 2001):
  - More than three people per bedroom
  - Lack of access to drinking water
  - Lack of access to the sanitation system
  - Lack of access to the waste collection system
  - Lack of access to electricity
  - Children above 7 years old and below 15 without access to education

According to the Family Budget Survey in 2017, 8% of Brazilian households were income-poor in the period, and 20% had one or more of their basic needs unmet. Based on Kaztman (1989), Fig. 18.1a presents the multifaceted nature of Brazilian poverty in 2017. Considering the prior discussion and the fact that those in chronic poverty both lack access to basic needs and live under the established minimum income, Fig. 18.1b has been prepared to better illustrate this relationship. Furthermore, to address how these different social vulnerabilities overlap with the geographical inequalities of the country in terms of wealth distribution, Fig. 18.2 presents the spatial distribution of key poverty-related indicators in Brazil and illustrates the considerably increased vulnerability in the north compared to the south.

Considering these different poverty and vulnerability profiles in Brazil, the next two sections explore energy consumption patterns in the country, considering the trajectories in territorial inequalities (Fig. 18.2).

18.5 How Energy-Deprived Are the Poor in Brazil?

The mainstream approach to analyzing energy access is through energy distribution systems. In other words, energy deprivation is measured in terms of a lack of access to power distribution grids and other fuels. SDG 7 itself measures the target 7.1, “to ensure universal access to affordable, reliable, and modern energy services” in terms of access to electricity, as its indicators

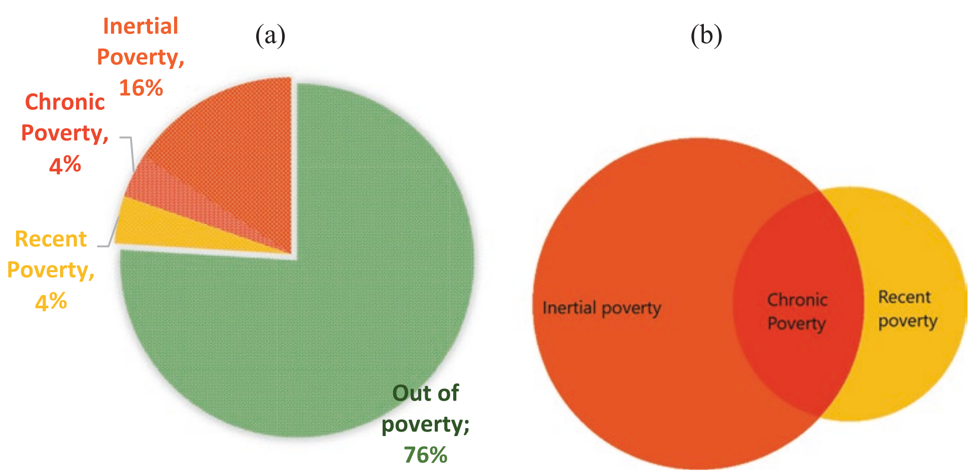


Fig. 18.1 Clustered poverty in Brazil. Note: (**a**) illustrates the share of households for each classification and (**b**) illustrates how their are interrelated with chronic poverty as their union intersection. (Source: Authors with data obtained from the Family Budget Survey 2018)

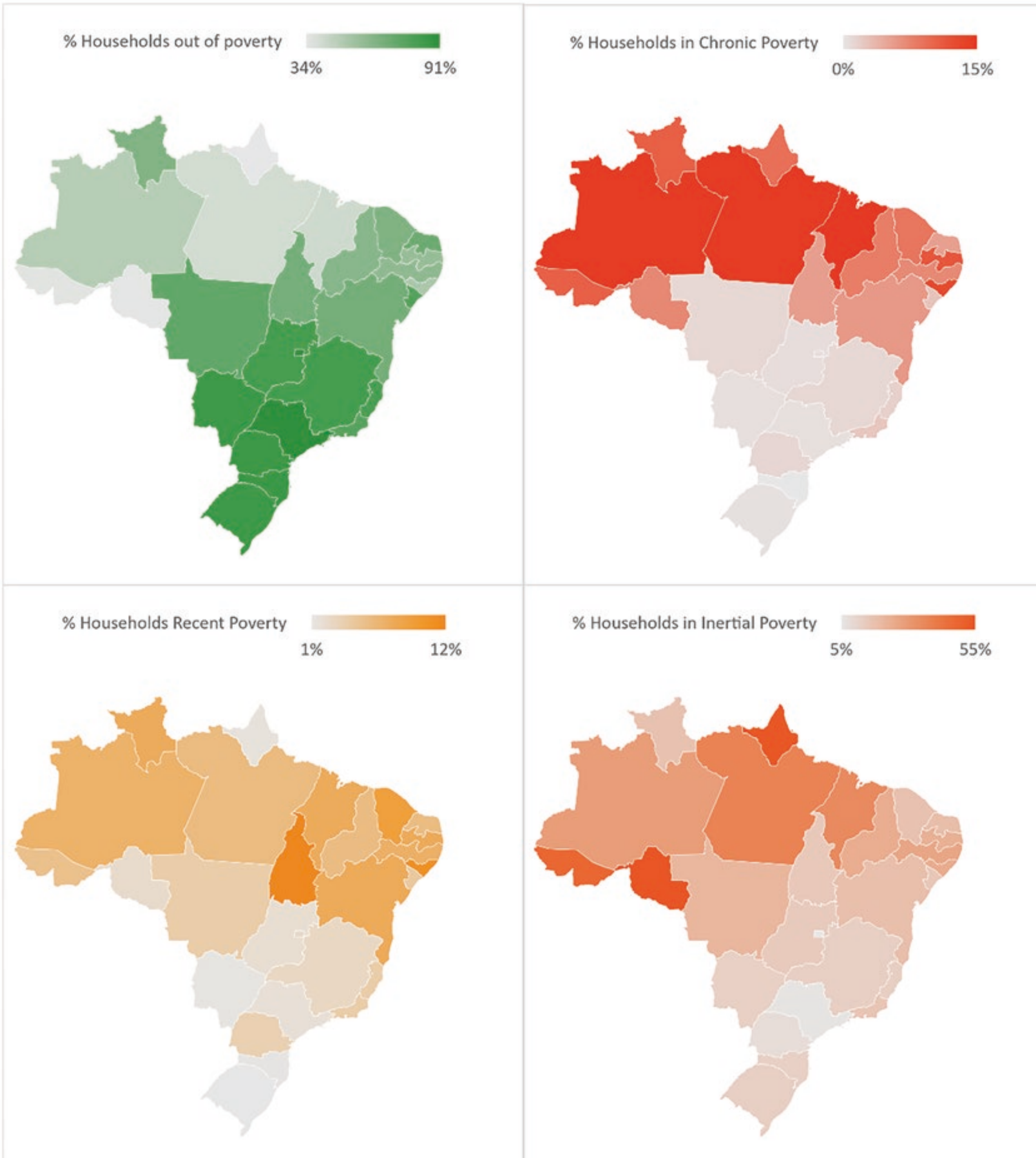


Fig. 18.2 Territorial inequalities in Brazil. (Da plataforma Bing © Microsoft, OpenStreetMap. Source: Authors with data obtained from IBGE, 2018)

analyze: (7.1.1) the proportion of the population with electricity access and (7.1.2) the proportion of people with primary reliance on nonsolid fuels (United Nations, 2022). Thus, as indicated in the Methodology section, the next subsections will analyze the level of energy deprivation in Brazil, using SDG 7's indicators.

18.5.1 Electricity Access

Brazil has a high rate of access to electricity. According to ESMAP's report "Tracking SDG 7" (2021), 100% of the Brazilian population has access (see Fig. 18.3). This universalization occurred at the beginning of the twenty-first cen-

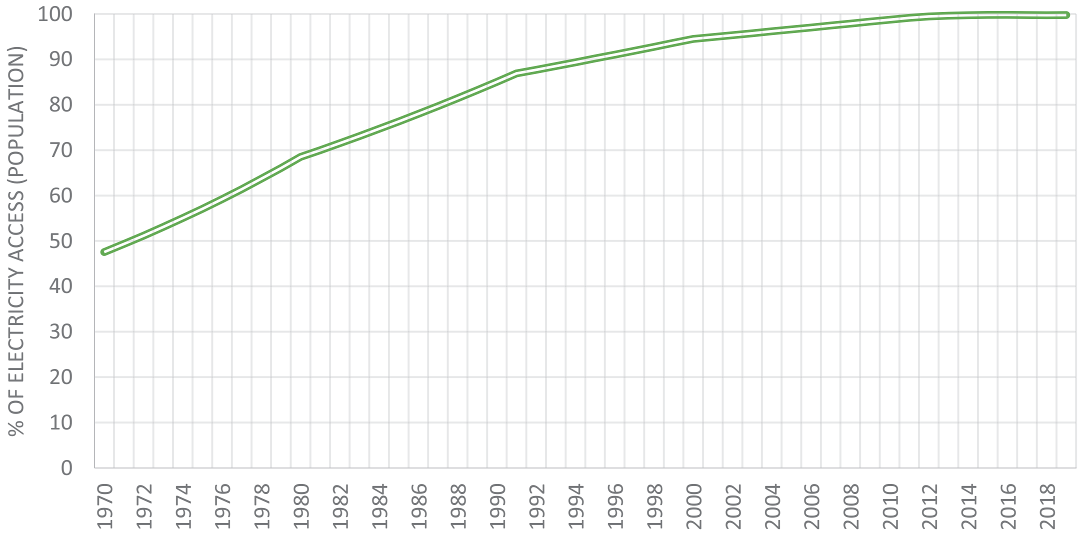


Fig. 18.3 Evolution of electricity access in Brazil. (Source: Inter-American Development Bank (IADB, 2021))

Table 18.4 Perception of residents on electricity supply

	Chronic poverty (%)	Inertial poverty (%)	Recent poverty (%)	Social integration (%)
Good electricity supply service	71.5	73.0	82.1	81.8
Satisfactory electricity supply service	14.3	16.3	11.8	13.7
Poor electricity supply service	9.6	8.9	5.7	4.4

Source: Authors with data obtained from IBGE (2018)

tury, and, among the many factors responsible for this, the most important was the launch of the program "Luz para Todos" (LPT, in English, "Light for Everyone"), which was mainly directed to guarantee that people in rural areas had access to electricity (Jeronymo & Guerra, 2018).

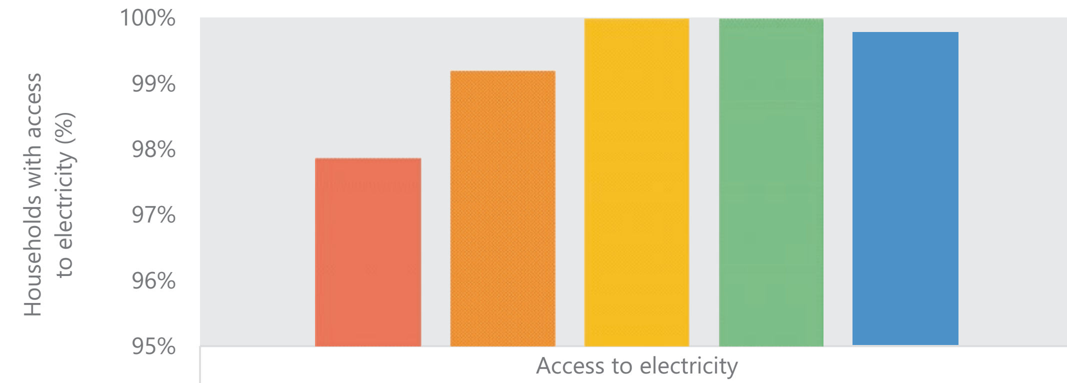
Even though electricity distribution is presented as an essential service in the Brazilian Constitution (Camargo et al., 2008), up to 2003, many people in rural areas were not connected to the national electricity grid. The LPT, which was introduced to respond to a prior crisis in the energy system (Jeronymo & Guerra, 2018), has assisted more than 15 million people, focusing on those living in rural settlements, extractive reserves, quilombola[6] areas, and indigenous lands (Fialho De Freitas et al., 2017).

Despite the high level of electricity coverage, the public perceives marked differences in the quality of electrical coverage. As illustrated in Table 18.4, vulnerability boundaries are accompanied by a difference in the quality of power delivered, as a significantly larger share of people in chronic and inertial poverty consider the electricity system a poor service.

In addition, the universal access to electricity in Brazil is a narrative choice that is not exempt from criticism. The presented indicator (100% access) is a rounding of 99.8% (IBGE, 2018), which means that 0.2% of Brazilian households (more than 150,000) still do not have access to electricity. This corresponds to approximately 450,000 people (IBGE, 2019), which, for comparison, is greater than the population of Iceland.

Figure 18.4 illustrates that these 150,000 forgotten households are all in poverty and vulnerable. The chronically poor and those suffering from inertial shortages are most affected, confirming both our third and fourth hypotheses.

[6] In the terms of Decree 4887, of 2003, these are the lands occupied by the remnants of quilombos communities, which organized themselves as a resistance to slavery and which have physical, social, economic, and cultural reproduction guarantees.



	Access to electricity
Chronic Poverty	97.9%
Inertial Poverty	99.2%
Recent Poverty	100.0%
Out of poverty	100.0%
BRAZIL	99.8%

Fig. 18.4 Access to electricity in Brazil from social extracts' lens. (Source: Authors with data obtained from IBGE, 2018)

Therefore, the use of a global indicator perpetuates the omission of people in the Brazilian energy system and clarifies that the issue of energy access regardless of what is sold as an incontrovertible truth is a still-to-be-solved issue. Given that a lack of energy access hinders human development (European Parliament, 2017; González-Eguino, 2015), energy access for all is also a matter of poverty eradication in Brazil.

18.5.2 Access to Clean Cooking Fuels

According to ESMAP (2021), access to clean cooking fuels is close to universal in Brazil, given that 96% of its population has access to at least one type of fuel. According to the latest Brazilian Household's Budget Survey (IBGE, 2018), 99% of households with access to clean cooking fuels use (not necessarily exclusively) bottled LGP or piped gas. Considering this and the fact that the residential consumption of LGP was 1500% higher than that of natural gas in 2019 (EPE, 2020), it is reasonable to infer that access to bottled gas is foundational for Brazilian success in terms of this specific SDG target.

The importance of LGP in Brazilian households has increased over time in relation to a decrease in wood consumption. According to Rodrigues and Gonçalves (2018), in 1970, residential wood consumption was 15 times higher than that of LGP consumption, and only in the 2000s did LGP begin dominating as a cooking fuel in Brazil. One of the main events that fostered its higher diffusion was the launch of the "Auxílio-Gás" (Gas-Aid Program) in 2002, which had the objective to direct to the low-income population, as a monetary transfer, the values corresponding to the prior and excluded subsidies for cooking gas consumption (Rocha, 2011; Rodrigues & Gonçalves, 2018).

It is undeniable that LPG consumption is important for Brazilian families, and that most have access and use this fuel. However, the fact that most Brazilian people have access to LPG does not necessarily mean that they do not consume wood for cooking, only that they do not rely entirely on it.

