Edited by
Nandakumar Janardhanan
Vaibhav Chaturvedi

Renewable Energy Transition in Asia

Policies, Markets and Emerging Issues

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Preface

The Asian countries have diverse economic profiles, energy consumption patterns, greenhouse emissions, climatic conditions and socio-political landscapes. These dynamics bring into focus that drawing a uniform framework to define the energy transition process for the region is a difficult task. Keeping in view of this reality, we embarked on the book project by identifying major themes and regions that would make a value addition to the existing literature on energy transition. The framework with which the book has been developed showcases the interplay of four critical influencers—businesses, political economy actors, governments and geopolitical actors—and the impact of the same on policy mechanisms, governance and institutions, politics, markets and technology; elements that have a remarkable influence on the energy transition in the Asian region. The framework also highlights the co-benefits of energy transition which include shaping climate mitigation initiatives, enhancing energy security, strengthening energy access, and addressing concerns pertaining to energy-water nexus.

This book project began in 2019. In early 2020, as we were nearing the final stage of the manuscript preparation, the COVID19 outbreak has tightened its grip over many countries. Today as we write this preface, we sadly note that the over 2 million people in the world have tested positive and over 130 thousand lost lives. It is mentioned here in the context that though the discussions do not cover any specific issues related to coronavirus outbreak, they will gain specific policy importance in the post-COVID period. The geopolitical equations that govern the global economic relations and trade especially that of the clean energy industry will witness remarkable changes in the months to come. The flow of finances and technology among countries that lead energy transition would also witness a far more different trend than what was evinced until 2019. Manufacturing and industries that have been part of conventional as well as non-conventional energy sector will witness changes in the coming months. This will also lead to corresponding changes in the patterns of interdependence among countries. The discussions in this book on International Solar Alliance, renewable energy development in India, China and South Korea, and the energy transition initiatives in the Persian Gulf region deserve special attention in this context. Similarly, technology will play a critical role in the energy transition in the years ahead. The collaboration between countries will be one of the major elements that the readers would find interest in.

We are hopeful that this book will present meaningful insights into the dynamics of energy transition in Asian region, to a wider set of readers in academic, policy making and research domains within Asia and beyond.

Hayama, Japan — Nandakumar Janardhanan
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PART I

Overview

CHAPTER 1

Framing the Renewable Energy Context for Asia

Nandakumar Janardhanan and Vaibhav Chaturvedi

1.1 Introduction

Renewable energy (RE) deployment has been making significant strides across the world in the past few decades. Perceptibly, global energy markets have started shifting towards different forms of renewable energy. This movement is driven to a great extent by concerns surrounding energy security and climate change. The securitisation of petroleum energy sector, the demand for diversification away from the conventional fossil fuel sources as a way for reducing the dependency on the geopolitically vulnerable petroleum producing region, and concerns related to mitigating climate change have contributed remarkably to the development of renewable energy sources. Early adoption of renewable energy technologies, mainly solar and wind, was propelled by the European countries, particularly

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Germany and Denmark, which paved the way for continued investment and achievement of economies of scale in the production of solar panels and wind turbines. The rapid decline in costs ultimately changed the direction of global energy markets. The question now is not 'if RE will come in a big way or not', it is 'what will be the pace of this expansion', and will it be fast enough for the world to achieve the ambitious deep decarbonisation targets adopted under the Paris Agreement. The Asian region will play an important part in this transition as the countries in the region are expected to contribute to a significant share of the future energy demand. Even on the supply side, Asia, particularly China, has captured a large share of the international supply of renewable energy technologies. Other countries have tried to increase their market share of the renewable energy technology supply. Currently one can witness that though the countries in Asia have very different political, economic, and social circumstances, renewable energy technologies have been increasing, and are expected to increase significantly in the long-term future irrespective of the contrasting contexts, and alter their footprint in Asia's energy scenarios with a higher share of renewable.

Challenges, however, remain for the pace at which renewable energy is going to be deployed. The biggest potential renewable energy resources, be it solar, wind, or tidal energy, are variable and uncertain. Technical challenges for integrating these sources in the grid are being faced and solutions are emerging. Technical challenges are arguably easier to solve. What is probably more difficult is changing the way economic rents in the energy sector are distributed. Business models that are emerging are challenging the status quo and altering the game. The issue of how to manage losers during the transition process is already throwing challenges. The discovery of unconventional fossil resources, especially shale gas, is only adding to the uncertainty. The geopolitics of the transition could also impede it. Asia has some of the largest oil producers in the world, who will need to implement and manage drastic changes to their economy to align with a renewable driven Asia.

This chapter presents a framing outline for the renewable energy transition in Asia. It first presents and discusses a framework for RE in Asia, its different elements, and then provides an overview of the key discussions that are the focus of this book.