This fact is particularly acute when we consider the risks associated with the indoor use of firewood to human health. In addition to its effects on the environment, pollution generated by the consumption of solid fuels, is a cause of

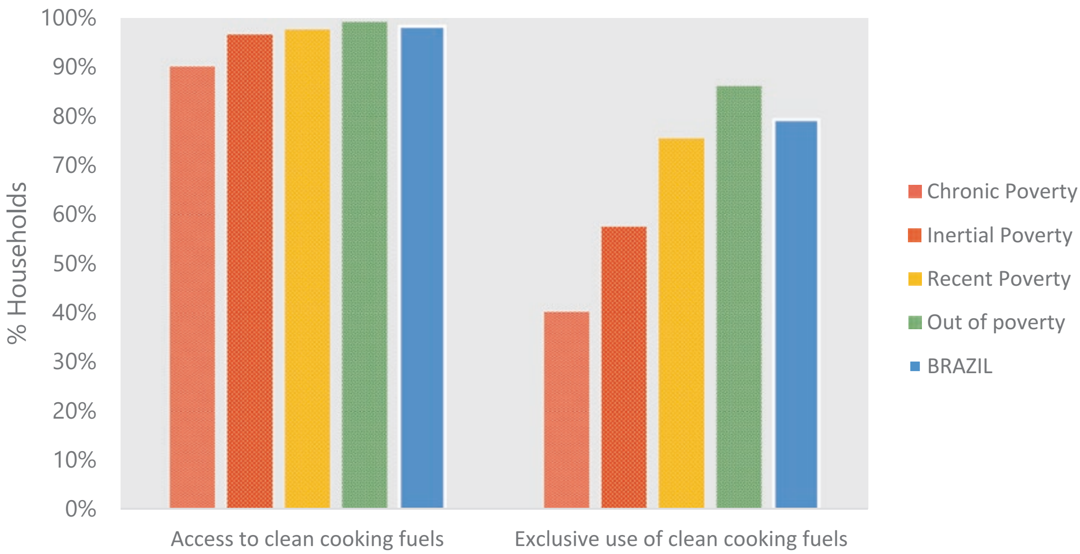


Fig. 18.5 Access to clean cooking fuels in Brazil from a social position. (Source: Authors with data obtained from IBGE, 2018)

severe health problems such as pneumonia and lung cancer (Rehfuess & World Health Organization, 2006). According to the World Health Organization (WHO, 2021), approximately four million people worldwide die every year because of polluting food preparation practices.

Our results in Fig. 18.5 illustrate a large difference between access to clean cooking fuels and their exclusive use in Brazilian households. Approximately 20% of Brazilian households that have access to clean cooking fuels also use polluting sources. Traditions, habits, and culture may explain the inclination to continue burning wood or charcoal to prepare their food. In southern Brazil, for example, there is a tradition of preparing barbecues in adapted rudimentary ovens by burning charcoal. However, the use of polluting sources can also be an alternative for people to respond to tariff increases or difficulty in purchasing and consuming clean fuels.

Figure 18.5 demonstrates that the level of access of the different social groups under analysis increase as we change the perspective. Again, the chronically poor and households suffering from inertial shortages are the most vulnerable, followed by the recently poor. This finding confirms our third and fourth hypotheses.

These differences become more evident as we analyze exclusive access to clean and polluting cooking fuels, as illustrated in Fig. 18.6. While most people under the social integration group only consume clean fuels, the number of households that do not use wood as a cooking fuel progressively decreases as we move to the chronic poverty group. In fact, approximately 8% and 2% of households under chronic poverty and inertial shortages, respectively, only consume polluting fuels to prepare their food.

18.6 How Does Energy Consumption Affect the Income of Low-Income Individuals in Brazil?

Although access from an infrastructural approach is an appropriate method to address the energy issue, there is always room for further discussion. It is obvious that people who do not have physical access to energy cannot satisfy their energy needs, but the opposite is not necessarily true. That is, simply because people are connected to the electricity grid or have access to clean cooking fuels does not mean that they can afford to

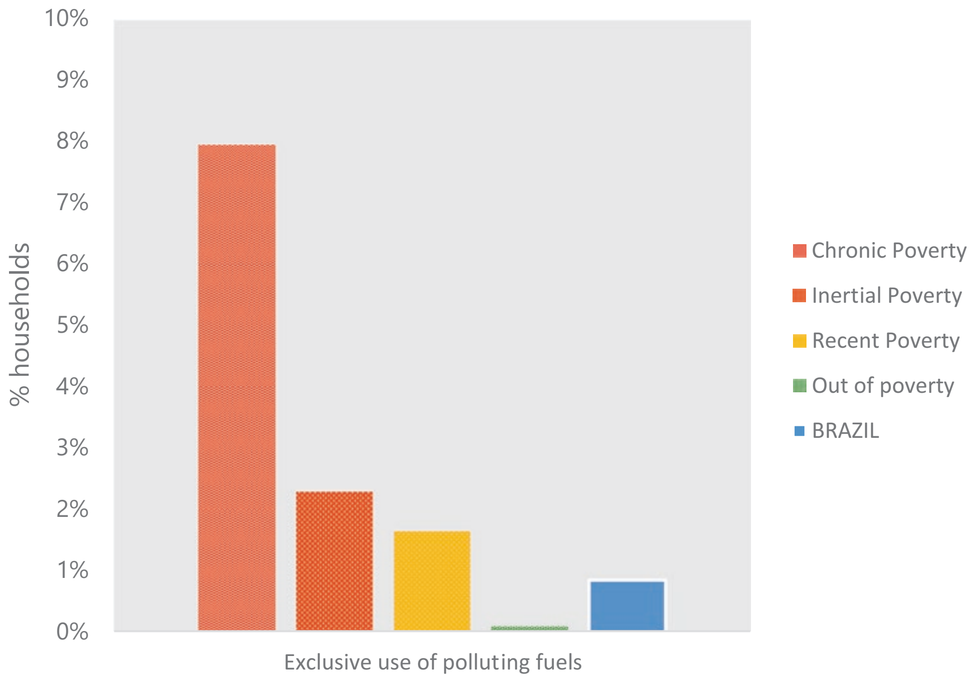


Fig. 18.6 Exclusive access to clean and polluting cooking fuels in Brazil from a social position. (Source: Authors with data obtained from IBGE, 2018)

use these resources. Thus, in order to analyze the impact of energy on household income, we analyzed energy expenditure using the four social groups under analysis, considering the energy expenditures as follows:

- Electricity
- Piped gas
- Bottled gas
- Kerosene (household consumption)
- Ethanol (household consumption)
- Diesel (household consumption)
- Coal (household consumption)
- Wood (household consumption)
- Gasoline (household consumption)

Figure 18.7 illustrates the energy expenditure to household income ratio in a boxplot. With respect to households out of poverty, the median expenditure on energy over the family budget is low because of the higher income of these households and because of the higher levels of efficiency of their equipment. The same applies to households in recent poverty, given their lower income; it is reasonable that their median ratio is significantly higher than the others, at around 14%. In addition, their equipment is likely less efficient than that of the higher-income groups, which could lead to higher consumption.

These results confirm our first and second hypotheses. Since many countries and authors measure energy poverty based on the 10% threshold defined by Brenda Boardman, it is interesting to note that the recent poor would most likely be those determined as energy-poor. However, the same does not apply to households in inertial poverty, whose median ratio expenditure is below 5% of their income. In addition to the fact that these people are not economically vulnerable, it is reasonable to assume that the low value for people in inertial poverty correlates to the fact that they are not meeting all their energy needs. These differences between inertial and recent poverty are particularly interesting when we consider that the latter is clearly more affected by a lack of access to energy; therefore, they are the most vulnerable and inclined to consume solid fuels in their cooking practices.

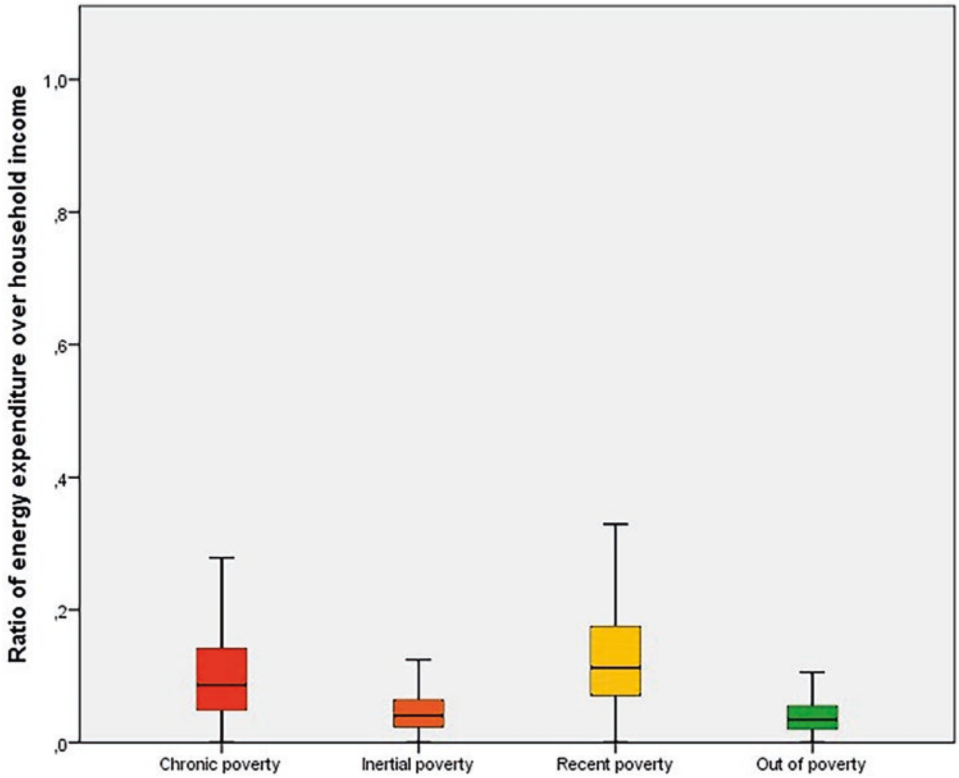


Fig. 18.7 Ratio of energy expenditure over household income. (Source: Authors with data obtained from IBGE, 2018)

Table 18.5 Households' difficulty to afford energy

	Chronic poverty	Inertial poverty	Recent poverty	Out of poverty
In the 12-month reference period, the percentage of households with delayed payment of water, electricity, or gas for reasons of financial difficulty	53.5%	35.2%	58.8%	29.8%

Source: Authors with data obtained from IBGE (2018)

The most unexpected result of this exercise was in regard to the energy consumption of people in chronic poverty. While this group is economically vulnerable, they are also more socially vulnerable, as they do not meet all their critical needs. It was expected that these people would also have difficulty meeting all their energy needs, but the median consumption over family income was close to 10%, which illustrates the impact that energy can have on the most vulnerable families. Furthermore, the fact that the median ratio was below 10% also shows how the use of absolute thresholds for measuring energy poverty can mask some vulnerability indicators and cause the energy experience of some people to be overlooked, given that less access to energy and lower consumption corresponds to lower impacts on the tariff.

These analyses correlate to the difficulties of paying energy bills as described by the residents of these households. As illustrated in Table 18.5, people in recent poverty find the most difficulty in paying their bills, followed by those in chronic poverty.

Regarding the effects of the consumption of the different energy sources on the total energy consumption of the households, it is clear that the consumption profile differs greatly among the different social strata under analysis (see

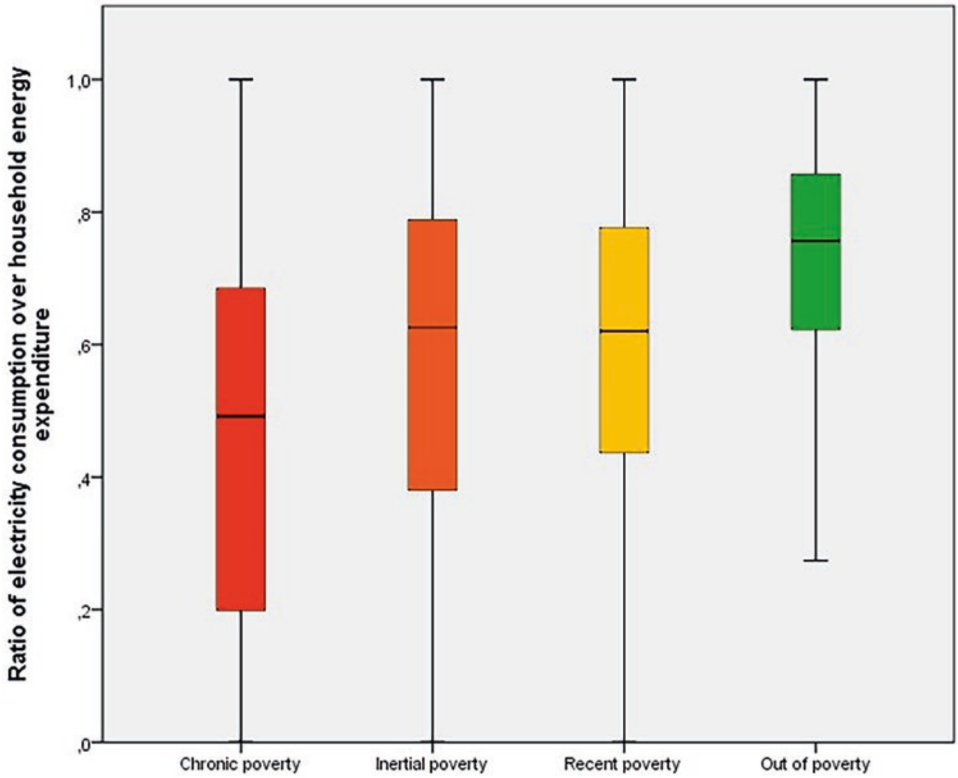


Fig. 18.8 Ratio of electricity consumption over household energy expenditure. (Source: Authors with data obtained from IBGE, 2018)

Fig. 18.8). While electricity consumption represents the largest share of energy consumption in socially integrated households, the consumption of LPG has an important weight in the lowest-income and most vulnerable households (see Fig. 18.9). This finding allows us to conclude that studies related to energy poverty in Brazil should prioritize the analysis of energy sources for cooking, since these are not only strongly related to human health but also affect the budget spending of the most vulnerable households.

18.7 Conclusion

Bridging energy poverty with the poverty debate, this study has raised important reflections that should be considered when addressing the energy poverty issue in the context of SDGs in developing countries, since energy poverty contributes to the increase of poverty and other inequalities that perpetuate poverty and resource scarcity. The success of SDG 7 is a transversal goal and a precondition for the success of other SDGs. For example, objectives such as no poverty (SDG 1) and the reduction of inequality (SDG 10) can be linked to the achievement of SDG 7.

First, this study has demonstrated that, in contrast to official reports, energy access is still a source of socio-spatialized inequality in Brazil given that those who lack access to electricity and most of those who have no access to clean cooking fuels do not meet their critical needs and/or live beneath the economic threshold required for proper social inclusion. This conclusion questions the value of the universalizing indicators of the sustainable development agenda, since they can omit socially and/or economically vulnerable people by masking their realities through the rounding of numbers or using a set of arbitrary priorities.

This situation was demonstrated in this study when the official indicator of access to clean cooking fuels was contrasted with the indicator of exclusive use of clean cooking

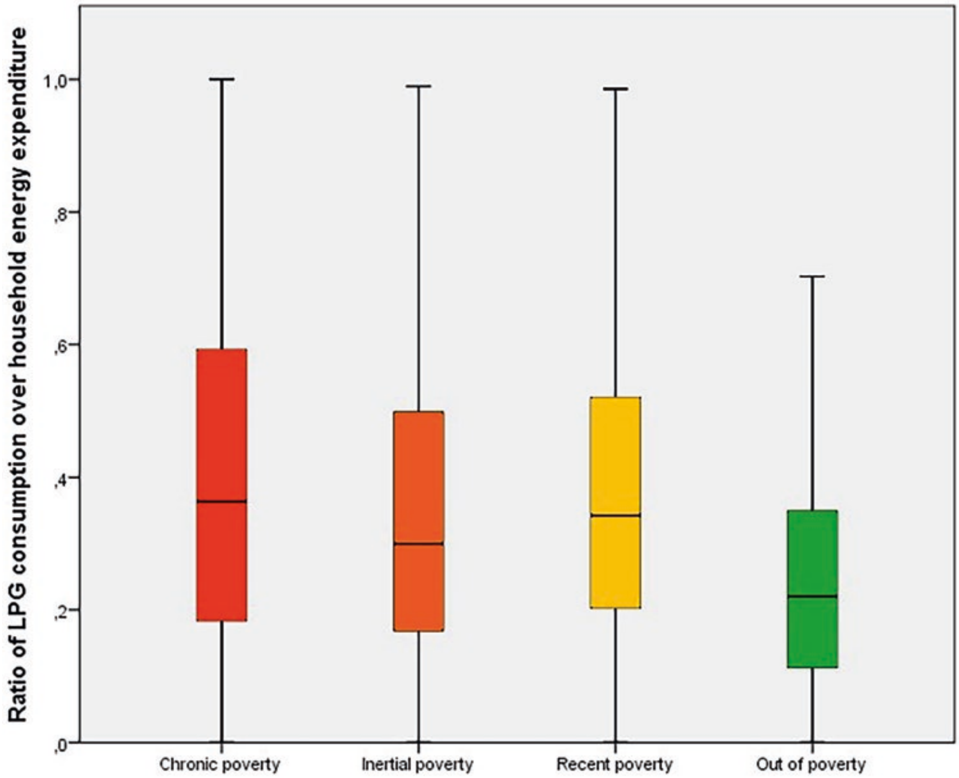


Fig. 18.9 Ratio of LPG consumption over household energy expenditure. (Source: Authors with data obtained from IBGE, 2018)

fuels, since only approximately 2% of Brazilian households lacked access to these fuels, while more than 20% did not use them exclusively. Ultimately, this result stresses the vulnerability of a considerable share of people to increasing prices of these fuels.

Second, our results demonstrate that energy policies aimed at subsidizing the energy consumption of Brazilian families must consider the marked differences between the social clusters analyzed in this study. According to our results, it is clear that electricity consumption affects the budget of families in chronic poverty and recent poverty, which implies that the analysis oriented toward monetary poverty allows us to identify those who urgently need a social tariff.[7] In addition, the results presented in this study allow us to conclude that the consumption of LPG, the main clean fuel used by Brazilian families in cooking practices, substantially compromises the income of families in chronic and recent poverty.

Third, with respect to energy poverty measurements, our results suggest that energy poverty should be taken as a multidimensional phenomenon that affects the vulnerability of the analyzed groups differently. For example, those in chronic and inertial poverty are more affected by access to energy; however, those in chronic and recent poverty are more vulnerable to consumption factors. Although these results are intuitive, they are not considered in some of the most common methods used to address and measure energy poverty, such as the 10% threshold proposed by Boardman (1991), the LIHC used in the UK (Hills, 2012), or the multidimensional indicator MEPI used worldwide (Nussbaumer

[7]Social tariff is the name provided to the subsidy offered to low-income families in Brazil with respect to their electricity consumption.

et al., 2012). In other words, biophysical indicators used to assess and measure energy poverty may overshadow the energy experience of the recently and chronically poor, who show difficulty in covering energy costs. Similarly, monetary indicators may overlook those who suffer from inertial and chronic poverty. Finally, multidimensional indicators may ignore people in recent and inertial poverty and identify only those with combined vulnerabilities, that is, the chronically poor. This result demonstrates the importance of awareness of the limitations of energy poverty measurements prior to using them. The outcomes may distort the debate, given that these socially vulnerable groups need to be specifically targeted in energy poverty eradication policies.

Considering that 4% of Brazilian households were categorized as chronically poor, which means that they endured a cycle of poverty that included that of energy requirements, there is an urgent need to prioritize their vulnerability, through the recognition of energy poverty in Brazil and the relationship between Sustainable Development Goals 1 and 7 (to end poverty and to ensure access to affordable, reliable, sustainable, and modern energy for all, respectively). Considering that the lack of access to energy is both a determinant and a consequence of poverty, the required policies must apply to the intersection of the goals. Therefore, recognizing those in poverty equates to identifying those considered energy-poor, thereby supporting the country to meet theSDGs.

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19 Energy Inequality in Central America: Concept, Challenge, and Opportunities

Lenin Mondol López

19.1 Introduction

Globally, the exponential increase in daily energy demand during 2019 reached an average per capita consumption of 60 kWh, far exceeding the 3.5 kWh of minimum energy required to cover the basic needs of vital reproduction. Consequently, this reflects a disproportionate increase in energy consumption that can only be justified by an inequality in the redistribution of the energy produced.[1]

This increase and unequal energy consumption of the richest quintile of the population accentuate other socioeconomic inequalities and directly affect the quality of life of the rest of the population[2] since it generates an abrupt impact on climate change given the use of unclean energies (CEPAL, 2021, p. 16).

In this sense, countries with environmental policy agendas have directed efforts to improve access and quality of energy sources by promoting the use of renewable energies, such as hydroelectric, wind, and solar.

However, the participation of these energies in the general matrix of energy consumption is still minimal since the use of nonrenewable sources and higher pollution worldwide continue at more than 90%.[3]

A more selective look at energy inequality also allows us to observe important variations between the so-called developed countries and those known as developing or poor countries. In the most vulnerable economic regions, nearly two billion people still use traditional fuels to meet daily energy needs, and more than 1.4 billion still do not have access to electricity (Nguyen et al., 2019, p. 1).

For the specific case of the Central American region, which is one of the most unequal economic and social regions in Latin America, the increase in energy access and consumption is associated with a differentiated production and distribution of it within each of the countries. Energy vulnerability persists in rural regions with a demographic majority of indigenous population. This means that there are territories marked by a historical state of neglect that results in a structural disparity.

Although it is also true that there is a regional effort to move toward cleaner and better-quality energies, in the last two decades,

[1] It is estimated that the richest 20% of the world's population consume 80% of energy resources.

[2] As it has been shown, the lowest-income quintiles end up using the vast majority of biomass and solid fuels.

[3] An example of this is the growth in the production and consumption of natural gas. In 2018, this variation was more than 5%.

L. Mondol López (✉)
Universidad Estatal a Distancia de Costa Rica, San José, Costa Rica
e-mail: lmondol@uned.ac.cr

L. L. B. Lazaro, E. Serrani (eds.), *Energy Transitions in Latin America*, Sustainable Development Goals Series, https://doi.org/10.1007/978-3-031-37476-0_19

the expansion of electricity coverage based on the use of clean sources and the promotion of projects to address the unfair distribution of energy have been a highlighted point on national policy agendas.

Energy inequality in Central America, usually addressed as a secondary issue to energy poverty, has been limited to contextual studies with little or no deepening of its thematic autonomy. In addition to this, there is a lack of studies that analyze regional integration articulated with the expansion of the energy market as a significant factor in the reduction of energy inequality.

This chapter seeks to contribute in this direction; therefore, it has delimited its central research questions in the following: (i) How do the main energy matrices differ between the Central American countries? And how does energy inequality vary depending on the economic sectors in each of them? (ii) Has the type of energy inequality changed in the Central American region?

Preliminarily, we can say that there is a significant decrease in energy inequality among Central American countries as a result of various factors. First, there is a greater convergence in the productive matrix with emphasis on increasing energy demand in the industrial and residential sectors. Also, the incorporation of targeted policy actions (at the regional and country levels) aimed at greater production and consumption of clean and renewable energy and greater commercial exchange of electrical energy throughout the region have weighted in. However, as we stressed earlier, inequalities associated with factors of spatial distribution (rural-urban) and ethnic segregation of social and economic development processes persist.

This chapter is organized as follows: Sect. 19.2 addresses aspects related to the theoretical approach of the study, as well as the referencing of related studies; Sect. 19.3 shows the main contextual background of energy development in Central America; Sect. 19.4 lists the main components of the methodological approach; and Sect. 19.5 presents the main results and findings. Finally, Sect. 19.6 specifies the main conclusions and recommendations of this chapter.

19.2 Theoretical Approach and References

The notion of energy inequality is used in reference to the variation in per capita energy consumption between different countries and regions in the world (Tirado Herrero et al., 2016, p. 77).

Even though the economic assumption of energy inequality directly associates energy inequality with an increase or decrease in income, studies show that this relationship is not always proportional. It has been observed that households with family monetary income above the poverty line may be in a marked situation of energy poverty (Tirado Herrero et al., 2016, p. 16).

On the other hand, energy inequality varies according to sociohistorical, economic, and territorial conditions between countries that may even share the same region. Inequity can be observed not only in access to energy but also in the gap to quality energy.

This last distinction is what has marked the latest studies on the subject. As the Economic Commission for Latin America and the Caribbean (ECLAC) points out, energy inequality has been addressed, fundamentally, from two perspectives at a theoretical-methodological level (Calvo et al., 2021, p. 8).

The first of these is the Price-Income Inequality Approach. From this point of view, access to energy services will be marked by a monetary gap directly associated with family economic income in relation to the market prices of the various energy sources. As a consequence, prices quantitatively mark the costs of family access to energy services.

The second approach emphasizes more on the relationship between access to energy and its quality. The fluidity of the energy service, its efficient use for environmental comfort according to climatic region, and the reduction in the risk of pollution due to energy use are some of the main indicators that are weighted when establishing a comparison of inequality (Calvo et al., 2021, p. 8).

On the other hand, it is important to point out that in the framework of capitalist economic development, energy vulnerability and its consequence in terms of inequality is not associated with a linear transition from the use of traditional sources to sources known as modern (as indicated by the linear model of the Energy Ladder). Actually, it refers to a mix of energy uses whose marginal cost derived from one type of energy to another, and it marks an energy inequality between different sectors (Han et al., 2018, p. 235).

This unequal and combined development and use of energy resources are also reflected in the modes of integration at the subregional level. Although the opening of markets has allowed the expansion of the energy matrix available for each of the countries, it is not a guarantee of a greater convergence to energy access with higher quality and environmental sustainability. This happens mainly because the access criteria are guaranteed by a price system.

19.2.1 Research References

The Latin American literature that accounts for studies on energy inequality is usually associated with issues of energy poverty or energy transition and dealing with the issue of energy inequality as a direct consequence of socioeconomic inequality (Borbolla-Gaxiola & Ávila-Ramírez, 2021).

At the regional level, an exception to the rule has been the research carried out by academics Shonali Pachauri et al. (2018), who specifically address the issue of energy inequality from simulation models on future dependence on fossil fuels for cooking in Guatemala, Honduras, and Nicaragua. They found out that income growth in the urban population is a determining factor of energetic convergence (Pachauri et al., 2018).

In a different latitude, the case study presented by economists Trung Thanh Nguyen, Thanh-Tung Nguyen, Viet-Ngu Hoang, and Clevo Wilson is a reference for this study as it analytically addresses the difference between income and consumption inequality in relation to energy inequality in Vietnam. Based on the analysis of data on residential energy for the period 2004–2016 in about 9000 homes, the researchers conclude that the energy demands in electricity tend to be increasingly equal, reflecting a fall in energy inequality at a rate greater than of income inequality (Nguyen et al., 2019).

Likewise, a direct reference for the methodological approach in the measurement of energy inequality is the study entitled "Inequalities by energy sources: An assessment of environmental quality" by Xin Yao, Rizwana Yasmeen, Ihstsham UI Haq Padda, Wasi UI Hassan Shah, and Muhammad Abdul Kamal. In the same paper, the authors analyze energy inequality between various subregions of the world, using the Theil Inequality Index, recognizing a divergence from the growth in energy demand and weighing the central role of market opening in the reduction of these inequalities (Yao et al., 2020).

19.3 Context

19.3.1 The Central American Energy Matrix

In 2021, the absorption of energy in Central America came from power plants (56%), thermal plants (23%), wind and solar generation (12%), and geothermal generation (8%) channeling a total of 55737.8 GWh (EOR, 2021, p. 88).

Regarding the use of imported fossil fuels, variations can be observed according to the type of energy matrix of each country. In the case of Costa Rica and Nicaragua, the demand for these fuels represented 51%, 74% for El Salvador, 52% for Honduras, and 38% for Guatemala.[4]

In the use of the so-called modern energies (hydrocarbons and electricity), El Salvador (90%) and Costa Rica (86%) stand out, while in the use and consumption of traditional energies – such as firewood – countries such as Guatemala (57%), Honduras (41%), and Nicaragua (39%) stand out (CEPAL, 2020, p. 60).

Particularly, in these last three countries, most of the biomass consumption is concentrated and used by about 16 million people for heating,

[4]This is according to the data from the Sistema de Información Económica Energética (SIEE) of the Organización Latinoamericana de Energía (OLADE).

cooking food, and in some cases for craft industries (CEPAL, 2020, p. 35).

When disaggregating the participation of each of the five countries based on energy absorption, differences are distinguished in the use of energy according to the energy matrix (see Table 19.1).

In 2021, more than 72% of the energy used by Costa Rica was hydroelectric, 61.2% in Guatemala, 37% in Honduras, and about 44.6% in El Salvador. For the cases of Nicaragua and Honduras (two of the countries with the lowest per capita income in the region), the use of energy was concentrated in Thermal, with a demand of 57.4% and 37.7%, respectively.

At the level of the entire region, Guatemala, Honduras, and Costa Rica account for more than 80% of energy requirements.

19.3.2 Energy Exchange

In the energy trade balance, the Costa Rican energy matrix is the one with the greatest export potential in the region, followed by Guatemala (EOR, 2021, p. 74).

El Salvador, Honduras, and Nicaragua are more dependent on net energy imports (see Table 19.2).

There are also variations between countries in terms of energy exchanges between them. As expected, the largest transactions are carried out through interconnections between neighboring countries.

Energy imports from the Salvadoran system are carried out in a proportion of 69% with Guatemala, and its exports are directed to a greater extent to the Honduran system (EOR, 2021, p. 55).

For their part, Honduras and Nicaragua are the main importers of energy in the region. Honduras trades mainly with Guatemala, Nicaragua, and El Salvador. The total relative weight of energy imports from the Honduran system with respect to El Salvador is 89%. In the Nicaraguan case, almost 98% of energy import exchanges come from Costa Rica (EOR, 2021, pp. 60–67).

Costa Rica exports energy to Nicaragua and Panama. Its imports come mainly from Panama.

Guatemala has stationary exchanges (depending on the presence or absence of rain) through the interconnections with El Salvador and Honduras, being El Salvador with whom it maintains a greater energy trade flow (EOR, 2021, p. 47).

The high degree of energy integration has meant that, in the last decade, the marginal costs for energy supply have decreased significantly in the Region. The Costa Rican case stands out among them, with average values of US$ 10.44 per MWh in 2021.

19.3.3 Use of Renewable Energies

Central American energy matrices continue to depend on fossil fuels. According to CEPAL data, the greatest dependency is in El Salvador (74%) and Honduras (52%) (CEPAL, 2020, p. 57).