1.2 Key Elements of the Framework

Several factors impact the future of RE in Asia. The first key element of the framework, that differentiates most countries in Asia from those in North America or Europe, is the policy priority increasingly being given to energy access. Access is not just about supplying energy, it is about supplying energy at an affordable cost to the poorer segments of the society. As grid extension is expensive, many developing countries are experimenting with off-grid solutions, which give a fillip to renewable energies like solar or biomass which are more amenable for off-grid and mini-grid solutions (Fig. 1.1).

Another fillip to RE comes from the interaction of energy security and climate change. Many Asian economies import fossil fuels to meet their energy requirements. At the same time, they also have significant domestic reserves of fossil fuels, e.g. coal for China and India. Addressing the challenge of climate change requires a serious move away from fossil fuels. While this is expected to enhance the energy security of many Asian nations that

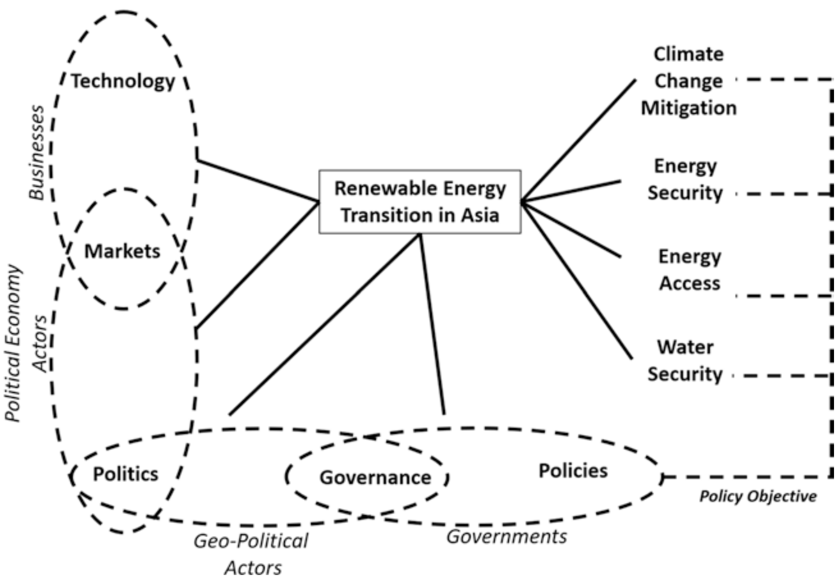

Fig. 1.1 A framework for renewable energy in Asia. (Source: Authors' analysis)

are oil importers, it also implies that they will not be able to use their domestic fossil resources, like coal in China and oil in the Middle East. Solar, wind, hydro, and biomass are resources that are available across all geographies and can be harnessed within countries for enhancing their energy security. Hence, the interplay of climate change and energy security implies a positive outlook for RE in Asia. This, however, is complicated by politics.

Another relevant debate is about the geopolitics in RE sector. As traditional energy producers and their revenue models get disrupted, their incentive is to impede the transition towards a low-carbon society, while traditional energy importers' incentive is to start gaining market access and power over the new supply chains that are being created for renewable energy. This can be best illustrated by the critical minerals required for solar panels. As more and more countries use solar panels, manufacturing of panels is emerging as a big business opportunity. However, some critical minerals are required for this process which are not available everywhere, or the process of mining these has a significant cost to the local economy in terms of local environmental pollution. Countries are already competing to gain control of global companies that have control over critical mineral mines. The emerging geopolitics will have its own winners and losers, and will shape pathways for energy markets, renewable technologies, and policies for pushing these.

The larger forces of policy objectives, geopolitics, and market dynamics determine the fate of technologies. Access to technology and energy sources is heavily influenced by politics and geopolitics, which introduce an element of competition between different countries and various market players. In contrast, there are also opportunities for technology cooperation that could be harnessed, ensuring a win-win for all. In the technology debate, a significant role is essayed by innovation, and research and development (R&D). R&D has been critical in the development of technologies like solar photovoltaic that are spearheading the revolution towards a green energy system. This book discusses technology collaboration among countries and introduces the concept of co-innovation, which is a collaboration and iterative approach to jointly innovating, manufacturing and scaling up technologies.

Markets are fundamental to any transition. The incentives provided by markets to actors on both the demand and supply side of any commodity make it possible for the commodity to move up the supply chain. Unless markets move decisively in the favour of RE, it would be impossible for the world to move away from fossil fuels. A key element in markets is prices of competitive goods that ultimately determines which commodity would dominate. Prices are shaped by many factors. The primary ones being R&D and economies of scale. Once R&D is successful in creating a scalable technology, the economies of scale have to play an important part in price reduction of that technology. Government policies play an instrumental role to drive up economies of scale.

Policies, in the context of RE, are measures introduced by governments to support uptake of RE. These ultimately either incentivise RE or disincentivise fossil fuels. In the beginning phases of the RE revolution, policies were critical in increasing its penetration. The German policy of incentivising roof top solar is much regarded as instrumental in driving solar panel prices down rapidly due to significant uptake of solar energy in its domestic market. Similarly, the Clean Development Mechanism (CDM), a market mechanism under the umbrella of Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC), is known to be instrumental in rapid penetration of wind energy in China and India. These policies changed the direction of energy markets by providing initial support to RE, driving up their demand, and leading to significant decline in costs with economies of scale in production. Once the market becomes competitive, the need for policy support declines and is not required beyond a stage. If this stage is achieved, policies have been considered as successful in achieving their objectives.