However, hydroelectric, wind, and solar photovoltaic generation has been gaining ground throughout the region (see Table 19.3). An example of this is the three renewable

Table 19.1 Central America: energy use according to each country

Country	Hydroelectric (GWh)	Wind/solar (GWh)	Geothermal (GWh)	Thermal (GWh)	Total (GWh)
Costa Rica	9303.99	1758.11	1671.29	93.76	12827.15
El Salvador	2228.08	674.02	1477.01	616.99	4996.1
Honduras	3748.14	2316.79	260.61	3825.33	10150.87
Nicaragua	425.77	863.8	207.31	2016.33	3513.21
Guatemala	7203.85	428.69	266.97	3862.71	11762.22
Total	22909.83	6041.41	3883.19	10415.12	43249.55

Source: Elaborated by the author based on Informe Económico Regional 2018–2019 SIECA (2020)

Table 19.2 Central America: imports and exports of energy

Country	Imports (GWh)	Exports (GWh)
Costa Rica	227.73	1235.36
El Salvador	1127.05	138.67
Honduras	383.67	559.21
Nicaragua	1051.33	37.62
Guatemala	406.09	606.33

Source: Elaborated by the author based on Informe Económico Regional 2018–2019 SIECA (2020)

Table 19.3 Central America: renewable energy generation. 2020

País	Hydro-electric (TWh)	Wind (TWh)	Solar (TWh)	Others including bioenergy (TWh)	Total
Costa Rica	8.29	1.46	0.06	1.71	11.52
El Salvador	1.99	0	0.5	2.15	4.64
Guatemala	5.77	0.31	0.21	2.23	8.52
Honduras	2.7	0.82	1.12	1.23	5.87
Nicaragua	0.57	0.73	0.02	1.31	2.63
Total	19.32	3.32	1.91	8.63	33.18

Source: Elaborated by the author based on Our World in Data (OWiD), 2022. https://ourworldindata.org/

energy projects in El Salvador that begun operations in 2020. They are the Ventus wind plant and the Penonomé1 and Penonomé 2 solar plants.

19.4 Methodological Approach

For the analysis of energy inequality, the Central American region, comprised of the countries of Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica, has been used as the reference unit.

Likewise, the comparison of the energy demand of each country in relation to the per capita income, as well as the historical disparities in energy consumption between countries (disaggregated into its main sectors of economic activity), allows establishing indicators of inequality. For comparative purposes, the series were limited to the period 2000–2019.

19.4.1 Energy Inequality Index

As a main indicator of change, a quantitative approach of energy inequality in Central America is employed from the use of TheIL's inequality index, which allows observations in energy consumption. The index establishes a temporary image of inequality between countries in the Central American region, as well as the difference between the internal economic activities of each country according to energy consumption.

The calculation of the participation in consumption by energy source for each country was obtained as follows:

$$E_{s,it} \tag{19.1}$$

where

t: time (annual) = 1,2,3…t
i: umpteenth country = 1,2,3… N

Since E_S corresponds to the share in energy consumption by source, where $E_{s,it}$ represents the energy consumption of the source "s" of the country i, in the year "t," we found that the total consumption of energy from source "s" for all countries "N" during years "t" is calculated as follows:

$$\sum\nolimits_{i=1}^{N} E_{s,it} \tag{19.2}$$

The proportion of a country in the total energy consumption in relation to the region (block of countries) would be given by

$$e_{s,t} = \frac{E_{s,it}}{\sum\nolimits_{i=1}^{N} E_{s,it}} \tag{19.3}$$

Likewise, the calculation of the population participation of a country in relation to the whole of the entire population of the region, in the year "t," is calculated as follows:

$$p_t = \frac{p_{it}}{\sum\nolimits_{i=1}^{N} P_{it}} \tag{19.4}$$

where "N" is the set of countries and "t" is the time in years.

In this formula p_{it} corresponds to the population of the country "i" for the year "t," and P_{it} indicates the total population of the entire region.

Finally, the measurement of inequality in energy consumption (coming from "s" type of energy) can be quantified through an index that indicates convergence or divergence of the economies.

$$CE = \sum_{i=1}^{N} e_{s,it} \ln\left(\frac{e_{s,it}}{p_{it}}\right) \tag{19.5}$$

19.4.2 Data

Official information by country and at the regional level was used, corresponding to development and population indicators from the World Bank's World Development Indicators database. For data on electricity and renewable energy consumption, information provided by the International Energy Agency (IEA), the Organización Latinoamericana de Energía (OLADE), the Comisión Económica para América Latina y el Caribe (CEPAL), and Ente Operador Regional del Mercado Eléctrico de América Central (EOR) were systematized.

Some of the data was verified through reports from Secretaría de Estado en Despacho de Energía (Honduras), Empresa Nacional de Transmisión Eléctrica de Nicaragua (ENATREL), the Ministerio de Energías y Minas de Guatemala (MIEM), and the Secretaría de Integración Económica Centroamericana (SIECA).

As we have mentioned, in order to obtain comparative time periods, in some cases the analysis was restricted to the period 2000–2019.

Finally, all indicators were disaggregated for each of the following countries: Costa Rica, El Salvador, Honduras, Nicaragua, and Guatemala.

19.5 Results

The main results obtained in relation to inequality in electricity consumption and access to electricity at the regional and country levels are briefly presented below.

Likewise, the issue of social segregation and its relationship with energy inequality in Central America is addressed. As we will see, the conditions for the reproduction of said inequality are structurally configured and focused by state action and the participation of actors in the energy market.

19.5.1 Inequality in Electricity Consumption

In order to observe the behavior of energy inequality in Central America, we base ourselves on the variation in electricity consumption of the five countries under study for the period 2000–2019.

From the calculation of an inequality index, a decrease in the energy gap at the regional level is observed. As Fig. 19.1 shows, there is a continuous decrease that converges in the year 2019 where the estimated inequality difference is 1.7. The change observed in relation to the year 2000, where the Energy Inequality Index (IDE) averaged 2.1 for the entire region, denotes an important effort for equity in energy policy.

Likewise, it is observed that the percentage variation in electricity consumption is positive for all countries, although with a greater weight in Nicaragua (+200%), Honduras (+115%), and Guatemala (+179%). The variation in Nicaragua should be highlighted since it is a country that went from a consumption of 4451 to 13368 Terajoules (Tj) per year. Similarly, the variation in Costa Rica and El Salvador meant important percentage changes, 76% and 78%, respectively.

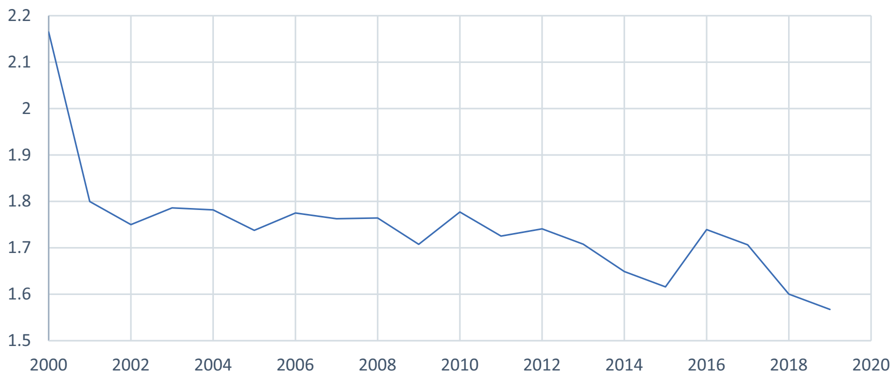

Fig. 19.1 Central America: inequality in electricity consumption. (Source: Elaborated by the author based on Organización Latinoamericana de Energía (OLADE), 2022. www.olade.org)

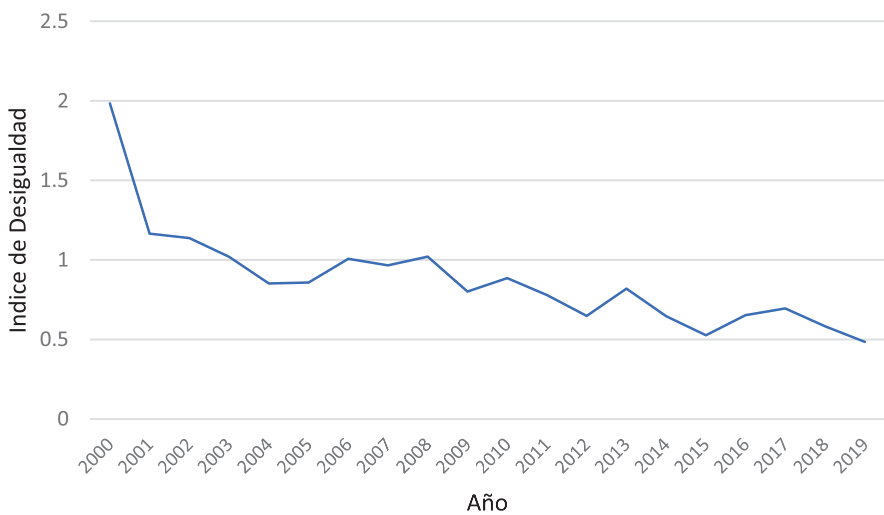

Fig. 19.2 Central America: inequality in electricity consumption in the industrial sector. Period 2000–2019. (Source: Elaborated by the author based on Organización Latinoamericana de Energía (OLADE), 2022. www.olade.org)

When differentiating energy inequality in economic sectors for the entire region, it is observed that the greatest relative weight of the change occurred due to consumption in the industrial and residential sectors (see Figs. 19.2 and 19.3).

The increase in industrial electricity consumption by Honduras and Guatemala for the period 2000–2019 was 157% and 173%, respectively, while Costa Rica (36%) and El Salvador (30%) showed a much smaller increase.

For the industrial sector, the decrease in energy inequality in the region was reflected in the drop in the IDE, which went from 1.98 to 0.48.

At the level of residential electricity consumption, the greatest variation in the period 2000–2019 was registered by Nicaragua with an increase of 186%, going from an annual consumption of 1577 *Tj* to 4518 *Tj*. Another country that exponentially increased its consumption was Guatemala, from 4990 *Tj* to 13488 *Tj*.

The increase in electricity consumption in Honduras was 72%, while El Salvador and Costa Rica registered 50% and 56%, respectively.

At a general level, there is a drop in the IDE in Central America in relation to residential energy consumption, going from 2.63 to 1.83.

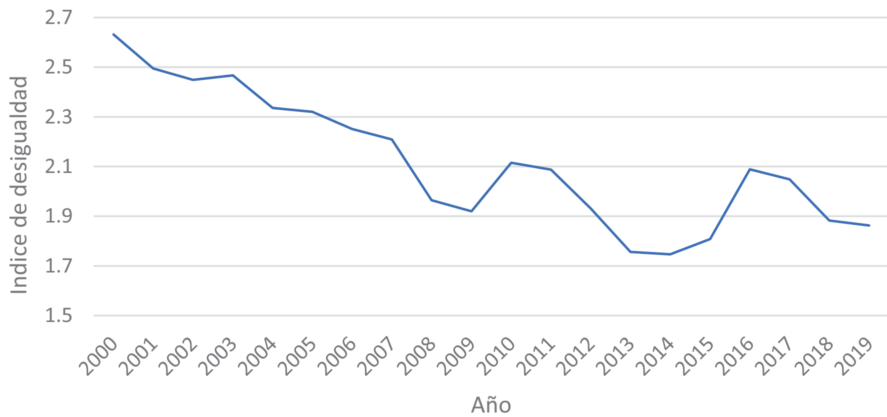

Fig. 19.3 Central America: inequality in electricity consumption in the residential sector. Period 2000–2019. (Source: Elaborated by the author based on Organización Latinoamericana de Energía (OLADE), 2022. www.olade.org)

As can be inferred, the greater variability that explains a lower rate of energy inequality in the region for the period 2000–2019 is established by changes in the industrial sector and to a lesser extent (although with important variations) in the residential sector.

The sustained and proportional variation in electricity consumption for service activities (commercial and public) of all Central American countries for the period 2000–2019 shows a relatively low-energy inequality index. In temporal terms, this variation is reflected in a minimum change of 0.08 in the IDE.

In the agricultural sector, the high ratings of inequality in the consumption of electrical energy are fundamentally explained by the high internal weighting, which is generated by the absence of electrical energy usage in the said sector by countries such as Guatemala and Honduras. Furthermore, El Salvador does not report electrical energy demand for agricultural activity during 2012.

19.5.2 Inequality in Access to Electricity

A preponderant factor in the measurement of energy inequality is the weight of vulnerability due to structural conditions of access.

For the period 2001–2019, all Central American countries, with the exception of Costa Rica, drastically increase their electricity access indicators. For example, Honduras increases its access by more than 28 percentage points, Guatemala does so by 22 points, Nicaragua by 16 points, and finally El Salvador goes from coverage with access to electricity of 87% in 2001 to 100% in 2019.

As shown by the relative trajectory of the population with access to electricity in Fig. 19.4, the increase in access is a continuous and persistent indicator.

In 2001, only 73.5% of the Central American population had access to electricity. The maximum access value of a country is 98.2% of the Costa Rican population and a minimum access value of 64.2% corresponding to the Honduran population.

These maximum and minimum access values tend to present a smaller and smaller gap. ~~For the year~~In 2019, El Salvador reports 100% access to electricity, and the minimum percentage of access to electricity by a country corresponds to 88.2% of the Nicaraguan population.

In general terms, this increase in access to electricity services in the region is attributed to continuous investment and expansion of infrastructure, as well as a growing policy of energy exchange given a greater opening of the market during the last 20 years.

Another important indicator is the relationship between per capita income per country and access to electricity, which makes it possible to account

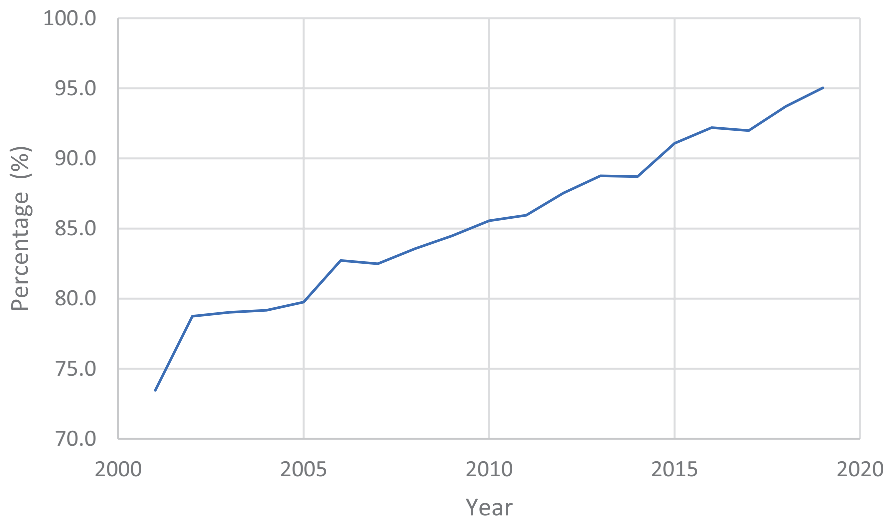

Fig. 19.4 Central America: population with access to electricity (%). Period 2000–2019. (Source: Elaborated by the author based on "Access to electricity" World Development Indicators. The World Bank Group, 2022. https://datos.bancomundial.org/indicador/EG.ELC.ACCS.ZS?view=chart)

for a structural decrease in energy inequality in the region.

Although there is a clear relationship between the increase in economic material well-being and the access to electricity, it can be observed for the Central American case that the access conditions for all countries were high, regardless of the gaps in their nominal per capita income (see Fig. 19.5).

This suggests that the redistribution factor tends to be more decisive in reducing energy inequality than the "spillover" effect of economic growth.

It should be noted that in the case of Costa Rica, the income gap tends to be reflected not only in access to electricity but also in the environmental quality of said consumption given its energy matrix.

The difference between Costa Rica and other countries such as El Salvador or Guatemala, which have access to electricity greater than 90%, lies in the fact that Costa Rica has configured a consumption based on renewable energy.

As can be seen in Fig. 19.6, the participation of renewable energies in electricity generation is close to 100% in Costa Rica.

19.5.3 Social Segregation and Energy Inequality

When the Central American energy panorama is analyzed in some detail, a clear correspondence is observed between inequality-energy poverty, rurality, socioeconomic development, and ethnic sociocultural origin of the population.

In the Guatemalan case, the greatest energy inequality is clearly defined in the departments with the lowest human development index and the greatest multidimensional poverty: Alta Verapaz, Huehuetenango, Izabal, Petén (mainly in the south), and Quiché.

All these departments have little access to electricity, a high dependence on firewood to cover basic energy needs (space heating, cooking food, home heating),[5] and a high percentage of the population have Mayan or Garífuna indigenous origin (MIEM, 2020, pp. 47–48).[6]

[5]In 2018, the Population and Housing Census indicates the department of Huehuetenango with the highest per capita demand for firewood for energy use.

[6]According to the Indicative Plan for Rural Electrification 2020–2032, 64.1% of the population of the department of Alta Verapaz, with a majority of the Mayan indigenous population, does not have access to electricity.

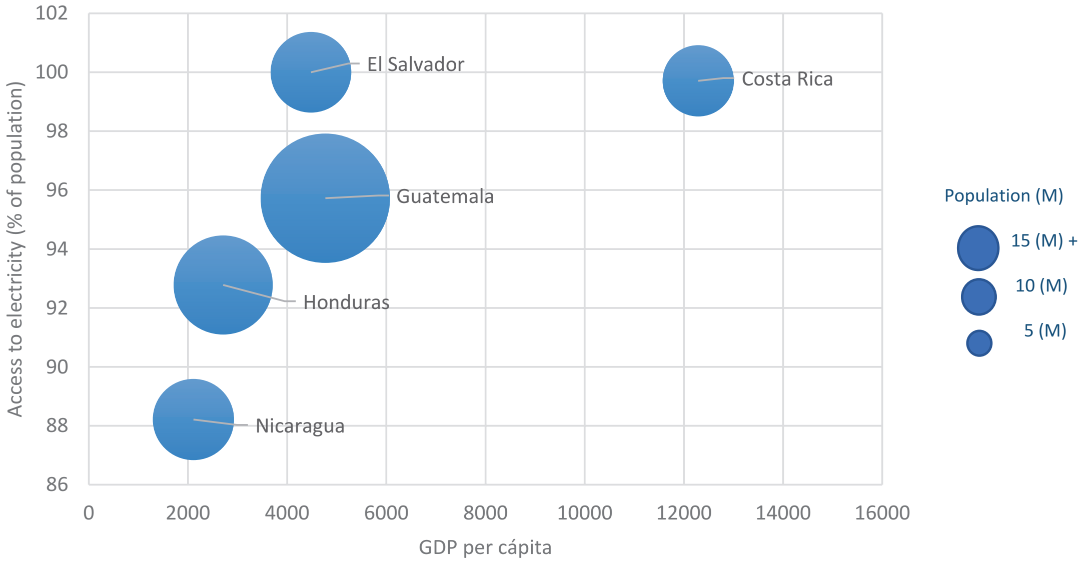

Fig. 19.5 Central America: access to electricity versus GDP per capita. 2021. (Source: Elaborated by the author based on "Access to electricity" World Development Indicators. The World Bank Group, 2022. https://datos.bancomundial.org/indicador/EG.ELC.ACCS.ZS?view=chart)

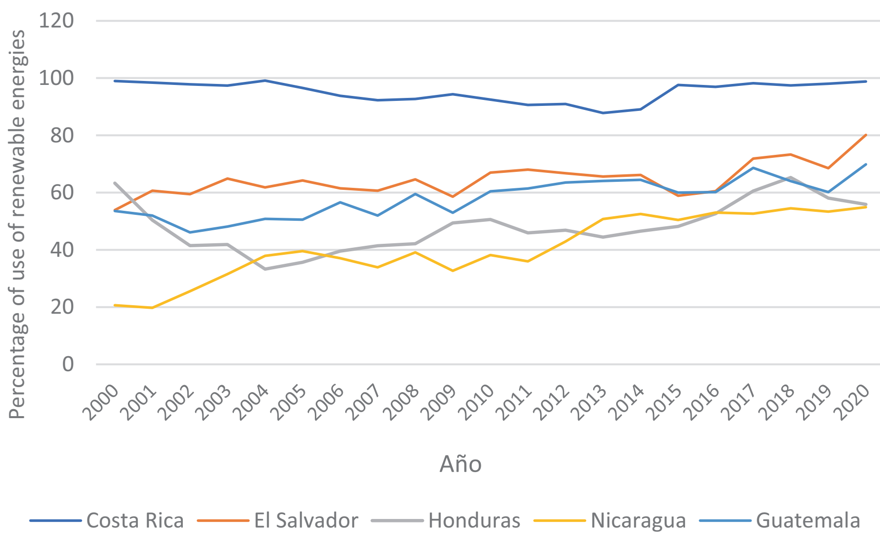

Fig. 19.6 Central America: participation of renewable energies in the available supply of electricity. (Source: Elaborated by the author based on "Renewable Electricity Production" World Development Indicators. The World Bank Group, 2022. https://datos.bancomundial.org/indicador/EG.ELC.RNEW.ZS)

Similarly, in Honduras there is a correspondence between energy vulnerability and socio-economic demographic-ethnic characteristics. The departments of Gracias a Dios and Olancho, whose majority of the population belongs to indigenous groups (Tawacas, Pehs/Payas, and Miskitus), have the least access to electricity (SEN, 2020, p. 4).[7]

[7] In 2016, the electricity coverage of the department of Gracias a Dios was the lowest in the country with 45.2% and Olancho with an index of less than 70%.

The Nicaraguan Atlantic coast, in the departments of the North Atlantic Autonomous Region (RAAN) and the South Atlantic Autonomous Region (RAAS), has the same profile described in the previous Central American departments. In these departments of the Nicaraguan Atlantic there is an electrical coverage that barely reaches 50% or less. In addition, there is a major presence of indigenous population (Miskitu; Sumo/Mayangna; and Rama) and Afro-descendant population (Garífuna and Creole).

In Costa Rica, although there is a historical minimum number of the population without access to electricity, a vast concentration of it is observed in the poorest regions of the country: Huetar Caribe, with the presence of the Bribri and Cabécar indigenous population, and the Huetar Norte region.

19.5.4 State Response with Targeting and Incorporation of Private Actors

The state has faced with these socio-spatial configurations, which are characterized by significant energy vulnerability. And its response has been segregated and focused. In fact, the participation of the private sector as a provider of clean energy has been incorporated in some cases.

In Honduras as in Nicaragua, part of the strategy to mitigate energy inequality has been the implementation of programs based on photovoltaic electrification with solar energy. These measures have made it possible to provide a short-term response and to save part of the investment costs involved in an adequate electricity network infrastructure.[8]

Furthermore, in Nicaragua, the National Program for Sustainable Electrification and Renewable Energies (PNESER) is in charge of the rural electrification policy based on the Electrification Project through Home Solar Panels.

Another mechanism adopted by the governments of the Central American countries has been the generation of state subsidies in rates with a maximum of electricity consumption. In the Honduran case, the subsidies are established from the Fondo Hondureño de Inversión Social (FHIS) that supports the Proyecto de Infraestructura Rural (SEN, 2020, p. 39), while for Nicaragua it is the Instituto de Desarrollo Nicaragüense that is responsible for guiding and assigning subsidy measures in the energy bill (Gámez, 9 Feb. 2021).

Likewise, the governments have also incorporated private actors for the generation of photovoltaic electricity in response to the energy vulnerability of depressed regions.

Particularly, in Honduras this participation began in the early 1990s with the US company ENERSOL Associates Inc. and more recently in Nicaragua and Guatemala with the incorporation of the company Kingo Energy for the provision of prepaid solar energy services[9] (Singh, 29 dic 2021a).

In this same sense, the transfer of electricity distribution to the private sector by the Guatemalan government in 1996 with the General Electricity Law stands out along with the subsequent focus of energy policy on vulnerable sectors and the creation of the Rural Electrification Program.

At the regional level, there is also an integrated response that is oriented toward targeting energy inequality as an opportunity to expand and make the energy market more flexible.

In 2020, from the declaration called "Centroamérica unida contra el Coronavirus," the Secretaría General del Sistema de Integración Centroamericana (SICA), and CEPAL agree with the Plan Energético Regional in order to guarantee liquidity in the electricity markets. This took place through the attraction of loans aimed at

[8] The Nicaraguan government has implemented photovoltaic solar self-consumption projects on the Caribbean coast (north and south) and Río San Juan (El 19 Digital, 3 Feb. 2022).

[9] This company, which emerged in Guatemala, offers services through a daily, weekly, or monthly payment system, operating as mini-grids in rural regions with little electrical infrastructure.

energy development, which were granted by multilateral organizations. With this plan, it is possible to economically support the productive energy sector and to guarantee the supply.

19.6 Conclusions

In relation to energy inequality in the Central American region, it is observed that there is a decrease in it as a result of three factors: (a) There is a significant increase in the industrial and residential energy demand for electricity during the period 2000–2019. Also, there is a tendency to be higher in previously lagging countries such as Nicaragua, Honduras, and Guatemala. (b) The energy market integration processes initiated in 1999 with the Puebla-Panama Plan (subsequently the Mesoamerican Integration and Development Plan) have had a growing effect on energy interdependence, which in turn has expanded and improved the electricity supply to regional level. (c) The governments of the Central American countries have promoted electricity consumption based on clean energy as a subsequent mechanism that seeks to boost the energy market with the participation of the private sector.

Energy inequality in Central America has decreased thanks to the exponential increase in access to hydroelectric, thermal, and intermittent energy consumption, as well as the slowdown in the consumption of traditional energy (wood, biomass, among others). Nonetheless, a new type of inequality is confirmed: energy inequality due to environmental quality. The production and consumption of electricity based on renewable energies shows marked differences between the energy matrixes of the Central American countries, from which the Costa Rican one stands out.

Central American governments continue to use price-income inequality approaches to address the energy vulnerability suffered by regions historically segregated from access to modern energy for consumption. This commitment to nonuniversal policy actions tends to favor the participation of private companies in the clean energy market given its low cost and high profitability.

A population sector, which is characterized by living in rural areas and/or indigenous territories, persists in the Region. This sector has a higher level of energy vulnerability, too.

The decrease in energy inequality in Central America is partially associated with increases in per capita monetary income. It cannot be verified that there is an unequivocal causal relationship between a higher income and an increase in access to electricity consumption.

Annexes (Tables 19.4, 19.5, 19.6, 19.7, 19.8, 19.9, and 19.10)

Table 19.4 Central America: electricity consumption inequality index. Period 2000–2019

Year	Index of inequality of energy consumption (electricity)
2000	2.164742261
2001	1.799810656
2002	1.750061836
2003	1.785984603
2004	1.781703242
2005	1.737661851
2006	1.774955009
2007	1.762835762
2008	1.764308097
2009	1.707677269
2010	1.777169834
2011	1.725417899
2012	1.740957709
2013	1.707820874
2014	1.649024857
2015	1.615923025
2016	1.739209149
2017	1.706582872
2018	1.600465282
2019	1.567377647

Table 19.5 Central America: electricity consumption inequality index in the industry sector. Period 2000–2019

Year	Inequality of energy consumption in the industry sector (electricity)
2000	1.983528261
2001	1.165313502
2002	1.137271672
2003	1.01971848
2004	0.851969642
2005	0.85745755
2006	1.007434562
2007	0.966189714
2008	1.020246887
2009	0.801127557
2010	0.885798466
2011	0.779434917
2012	0.648397525
2013	0.819261392
2014	0.64583751
2015	0.526110783
2016	0.652450288
2017	0.695448663
2018	0.582718289
2019	0.484940671

Table 19.6 Central America: electricity consumption inequality index in the residential sector. Period 2000–2019

Year	Inequality of energy consumption in the residential sector (electricity)
2000	2.631762049
2001	2.494816875
2002	2.448686368
2003	2.467099834
2004	2.335992898
2005	2.320094122
2006	2.251060593
2007	2.209179926
2008	1.964217748
2009	1.919733634
2010	2.115295549
2011	2.087504231
2012	1.931341733
2013	1.756139664
2014	1.746682248
2015	1.807895277
2016	2.088591377
2017	2.048634636
2018	1.882434921
2019	1.86266316

Table 19.7 Central America: electricity consumption inequality index in the commercial and public services sector. Period 2000–2019

Year	Inequality of energy consumption in the commercial and public services sector (electricity)
2000	2.425496012
2001	1.9244214
2002	1.942366335
2003	1.981414417
2004	2.135856146
2005	2.298429064
2006	2.325498427
2007	2.449660343
2008	2.664856214
2009	2.92587765
2010	2.738960058
2011	2.747085482
2012	2.555773062
2013	2.632959883
2014	2.567333764
2015	2.52445909
2016	2.347936241
2017	2.228069823
2018	2.257656755
2019	2.344231773

Table 19.8 Central America: electricity consumption inequality index in the agricultural sector. Period 2000–2019

Year	Inequality of energy consumption in the agriculture sector (electricity)
2000	9.021174168
2001	9.190708727
2002	9.545936356
2003	9.657992306
2004	9.727954534
2005	10.01804323
2006	10.63453677
2007	10.8396215
2008	10.59061945
2009	10.13648589
2010	10.4285884
2011	10.20903294
2012	13.2770257
2013	13.52623224
2014	12.88607056
2015	12.44524464
2016	13.10370716
2017	13.45476008
2018	12.85477568
2019	12.88661139

Table 19.9 Central America: access to electricity. Period 2001–2019

Year	Population with access to electricity (%)
2001	73.45106996
2002	78.74639235
2003	79.02593163
2004	79.16208185
2005	79.75003216
2006	82.72254752
2007	82.48795439
2008	83.55996847
2009	84.48324124
2010	85.55382323
2011	85.94773412
2012	87.5302592
2013	88.75631239
2014	88.70395711
2015	91.08293763
2016	92.20082091
2017	91.98742356
2018	93.71385449
2019	95.04326823

Table 19.10 Central America: access to electricity versus nominal GDP per capita. 2021

Country	GDP nominal per capita (2021 $)	Access to electricity (% of population)	Population
Costa Rica	12290.0	99.7	5,047,561
El Salvador	4480.0	100.0	6,453,550
Honduras	2710.0	92.8	9,746,115
Nicaragua	2110.0	88.2	6,545,503
Guatemala	4770.0	95.7	16,604,026

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20 Considerations on Energy Planning Evolution, Energy Transition, and Sustainable Development Goals: Keynotes from Nicaragua

Flávia Mendes de Almeida Collaço
and Carlos Germán Meza González

20.1 Introduction

Primary notions of energy planning have been put into practice since the pre-industrial ages (see Crosby, 2006, and Burke, 2009). Nonetheless, before pre-industrial societies, the most important objectives of what we understand today as energy planning were to guarantee the availability of biomass (i.e., firewood and charcoal as fuels),[1] muscular power (i.e., food and pasture for animals and humans), and to direct the exploitation of intermittent energy fluxes (mainly wind power and waterpower) (Sieferle, 2001).

The industrial revolution (~200 years ago) marks the beginning of a unique era of rapid economic growth that extends until today (Kander et al., 2014). This economic growth has been made possible largely by increased consumption of energy, with the historical peculiarity that fossil fuels became the principal primary energy source (i.e., coal, oil, and natural gas) (Wrigley, 2013). Naturally, the burning of fossil fuels has so far implied an increase in anthropogenic greenhouse gas (GHG) emissions that are interfering with the biogeochemical cycles of the planet.

The abovementioned provides a historical context to understand the evolution of modern energy planning. Del Valle (1984 apud Bi, 2011) defined modern energy planning as a process that provides rational and systematic guidance for energy development. Bi (2011) added that it is a process of formulating, implementing, monitoring, and adapting energy policies and plans, based on current consumption patterns and existing policies, whose objective should be to promote the best option in terms of financial and environmental goals to satisfy energy demand and economic growth.

Methodologically speaking, one of the main features of energy planning is the extensive use of models as tools to design and propose energy systems (Nakata, 2004). Pfenninger et al. (2014) indicate that energy system models help planners understand their industry, which has grown in a complex way worldwide. In this sense, the models assist in proposing policies and decision-

[1]In fact, the origin of the term "Sustainability" is "Nachhaltigkeit" used by Hans Carl von Carlowitz (1713) in his exceptional treatise of forestry entitled "Sylvicultura oeconomica, oder haußwirthliche Nachricht und Naturmäßige Anweisung zur wilden Baum-Zucht."

F. M. de Almeida Collaço (✉)
Programa de Pós-graduação em Administração e Controladoria, Universidade Federal do Ceará e Instituto de Estudos Avançados, Universidade de São Paulo, São Paulo, Brazil

C. G. M. González
Universidad Americana (UAM) de Nicaragua y Centro de Análise, Planejamento e Desenvolvimento de Recursos Energéticos (CPLEN), Universidade de São Paulo, São Paulo, Brazil

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making. Through them, it is possible to build scenarios, understand, and even visualize the complex relationships between the various economic sectors and energy.

Nevertheless, energy modeling studies rarely develop a theoretical analysis of each kind of modeling approach (i.e., Adil & Ko, 2016; Bhattacharyya & Timilsina, 2009, 2010). The great majority of papers are purely descriptive and comparative. In contrast, there is expressive scientific production on planning theories (Falude, 1973; Friedmann, 2008, 2011; Klosterman, 1996; Wildavsky, 1973).

Energy planning, in a structured way, began to be developed as a response of developed countries to oil crises in the 1970s. Thus, it is a recently emerged area of concern, and since the beginning, energy security at minimum cost was the dominant objective of the planning process. However, a recent challenge for this rather sectoral approach is the need for the expansion of its paradigm by considering also the social, political, and environmental dimensions of its economical approaches. This increased complexity is especially challenging for Latin America and the Caribbean region (LAC). This chapter provides a tutorial review on energy planning to identify existing gaps, as well as contribute to energy decentralization, democratization, and achieving Sustainable Development Goals.

This chapter is organized as follows: first, we present a literature review of the types of energy planning models and their evolution. Second, we discuss the results and implications of the review. Third, we contextualize the discussion by offering a general reflection on the present and future of energy planning in the LAC and Nicaragua region. The final section presents the conclusions of this chapter.

20.2 Types of Energy Planning Models

Models used for energy planning can be broadly categorized as follows: energy system models, energy-economy models, partial systems models (such as those focused on the electricity system), optimization models, simulation models, hybrid models (simulation and optimization), top-down (econometric) models, bottom-up (or analytical) models, input-output models, and energy-engineering models, among others (Hiremath et al., 2007; Li et al., 2015; Nissing & Von Blottnitz, 2010; Ren & Gao, 2010).

According to Hoffman and Wood (1976), energy system models are formulated using theoretical and analytical methods from various disciplines, including engineering, economics, operational research, and administration. Different techniques are also used including mathematical programming (especially linear programming), econometrics, and the respective methods of statistical analyses and network analyses.

Bhattacharyya and Timilsina (2010) state that, since the early 1970s, a wide variety of models have been created to analyze energy systems or subsystems. Some of them analyze energy systems on a global, national, state, and municipal scale, and there are also models to analyze sectors or end uses (Jebaraj & Iniyan, 2006). In addition, since 1980, energy models have adopted a long-term and energy-environment focus, taking an interest in “green development,” meaning that the focus has shifted toward energy-environment interactions and climate change-related issues (Pachauri & Srivastava, 1988).

Markandya (1990) presented different approaches to energy system models focused on the energy versus environment relationship (the models concerned with climate change and integrated planning are also included here). Some of these mechanisms include environmental costs as part of the energy supply. Others include environmental impact calculations to evaluate alternative energy supply scenarios and, finally, models not based on optimization, but with an interest in the impacts of different scenarios adoption of alternative energy sources.

The energy balance (energy accounting) uses a methodology similar to accounting, to generate a consistent view of energy demand (and supply), based on the physical description of the energy system. Scenarios are generated to develop consistent evolutions of demand. For the supply side, it is possible to visualize different scenarios around the adoption of different technologies (Bhattacharyya & Timilsina, 2010).

In general, optimization models seek to point out the best energy supply options to meet forecasted energy and/or power demand at the least cost, for example, the Brookhaven Energy System Optimization (BESOM) developed in the 1970–1980s (Kydes, 1980). Since optimization models began to be developed after the rise in oil prices (1970), they are considered part of strategic energy planning (Bhattacharyya & Timilsina, 2010).

Tools that focus on the interface between the economy of the energy systems are usually called energy-economy models and seek to understand the economic impacts of energy system configurations. For example, through the application of economic concepts (such as market equilibrium), it can be estimated the impacts of a carbon tax on CO_2 emissions. Also, through the application of equilibrium theory, it can be estimated the effects of market penetration of alternative energy conversion technologies (Nakata, 2004).

Broadly speaking, energy-economy models deals with both the supply and demand sides of energy and the quantity and prices of inputs. The GREEN model (developed by the OECD, 1994), MARKAL (Market Allocation Model), and LEAP (Long-Range Energy Alternatives Planning System) are examples of energy-economy (or econometric) models (Bhattacharyya & Timilsina, 2009; Nakata, 2004).

Corresponding to integrated planning, the model d'Evolution de la Demande d'energie (MEDEE) is an input-output type of model, which is also an energy-saving model that includes data on the energy sector. These types of hybrid models relate macroeconomic elements with data on energy end uses; they are also analytical and capable of capturing the contribution of activities related to intersectoral linkages in the economy. In this way, they capture the direct energy demand and the indirect energy demand (Bhattacharyya & Timilsina, 2009).

Finally, the socio-technical energy transition (STET) models, or socio-technical energy transition models, seek to add to the analysis of the economic sectors and also the social and institutional elements. In this sense, STETs are aligned with the socio-technical transition theory. Some examples are BLUE-MLP, ElecTrans ENGAGE, ENGAGE DFR Module, and Transition Lab Framework REMG (Li et al., 2015).

What has been mentioned throughout this section indicates that models share elements in common and that in some cases the variations correspond to the needs of the energy planner (without denying the importance of computational advances in information processing). There is no gold standard for classifying the range of energy planning models. More than 30 models/programs/software/methodologies used in energy planning were identified in this work.

Indeed, new methods and multiple forms of analysis, goals, and approaches have been developed in recent years, but quantitative and economic tools prevail. Also, the inclusion of environmental and social aspects is becoming more relevant and explicit, but the "energy-economy" paradigm as a guide for planning is preserved. Table 20.1 groups energy planning models into four main categories based on the most distinct methodological approach to links economics and energy: simulation, optimization, hybrids, and equilibrium.

Simulation, optimization, and balance models have their applications in end-use models, energy generation, energy systems and subsystems, and input-output models. All of them have further ramifications, such as demand-side planning, energy-environment models, and STET. The last ramification is verified in the figure of the climate change and urban energy system models.

Although some authors treat top-down and bottom-up approaches as an energy system model, this work is in line with Nakata's (2004) vision: "Top-down and bottom-up models are the two basic approaches to examine the linkages between the economy and the energy system" (Nakata, 2004, p. 420). There are, however, differences in the adoption of one approach or another: the top-down approach evaluates the system based on aggregated macroeconomic variables, while the bottom-up approach uses energy end-use data (e.g., residential, commer-

Table 20.1 The energy planning modeling paradigm

Model paradigm	Type	Main features	Approach	Method	Examples
Energy-Economy (or Econometric)	Simulation	Simulation models use accounting methodology to generate a consistent view of energy demand (and supply) based on the physical description of the energy system. Scenarios art generated to develop energy demand and supply-side evolutions. You can visualize different scenarios about the adoption of different demand strategies and supply technologies. Therefore, it is an analytical tool focused on Planning	It can be used to model energy demand and/or supply (mainly demand) It can be bottom-up or top-down (usually bottom-up) It is often used in blocks with optimization models Time horizon: medium to long term	It can incorporate many methods: Energy Balance, End-Use Analysis Economic Macroeconomics (aggregate data); Microeconomics (disaggregated data); Fuzzy Logic Demand side planning, Linguistic Variables GIS data, fluid dynamics, agent-based modeling, among others	LEAP, MEDEE, Prospective Outlook on Long-term Energy Systems (POLES) (Jebar & Iniyan, 2006)
	Optimization	Characterized as classic modeling it aims to point out the best energy supply options, which will meet a future demand forecast, with the lowest cost as a goal for the choice of Optimization supply technologies. It is a partial equilibrium model and has an operational profile, directed to the dispatch of the energy system. It is considered part of the Strategic Energy Planning methodology	Energy Supply Model. Mostly bottom-up (some top-down approaches are recent) It is a normative Often used in conjunction with a simulation model Time horizon: medium to long term	Mainly mathematical programming linear programming and MLP, statistical analysis, time series, and multi-periods, Life Cycle Analysis, Stochastic Programming Parametric Programming, Fuzzy Program Probability, and Time Series among others	BESOM; Regional Energy Scenario Generator (RESCEN); MARKAL. (Bhattacharyya & Timilsina, 2009)
	Equilibrium	It analyzes the behavior of economic agents and seeks to achieve a market balance between demand and supply. It can consider the entire economic system (general equilibrium), or only part of it (partial equilibrium). It has an economic nature, and its objective is to project prices and quantities of energy (as of commodity)	It mainly focuses on the supply side Top-down and bottom-up approached are used Can be used with (or be part of) other energy-saving models Time horizon: medium to long term	Price/cost-driven, General Market Equilibrium Theory, Behavioral Economics, Algorithms, Econometric Estimates, Macro and Microeconomics principles, growth rate, demand forecast, and GDP	Energy and Power Evaluation Program (ENPEP) Model for Evaluation Regional and Global Effects of GHG Reduction Policies (MERGE) (Bhattacharyya & Timilsina, 2009; Nakata, 2004)
	Hybrids	Hybrid models combine top-down and bottom-up approached. They consider market behavior and, in this way consider the economic effects on their results	They can be used to model demand or supply (mainly demand). They represent the fusion of top-down and bottom-up approached. Time horizon: medium to long term	They can use all the methods mentioned above (Simulation, Optimization, and Equilibrium models)	Asian-Pacific Integrated Model (AIM) MARKAL TARGETS-IMAGE Energy Regional Model (IMAGE/TIMER) Partial equilibrium model (PRIMES) (Dementjeva, 2009; Pfenninger et al., 2014)
Literature review (all models)		The other type of models found in the literature are considered by the present research and derivations of the simulation, optimization, equilibrium, and hybrid models described above: energy-environment Models; Engineering-Energy Models; Power Systems Models; Models of Partial Energy Systems; Top-down and bottom-up models, Input-output models; Sociotechnical Energy Transition Models, Integrated Planning Models, Sustainable Models			

cial, and industrial characteristics) and disaggregated microeconomic and energy data. Such differences are reflected in the results obtained from the application of each approach (e.g., the degree of detail and granularity of bottom-up models is superior), and the differences produced are rooted in the complex interaction between the objectives, financial and technological resources, model structures, and input assumptions.

Finally, top-down and bottom-up approaches also have different assumptions and expectations regarding efficiency improvements. On the one hand, bottom-up models generally aim at gains through energy efficiency arising from the adoption of more efficient technologies, both in supply and demand, with a given technical performance and cost (replacing appliances or techniques). On the other hand, in the top-down approach, technology is generally represented by the actions of purchasing a given input in intermediate consumption (e.g., labor, capital, among others) (Nakata, 2004). Some authors, however, such as Hourcade et al. (2006), mention the current tendency to use hybrid approaches that seek to combine bottom-up and top-down strategies to complement them.

Simulation and optimization models demonstrate two different approaches to dealing with technological aspects: the view of traditional economists, which is based on the optimization of the system within the neoclassical tradition, and the simulation that follows the engineering tradition, criticizing the limitations of the rational and optimizing behavior assumed in the traditional analysis. In this way, other assumptions are introduced, such as the satisfactory performance approach or the evolutionary approach to technological change. Divergence in viewpoints dominated the energy literature in the past and led to the emergence of two distinct traditions of energy analysis—the econometric approach and end-use engineering (Bhattacharyya & Timilsina, 2009).

Currently, quantitative energy models limit their performance to the description of techno-economic factors; some include environmental variables, which often refer exclusively to GHG emissions. Analyses of the political, social, and behavioral aspects of the proposed scenarios are left to the decision-maker to frame it exogenously. There are few attempts to introduce socio-technical perspectives in energy models, linking, for example, models with normative views of stakeholders (Li et al., 2015), modeling through the insertion of governance issues, or including behavioral heterogeneity (Strachan & Warren, 2011).

As a result of this situation, we point out the fragility of these tools in providing quality evidence to support public policies that will have to deal with Sustainable Development Goals (SDGs) integration and energy transition challenges, once its subjects present frontiers of action that overcome this paradigm (mostly economic and financial).

It is worth noting, however, that new ways of thinking about planning and modeling are emerging, in which there is a need for greater transparency, participation, and social awareness. To this end, such trends make use of mixed, qualitative approaches, using simple tools such as spreadsheets and Excel (Pfenninger et al., 2014), and they also begin to be concerned with the human dimension, such as behavioral and political aspects.

In addition, according to Fodstat et al. (2022), despite a large body of ongoing research within the energy systems modeling field, there are many uncovered aspects for modeling to address energy transition: there is a need to model cross-sector interdependencies among energy carriers to have strong evidence on renewable integration. Moreover, there is a lack of studies modeling uncertainties related to emerging technologies, and energy consumer behavior is one of the major aspects of future research.

Finally, it is worth wondering how specific problems that the global south face are being envisioned by current energy planning modeling. Energy planning models mostly originated in developed countries and are primarily aimed at reducing greenhouse gas emissions while enhancing energy security at a minimum cost. In contrast, most, if not all, countries in the global south are predominantly concerned with ensuring affordable reliable, sustainable, and modern energy access.

20.3 Pending Tasks and New Frontiers on Energy Planning in LAC Countries

More than 12 million people in Latin America and the Caribbean (LACs) still lack access to electricity, and nearly 70 million people lack access to clean cooking facilities (World Bank, 2021). A large part of this population is in rural regions, living in remote, hard-to-reach communities. Therefore, ensuring access to affordable, reliable, sustainable, and modern energy for all (Sustainable Development Goal 7 (SDG 7)) is a must, and it will require increased efforts and investments in an adequate combination of centralized and decentralized energy infrastructures.

Meeting SDG 7 is crucial for ensuring human well-being (e.g., poverty eradication, human development, access to clean water, food, energy, and so on) and for protecting the environment and natural resources. However, there are also trade-offs related to the tension between the need for rapid investments to address key issues for human well-being and the careful planning needed to achieve efficient, affordable, and reliable energy systems with high integration of intermittent renewable energy (Fuso Nerini et al., 2018).

If we compare LACs with the world, the region's renewable electricity output (% of total electricity output) was 51% in 2015 while worldwide renewable generation was 23% (World Bank, 2021). Countries like Costa Rica, Paraguay, and Uruguay produce ≈98% of their electricity from renewable sources (World Bank, 2021; IRENA, 2021).

It is worth mentioning that renewable electricity matrices of these countries are possible because of the significant share of hydroelectricity generation in total electricity production.[2] Yet, it is not clear if the rest of the LACs can follow suit. The electricity demand for LACs is projected to double by 2050 (Balza et al., 2016), so it will be necessary to add significant generation capacity. Historically, the long-term energy planning in LACs prioritizes hydropower capacity additions. Yet, hydroelectric plants are being strongly contested for their negative socio-environmental impacts (Atkins, 2020; Israel & Herrera, 2020; Reel, 2020), and the nuclear option in the Brazilian case is under intense scrutiny (see, De Carvalho & Sauer, 2009; Dos Santos et al., 2013).

In such circumstances, the path for a clean energy transition in LACs should rest mainly on a large increase in wind and photovoltaic generation (utility-scale and distributed generation), particularly considering the high potential in the region and the substantial reduction of the levelized costs of electricity (LCOE) of these sources in the last decade (IRENA, 2019). Yet, the penetration of intermittent, climate-dependent, nondispatchable energy sources that are not perfectly correlated with demand such as wind and solar is requiring a closer look at the following topics in the planning and operation of electricity systems: (a) reliability of the electricity system (b) transmission and distribution requirements to integrate the renewable electricity production, and (c) ancillary services requirements of the grid (i.e., frequency and voltage control) (Heard et al., 2017).

In fact, due to the small number of cases of 100% renewable-electricity systems around the world, there is a debate in progress on the feasibility and viability of these systems, and the arguments mentioned above are some of the topics under examination (see Heard et al., 2017 vs. Brown et al., 2018). Unquestionably, an energy transition based on variable renewable energy sources demands the inclusion of new topics that tend to make energy planning and operation more complex than in the recent past. The following are some of the most important issues to consider:

- Typically, energy planners and operators consider that intermittent renewable sources have no capacity value to the grid (only energy value). Nevertheless, recent studies are showing that is possible to determine the capacity value of intermittent sources such as wind and

[2]For instance, due to the existence of Itaipú (hydropower plant with installed capacity of 14,000 MW), all the electricity demand of Paraguay is meet with Itaipú.

solar (see Amado et al., 2021, for the Brazilian electricity system). Recognizing the capacity value of renewable sources will contribute to accelerating the insertion of modern renewable sources in the electricity sector.

- Moving toward 100% renewable-electricity systems with intermittent sources requires energy and electricity storage to compensate for the displacement of dispatchable fossil fuel plants (e.g., combined-cycle power plants). Previous studies have emphasized the need for recognizing the importance of pumped-storage hydro plants, batteries and green hydrogen (Oliveira et al., 2021) in the evolving energy systems.
- In the transport sector, the tendency toward electric mobility integrates the transport sector with the electricity sector, creating new energy and power demand and potentially transforming the load curve but also opening the possibility for car batteries to give back to the power grid (vehicle-to-grid or V2G). V2G is an arising socio-technical challenge that should be overcome to scale up (Lance et al., 2019).
- The advent of the smart grid, in general, has raised awareness about the growing importance of information and communication technologies (ICT) for the energy sector and digital societies (see OECD/IEA, 2017). LACs must reduce the existing technological gaps.
- The spread and interaction between small-scale renewables, electric vehicles, batteries, and demand response measures increase the complexity of short-term demand forecasting and require high spatial and temporal resolution data (Hong & Fang, 2016).
- Inevitable regulatory changes and new business models are required in the energy sector.
- LAC countries such as Bolivia, Chile, Argentina, and Mexico have the largest lithium reserves on the planet. This mineral is crucial to produce batteries for electric vehicles and should be considered a strategic resource for medium- and long-term energy planning in the region.
- Finally, the energy planning process should incorporate new socio-technical changes but also include specific moral and political considerations in the energy decision processes. A series of recent studies have indicated that issues such as gender (Johnson et al., 2019; Pueyo & Maestre, 2019), feminism (Bell et al., 2020), race (Newell, 2021), democracy (Cantarero, 2020), and justice (e.g., Sovacool et al., 2017) are especially important for underdeveloped regions such as the LAC countries.

20.4 Keynotes from the Nicaraguan Energy Transition Studies

Nicaragua is an underdeveloped country with a population of 6.2 million inhabitants, located in Central America. The country has around 99% electricity access (MEM, 2022) and, despite having a substantial renewable energy potential (geothermal, wind, solar, etc.), is nearly 70% renewable (MEM, 2022), but the entire energy system is highly dependent on imported fossil fuels (Meza et al., 2017).

According to Cantarero (2018), in 2012, Nicaragua had reached a peak in clean energy technology investments, but the renewable installed capacity used at that time represented only 12% of the theoretical potential. Currently, the electricity demand accounts for less than 16% of the country energy consumption, and by following the existing energy policies at that moment, this is likely to remain the case by 2030. This situation, according to Cantarero (2018), will not enable the country to actively tackle climate change and meet the Sustainable Development Goals (SDGs) simultaneously, suggesting that energy policies and decarbonization plans must take place in the radical change of the country energy system and in the fuels used for transportation and for cooking.

In this regard, Meza et al. (2017) suggest that Nicaragua could transform its entire electric sector by creating a positive technical and economic condition to the penetration of electric mobility in the country that is the second largest energy consumer in Nicaragua, relying solely on oil derivatives. This could be achieved by prioritizing the development of geothermal (high-capacity factor to meet the base load with the lowest cost), wind, hydro, and biomass sources and energy-efficiency programs. The results highlight the direct link between the decarbonization of the transport sector and of the power sector.

There is still little research on specific LAC countries energy transition situation. Overall, the pieces of research focus on the need for the implementation of energy technologies cost-effectiveness or in the improvement of energy system efficiency, affordability, and reliability. However, there is still pending tasks for Nicaragua scholar to further explore in order to achieve studies that collaborate with simultaneously with energy transition and sustainable development, for instance, there is a need for the redefinition of citizens' participation in energy planning and policymaking.

Finally, another important challenge is that DG systems have become more popular in recent years, but the increasing adoption of DG will create obstacles for system operators due to the uncertainty in forecasting future demand and impact on electric rates.

20.5 Conclusion

This chapter has compiled and discussed the evolution of energy planning models. We are not aiming for a comprehensive review. Instead, we try to provide enough background knowledge and good sources of references. Energy planning is guided by energy modeling in which technical-economic aspects are prevalent. Supply-side analysis tends to assess the feasibility of replacing fossil energy resources with RES; demand-side studies, in turn, usually focus on the technological replacement of devices and other technologies, which means, in general, that energy-efficiency strategies are the only ones guided.

This study argues that research should go beyond the investigation of technological options, consumption of electronic devices, and individuals' behavior, to adopt a broader scope, since technological and behavioral aspects are just two of the various parameters that have a relation to the energy use (i.e., urban form, economic structure, bioclimatic and governance aspects, among others) inside a territory.

New frontiers are emerging considering the renewable energy transition and Sustainable Development Goals. The need for an energy transition based on renewable energy sources poses challenges to traditional energy planning and operation. This is especially true if we consider that the renewable sources prioritized for the energy transition are intermittent and non-dispatchable sources. To this technical complexity must be added the need for the energy transition oriented toward achieving Sustainable Development Goals. Together, the technical challenges and the need to reduce the trade-offs and promote the synergies that exist between energy and sustainable human development are forcing an evolution in the management and planning of energy systems toward a deepening of interdisciplinarity.

There is an urgent need for energy planning and energy modelers to consider emerging socio-environmental and ethical issues such as climate justice for the proposition of energy use in future scenarios and policies. LAC countries are still indebted to an important part of their population regarding the sustainable development objectives related to climate and energy. Financial resources are limited, and growing international solidarity and complementarity are required to advance on these issues.

This study argues that understanding the frame and reframing by policy actors of past, present, and emergent problems is fundamental for building shared visions and lasting policy coalitions. We consider the techno-scientific apparatus as one of the main stakeholders to be analyzed since scientific research often implies and sometimes covers the existence of specific ideas and values, which are also used for building an agenda and implementing public policies. Finally, energy planning models play an essential role in the development of the energy sector at global, national, and regional levels by enabling informed decision-making. In developed countries, the focus today is on reducing emissions while enhancing energy security, primarily characterized by a shift from fossil fuels toward more renewable resources. However, LAC countries are concerned with increasing access to electricity, which is considered a prerequisite for development and economic empowerment, as reflected by the inclusion of energy as a goal in the Sustainable Development Goals.

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21 Conclusions: Energy Transition Agenda for Sustainable Development in Latin America

Lira Luz Benites Lazaro and Esteban Serrani

In the book *Energy Transitions in Latin America: The Tough Route to Sustainable Development*, we examined the opportunities and challenges of transitioning toward renewable sources. Latin America is a region that has significant potential for renewable energy generation due to its abundant natural resources, including hydroelectric, solar, and wind power, as well as minerals essential for developing clean energy technologies, such as lithium. However, the energy transition in some countries of the region has been slow due to various factors such as political instability, economic challenges, and regulatory barriers. In addition, there is often a lack of political will to support renewable energy, as some governments prioritize traditional energy sources over renewable energy. Some countries in Latin America have made progress in transitioning to renewable energy. For example, Uruguay has successfully shifted to renewable energy, with most of its electricity generated from wind and solar power. Paraguay, Ecuador, and Costa Rica have done so, mainly based on hydroelectric power. Chile has also made significant progress in renewable energy, particularly solar power, which has helped to reduce the country's dependence on fossil fuels. In contrast, some countries in the region are still heavily dependent on fossil fuels, particularly oil and gas. For example, Venezuela and Mexico continue to rely on oil as a significant source of revenue and energy, despite the potential for renewable energy.

Throughout this book, we aimed to thoroughly evaluate whether the energy transition policies and actions adopted by Latin American countries are promoting sustainable development while considering the intricate social relations presented by the energy system and the region's particularities and challenges. In this book, we have analyzed the complex issues of energy transition, focusing on four key areas; below, we provide a detailed description.

21.1 The Geopolitics of Energy, the Energy Mix, and National Decarbonization Plans in Latin America

The first section highlights the changing energy mix in Latin America and the geopolitical implications of the region's increasing reliance on

L. L. B. Lazaro (✉)
Department of Environmental Health, School of Public Health, University of São Paulo, São Paulo, Brazil

Durham Energy Institute and Department of Anthropology, Durham University, Durham, UK
e-mail: lbenites@usp.br

E. Serrani
National Scientific and Technical Research Council (CONICET), National University of San Martín (UNSAM), San Martín, Argentina
e-mail: eserrani@unsam.edu.ar

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renewable sources. Regarding the shift in the energy mix, this book presents the South America case as the region that has made significant progress in increasing the installed capacity of low-carbon sources, particularly in solar and wind energy. While hydroelectric power has also increased, climate change-induced droughts have led to modest growth (Sabbatella, Chap. 2, this volume). These changes in the energy mix and the diversifications of energy sources are also related to Latin America's energy geopolitics, which has undergone significant changes in recent years, with the emergence of China as a critical player in the region. China's growing economic and political influence in Latin America has significantly increased investment in energy-related projects, including renewable energy, mining, and oil and gas extraction. One of the main drivers of China's interest in Latin America's energy sector is its growing demand for natural resources. As China seeks to secure its access to these resources, it has invested heavily in the region through direct investment and strategic partnerships with Latin American countries. One area of particular concern is China's investment in critical infrastructure projects, such as ports, highways, and energy facilities.

As described by Ugarteche and Garcia (Chap. 4, this volume), Chinese investments in Latin America have played a crucial role in developing alternative energies over the past few years. China has become the primary investment partner for most South American countries, contributing significantly to the region's renewable energy, lithium, copper, and iron mining sectors and the expansion of electric mass transit systems. Brazil has become a top destination for Chinese investment in electric vehicles and related infrastructure. At the same time, Peru, Argentina, and Chile report the highest levels of Chinese investment in the renewable energy industry. Therefore, energy transition in Latin America must be recontextualized to recognize the interweaving of geopolitical and social dimensions while focusing on the Sustainable Development Goals (SDGs). This requires balancing the need for energy security and a just transition to provide affordable energy for all. In today's complex geopolitical world, strategic resources are being contested by both old and emerging powers, including China, which has emerged as the leading investor in Latin America (Guerrero, Chap. 3, this volume).

21.2 Oil and Gas Dilemmas: Income Dependence and Obstacles to Energy Transitions

The second section examines the dilemmas faced by countries that rely on oil and gas revenues and the obstacles they face in transitioning to a low-carbon economy. These countries often have economies that are heavily dependent on the export of fossil fuels, making it challenging to transition to a low-carbon economy rapidly. Additionally, many of these countries face significant political and economic obstacles that make it difficult to diversify their economies and reduce their reliance on oil and gas. For example, Mexico's energy policy is heavily influenced by its history of relying on oil, which has been a key element in its energy policy, national growth, and foreign policy. The government's energy policy focuses on replenishing oil reserves, increasing production, and renewing its refinery system. This approach results from Mexico's deep dependence on oil and the United States' economy, which have been central to the country's national growth and foreign policy. Fossil fuels are a significant source of income and political power, and Mexico's economy relies heavily on them. The country also depends on the United States for essential energy resources and exports most of its oil there. However, this dependence is reinforced by Mexico's uneven regional integration in North America, making it challenging to implement a sovereign energy policy that includes a transformative energy transition model (Sandoval, Chap. 5, this volume).

Furthermore, Mexico faces significant contradictions between its energy and climate change mitigation policies. On the one hand, the country's energy policy hinders its climate mitigation goals by compromising on emissions reduction. On the other hand, climate policy can affect energy security by making it more difficult to afford energy. These contradictions demonstrate the challenges of balancing the need for reliable and affordable energy with the urgent need to mitigate climate change (Zimmermann and Rodríguez, Chap. 6, this volume). Mexico, like many other countries, must work to develop policies that can reconcile these competing priorities and promote sustainable energy systems that support climate goals while also ensuring energy security and affordability.

In Brazil, as described by Lazaro et al. (2022), the discovery of Pré-sal has impacted the energy transition to renewables in the country. The Brazilian government and investments have been focusing on the potential of Pré-sal for oil production and its by-products, which has led to an investment prioritization of hydrocarbon energy over alternative and renewable energies. According to the 2029 Energy Plan, Brazil will concentrate more than 70% of its investments in the oil and gas sector, 19.6% in electricity, and only 2.3% in biofuels in the next 10 years (EPE, 2020). This suggests that the income generated from the exploration of Pré-sal has not been directed toward supporting renewable energy sources as was initially proposed. Furthermore, the impact of the Pre-Salt on different sectors of the Brazilian economy has been quite uneven. While some sectors have significantly benefited, others have experienced a decline in their share of the economy and exports, similar to the "Dutch disease" effect. This can be attributed to a concentration of productive factors in the oil extraction industry, leading to increased input prices (labor and capital) and a revenue-dominated foreign trade balance.

Consequently, the Brazilian economy has become more dependent on oil production, and oil export revenues have dominated the country's foreign trade (Magalhães & Domingues, 2014). However, some Brazilian authors believe that the resources generated from Pré-sal could be used to promote renewable energies (Goldemberg et al., 2014) (Almeida et al., Chap. 9, this volume). The impact of the discovery of Pré-sal on Brazil's energy transition to renewables is a matter of debate. It depends on the government's policies and investments in the future. The practical discourse for such an agenda occurs in the political arena, where conflicts of interest are often among the various stakeholders involved. However, it is worth noting that many countries have been disappointed by the promises of oil revenue to support energy transition and environmental protection. Ultimately, whether Brazil will use its oil income to invest in renewable energy sources remains to be seen (Werner & Lazaro, 2023).

Ecuador and Venezuela face the challenge of reducing their dependence on oil, which they rely on to finance their economy through rents and exports while meeting growing energy demand. This has led to a failed energy transition and a lack of diversification in the energy mix. As pointed out by Fuentes and Fontaine (Chap. 8, this volume), despite attempts to reduce dependence during the liberal era of the 1990s and the resource nationalism era of the 2000s, their efforts have been hindered by the resilient rentier state and path dependence of natural resource overload in their development models. Since the early twenty-first century, both countries have claimed to adopt decarbonization aims, using oil rents to finance energy subsidies and state-driven policies to secure political agreements and resolve social disputes while investing in hydropower capacities. Although the electricity supply has increased notably due to massive investments in hydropower, the energy mix diversification remains a mere aspiration, as it has not been adequately implemented due to various factors such as ill-designed policies and economic dependencies on the oil industry. In Ecuador, although there is increased investment in hydroelectric energy in the last decades, oil remains the primary energy source and the foundation of the country's capitalist development. Historically, the energy subsidy system, which is aimed at fossil fuel consumption, remains regressive and benefits mainly the wealthiest income quintiles. This characteristic has not changed with its application (Fernández and Mideros, Chap. 7, this volume).

Argentina's challenges in transitioning toward low-carbon sources include reducing its dependence on fossil fuels, increasing energy efficiency, and promoting renewable energy. The country has historically relied heavily on imported oil and gas to meet its energy needs, leading to high vulnerability to global market fluctuations and supply disruptions. This dependence has also strained the country's balance of payments, as energy imports account for a significant portion of its foreign currency expenditures. Therefore, the energy transition presents an opportunity to leverage the country's productive and technological system but also requires substantial investment. To address these challenges, the Argentine government has set ambitious targets for renewable energy development and energy efficiency improvements, as well as initiatives to promote investment in Vaca Muerta. However, implementing these policies has faced significant challenges, mainly due to budget constraints and political instability (Serrani and Barrera, Chap. 11, this volume).

Furthermore, Roig and Massi's (Chap. 10, this volume) presented a multi-scale perspective on energy transition, focusing on the cases of Neuquén and Río Negro in Argentine Patagonia. The study highlights a transition strategy based on the commodification of energy controlled by actors who concentrate and seek to reproduce a vast repertoire of power resources. The dominant discourse in Argentina suggests that the extensive exploitation of nonconventional hydrocarbons (NCH) would result in a virtuous combination, as increased international investment, production, and exports would help overcome the obstacles to development imposed by external difficulties and contribute to the energy transition process in Argentina. However, doubts cast on the idea of gas as a "bridge fuel" aside; the cases of the provinces of Neuquén and Río Negro reveal a catch lying within this kind of articulation. Although macroeconomic and regional benefits can be achieved in the short and medium term, this can only be conducted at the cost of deepening or even creating new sacrifice zones.

21.3 Energy Transitions and Renewable Energies: Production, Technology, and Costs as Limits and Opportunities

The third section focuses on the policies and technologies needed to facilitate the expansion of renewable energy sources in the region, including the role of national industries and the development of local technology. Uruguay was one of the countries in the region that has achieved remarkable success in transitioning to nonconventional renewable energies, with the public sector playing a key role in guiding the process. The country's state policy and the preexisting institutional framework, which had a vertically integrated public company as its axis, were crucial factors in this success. However, the ongoing privatization of generation poses several future challenges and problems that need careful consideration. One of the emerging issues is the management of intermittent sources, and the commitment to pay a dollar-denominated price for energy generated by private agents may distort the market. Moreover, the analysis of available evidence suggests that the national investment component has had only a modest impact as an industrial policy tool. Therefore, public control over the transformational dynamics is necessary to support the country's development of domestic production and social welfare (Bertoni and Messina, Chap. 12, this volume).

The energy transition in Colombia is being driven by private and public agents, with a soft focus on sustainability guiding official efforts. Challenges remain while the state has implemented regulatory and fiscal measures to promote the transition, such as stimulating renewable energy projects and promoting partnerships between national and foreign companies. These challenges include reconciling extractives interests with sustainable development, maintaining private bank support, encouraging the adaptation of vehicles to natural gas, and facilitating technology updates for national companies through alliances between foreign and local companies. A good governance environment is necessary to address these challenges and ensure a sustainable energy transition (Reina and HernÃ¡ndez, Chap. 13, this volume).

In the context of Argentina, the study of Canafoglia (Chap. 14, this volume) highlighted the regional features of the energy diversification process, with a particular focus on solar energy. While the national industry faces difficulties in competition and pricing, the involvement of foreign stakeholders and their partnership with local stakeholders determine the proportion of local products in the market. The conditions of social relations of production and macroeconomic factors determine local stakeholders' margin of competition or collaboration, the continuity of their commitment, and the capital invested in these projects. Energy production policies and associated incentives become necessary articulations in the territory, but they must be anchored in the potential profitability obtained from the undertaken projects. Incentive policies for intensive capital investments would favor the insertion of specific stakeholders and products over others. Policies should sponsor national industry and manufacturing by diversified local stakeholders and users of different sizes/types, including residential, industrial, and agricultural sectors, to promote sustainable development.

In the context of Brazil, two chapters presented the challenges and opportunities in transitioning to renewable energy sources. Grangeia and Santos (Chap. 15, this volume) highlighted the uncertainties surrounding transportation planning in Brazil and the choice between traditional biofuels and electric mobility in the context of climate change. Although Brazil is a pioneer in the bioenergy sector, international pressure to decarbonize the transport sector through electrification could isolate the country in the global market. To prevent this it is necessary to understand the Brazilian position on electric mobility, which currently lacks a National Plan and requires technical-economic feasibility studies, regulatory aspects, legal framework, financing models, and technological improvements to improve the competitive position of the national automotive industry. A comprehensive agenda that incorporates more efficient and clean propulsion technologies is needed, supporting the construction of models that give scale to the electric vehicle market while fostering healthy competition and cooperation with biofuels. The study by Soares et al. (Chap. 16, this volume) examines the factors contributing to the diffusion of solar photovoltaic (PV) energy in the São Paulo Macrometropolis, focusing on Holambra. The findings reveal that middle actors, such as PV companies, play a crucial role in steering the diffusion of PV systems by making people aware of the advantages and persuading them to purchase the systems. The high energy cost is the key driver for the distribution of solar energy PV in Holambra. However, distributed PV generation lacks incentives and clear investment regulations, and social and market acceptance is important for the technology's adoption. Solar energy has the potential to contribute to various sustainable development goals, including poverty reduction, gender equality, reducing inequalities, and tackling climate change.

21.4 Energy Services: Access, Energy Poverty, Decentralization, and Democratization

The fourth section explored the issue of energy access and the democratization of energy generation in Latin America, including efforts to address energy poverty and the growth of distributed energy and prosumers. Energy poverty and democracy are crucial issues that require urgent attention from decision-makers in the region. By addressing these issues, countries can reduce energy poverty, promote sustainable development, and ensure equitable access to energy services for all. Therefore, policymakers need to prioritize these issues and work toward developing innovative and practical solutions to address energy justice and poverty and democratizing energy generation in Latin America.

The chapter by Kazimierski (Chap. 17, this volume) sheds light on the trend of decentralized energy generation in Argentina, Chile, and Uruguay. The energy sector in Argentina and Chile is primarily dominated by large corporations, which has resulted in public debates on profits and legislation protecting these corporations. In contrast, Uruguay has successfully implemented decentralization, with the public sector playing a vital role. However, for decentralization to succeed, it is crucial to have a sustainable remuneration model and the integration of the deconcentration of the system into innovative ideas from the political and civil society. Moreover, this shift toward decentralization raises important questions about the impact on the concentration of generation and the role of public-social experiences in the energy sector. Decision-makers need to consider these factors to ensure that the benefits of decentralization are accessible to all and to address concerns regarding energy poverty and the democratization of energy generation.

In this section, Soares et al. (Chap. 18, this volume) present a critical study on the relationship between poverty and energy poverty consumption in Brazil, emphasizing the need to consider energy poverty within the context of sustainable development goals. The study argues that energy poverty perpetuates poverty and resource scarcity; thus, achieving SDG 7 is a prerequisite for the success of other SDGs. The authors highlighted that energy policies should consider the marked differences between social clusters and consider energy poverty as a multidimensional phenomenon that affects vulnerable groups differently. The study suggests that an awareness of the limitations of energy poverty measurements is crucial to develop effective policies for eradicating energy poverty. Furthermore, the study emphasizes the urgency of recognizing energy poverty in Brazil and its relationship with SDGs 1 and 7 to support the country in meeting these goals. Mondol's (Chap. 19, this volume) chapter explores energy inequality in Central America and notes that while it has decreased in recent years, a new type of inequality has emerged based on environmental quality. The chapter highlights the persistent energy vulnerability among rural and indigenous populations, and the decrease in energy inequality is only partially associated with increases in per capita income. Despite this, the governments of Central American countries have been taking nonuniversal policy actions to address energy vulnerability, often favoring private companies in the renewable energy market. These studies emphasize the need for inclusive, equitable, and sustainable policies that prioritize the needs of vulnerable populations. In this context, promoting low-carbon energy and integrating energy markets are seen as positive developments. Still, more needs to be done to ensure that everyone has access to reliable and affordable energy services and that the benefits of the energy transition are shared fairly.

Finally, the chapter by Collaço and Meza (Chap. 20, this volume) described the challenges that the renewable energy transition and sustainable development goals pose to traditional energy planning and operation, emphasizing the need for a shift toward interdisciplinarity and the consideration of socio-environmental and ethical issues. Energy planning is crucial for enabling informed global, national, and regional decision-making. It must incorporate the impacts of the energy transition on social equity, environmental justice, and human rights (Abram & Weszkalnys, 2013). There is a need to underscore the importance of engaging communities and stakeholders in the planning process and the need for transparent and participatory governance mechanisms to ensure that energy policies and investments align with the needs and aspirations of diverse populations. Therefore, a comprehensive and inclusive approach to energy planning and governance is necessary to build a sustainable and just future for all.

This book offers a thorough and insightful analysis of the challenges and opportunities related to transitioning to sustainable energy systems in Latin America. It sheds light on the issues faced by countries dependent on oil and the urgency of tackling climate change. Moreover, it highlights the need for a collaborative and holistic approach to achieving sustainable development goals in the region. The diverse range of topics covered in this book, including geopolitics, energy access, poverty reduction, decentralization, and democratization, presents a multidimensional perspective. Overall, this book provides a valuable resource for anyone seeking to understand the complex challenges and opportunities in transitioning to Latin America's sustainable energy systems.

21.5 Energy Transition Agenda for Sustainable Development in Latin America

Achieving Sustainable Development Goals in Latin America requires a comprehensive draft agenda examining energy transitions from and for Latin America. This book presents key findings that can serve as a basis for developing such an agenda. While not an exhaustive list, these concepts and reflections are intended to guide discussions on energy transitions in the region and within the context of global climate policies. The proposed agenda considers the unique characteristics of the Latin American energy landscape and the urgent need for sustainable solutions. This draft agenda provides a starting point for ongoing dialogue and action toward this important goal. It emphasizes the need to:

21.5.1 Rebalancing the Energy Trilemma, in Tune with the Reality of Latin America

The energy trilemma – comprising energy security, equity, and environmental concerns, including sustainability and climate change (World Energy Council, 2022) – is complex, and its dimensions must be rebalanced considering the unique realities of Latin America. The energy transition is not only about changing the energy mix; it must also prioritize improving the structural conditions of the economy and society, meeting people's needs, and distributing social welfare equitably. Analyzing the energy trilemma requires a deep understanding of the region's historical and structural challenges, such as social inequality, economic underdevelopment, environmental liabilities, and informal labor. To achieve sustainable development goals, reconnecting the region's perspective on the energy transition with the energy trilemma analysis is crucial. By adopting this approach, Latin America can significantly reduce income inequality and improve social welfare, thereby creating a more just and equitable society.

21.5.2 Rethinking the Financing Limits and Fiscal Transition of the Energy Transition

Developing countries often face significant obstacles in securing funding for infrastructure projects crucial for economic development (World Bank, 2023). Latin America's inadequate public financing for the energy transition is a clear example of this challenge, mainly due to insufficient investment from multilateral banks and developed countries failing to fulfill their promises to support climate change adaptation programs. As a result, many renewable energy projects in the region are financed primarily by international private investment, while the impact of green taxes as incentives for decarbonization remains limited (ECLAC, 2022). Additionally, in the short term, many countries in the region rely on revenues from natural resource extraction, making it difficult to implement long-term financial strategies and assess the actual impact of stranded assets. It is essential to analyze the costs of the fiscal transition implicit in the energy transition for Latin America and identify the political and social coalitions that can drive these changes forward.

21.5.3 Reviewing the Distribution of Liabilities in the Energy Transition as a Platform for Taking a New Extractive Cycle

Latin America has long relied on exporting natural resources while importing high-tech products. However, as the global economy shifts toward decarbonization and Industry 4.0, it is necessary to ask whether accelerating natural resource extraction will benefit the region in the energy transition. Specifically, we need to consider whether a new phase of rapid natural resource exploitation will enable Latin American countries to benefit from the energy transition or merely leave environmental liabilities in the territories where mining occurs, perpetuating exploitation and the ecological degradation cycle. To avoid perpetuating this new extractive cycle, even if it is covered in "green" discourses, we must analyze global value chains and consider the geopolitical context of the energy transition. For example, depth studies from critical and justice perspectives are needed on extracting lithium from South America to manufacture electric cars to supply markets in developed countries, understanding the costs and benefits, identifying the losers and winners, and the environmental damage behind this extraction.

21.5.4 Industrial Policy to Overcome Technological Dependency and Create Employment

Latin American countries face significant challenges in promoting sustainable development and creating jobs due to limited financing access and dependence on the global economy. To overcome these challenges is crucial to implement industrial policies that encourage the development of local companies in the green economy sector, reduce technological dependency, and create local value chains. Although it is not easy to overcome technological dependence solely through incentives for national renewable energy companies, improving productive and technological capacities in some links of the value chains is possible. It is necessary to identify which segments have greater technological capabilities and which industrial policies can be implemented to increase local value creation. Several developed countries are already using industrial policies to promote the creation of local productive chains and incentivize green investments, for example, the European Green Deal Industrial Plan (European Commission, 2023) and the Inflation Reduction Act in the United States (The White House, 2023), which can serve as a model to adapt for Latin American countries context.

21.5.5 Ensuring Just Distribution of Benefits in the Energy Transition

As the world transitions to renewable energy, examining whether this shift will lead to a more equitable and just society in Latin America is crucial. It is essential to consider how to distribute the benefits of the energy transition so that vulnerable communities are not left behind. Will higher-income groups change their consumption patterns to adopt sustainable practices or will the growth only benefit a few privileged groups? How can the shift to electromobility in Latin America be leveraged to enhance public transportation infrastructure and systems rather than simply replacing private fossil fuel cars with electric ones? These issues require a nuanced and critical perspective that highlights emerging injustices. Latin America is not only a provider of natural resources to sustain consumption in developed countries but a region that needs an energy transition to improve the living conditions of its population.

21.5.6 Redesigning the Energy System to Address Energy Poverty and Democratize Access to Energy

The energy transition presents a unique opportunity for Latin America to address structural problems and achieve sustainable development. Latin American countries must focus on revitalizing their economies with a strong emphasis on sustainable industrial development policies, local job creation, and promoting renewable energy value chains. However, the success of the region's energy transition will depend on the direction and form it takes, as it could either help achieve sustainable development goals or worsen economic asymmetries and technological dependence. This ongoing debate requires extensive research and critical analysis, as it will remain a key challenge for the global and regional agenda for decades.

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