Energy policies, however, also have to be mindful of the impact on other sectors, and interaction with other sectoral policies. Energy policies favouring fossil fuels have also resulted in significant air-pollution, both domestic and ambient, as well as water stress in many parts of Asia. Water policies have an unavoidable nexus with energy policies. Traditionally, these resources have been managed in their own silos due to the very different nature of these resources. But it is evident now that choices for RE could impact water security negatively, which is another important objective of policy makers.

The overarching framework, within which policies are and would be devised, markets would be shaped, RE technologies would be ramped up, geopolitics would be managed, and policy objectives would be achieved, is the framework of governance. There could be different models of governance, that countries in Asia choose and have chosen in the past. This would be another critical element that would shape the future of RE in Asia. The book also presents the discussion on internal geopolitics. In the chapter on political risk assessment, the author discusses the interplay of external and internal geopolitics and highlights the finer nuances of the political economy of centre-state engagement in the Indian context.

Ultimately, it is the actors that play different roles across multiple elements of the framework that we have presented. These actors are governments, business, and actors in the political-economic and geopolitical arena who make choices to achieve their respective objectives. Businesses deal with technologies and markets, governments deal with politics and policies, actors in the political economy of any transition influence political and market choices, and similarly actors in the geopolitical arena influence politics and governance. Understanding the incentives of all the actors related to each element of the framework is going to be critical to understand and influence the future of RE in Asia.

1.3 Energy, Geopolitics and Transition

The unequal geographic distribution of hydrocarbon sources in the world has always been one of the major reasons for geopolitical tensions between countries. The decision of British Royal Navy to shift from coal to oil as fuel to propel the British Military Ships (Yergin 2011) has been often noted as one of the most critical policy decisions that have made way to bringing petroleum resources to the forefront of global energy geopolitics. Subsequently, the surging use of petroleum fuels during World War II has further magnified the role of oil as a strategic commodity that has an undeniable role in the global security domain. It is noted that in international politics energy has been one of the major elements that often brings countries together to corporate and at times to the battlefront.

While the conventional energy sector has been at the epicentre of the global energy geopolitics for long, in the recent years the development of alternative energy sources, the trade associated with the equipment export and import of same and the search of dominance in the global renewable energy market also have been shaping the global geopolitical landscape into a new paradigm. Several points are critical as energy transition emerges as priority in today's world. These include the conflicts between conventional and non-conventional energy sector and the changing debates of geopolitics of energy and of the energy markets.

Dominant energy sources and the industries behind it have always received enormous support from the end-users. As a result, the conventional fossil fuel industry has emerged as a strong player influencing government policy and public perception. The fossil fuel industry has often influenced and shaped bilateral relations between producing and consuming countries. It is also noted that the conventional energy sector has played a critical role in limiting the entry of renewable or alternative energy sources into the mainstream. This is especially important in the case of countries which have been heavily dependent on fossil fuel revenues. Today, some of the major petroleum producers in the world are located in the Persian Gulf region and the non-conventional energy sector is yet to make any significant growth in these countries. For example, the renewable energy sector within the Gulf Cooperation Council (GCC) countries is considered to be at an early stage, through the plans and aspirations are being gradually shaped. (Mas'ud et al. 2018). There are inherent challenges faced by the alternative or renewable energy sector in the GCC countries. First of all, the leading petroleum producers lobby traditionally did not support of the development of alternative energy sector fearing a potential challenge to its own existence. Secondly, there have been huge subsidies given to the conventional sector. These subsidies give conventional power a significant unnatural advantage over RE and limit the private investment in the sector, making RE compete with energy sources that are already cheap and widely available (Ferroukhi et al. 2013).

The global climate mitigation debate and the concerns surrounding conventional energy sector have given way for development of renewable and alternative energy sources in a remarkable way. Even in academic research and policy studies, a significant change has been evident. Though the energy debates have been dominated by conventional energy sector, the perception that interruption of petroleum supplies presents an existential threat to economies has largely changed as countries began to invest heavily in the non-conventional energy. Transitioning to cleaner energy sources has already been a part and parcel of every country's energy policy. Technology cooperation between countries has been an important element in the global energy and climate discourse and has been argued as critical for the transition towards the 'well below 2 Degrees' world (Ghosh 2019). The growing policy attention gained by the alternative energy sector was an outcome of three factors. 'First, the global efforts to reduce energy-related emission led fossil fuel dependent countries to promote energy transition domestically. Second, the over reliance on conventional fossil fuels also posed various economic challenges to fossil fuel importing countries. Energy diversification emerged as significant policy tool to enhance the alternative energy sources and minimize the energy bill incurred to importing countries. Third and the most important factor that shaped energy policy in favour of alternative energy sources has been the security concerns associated with the external supplies of fossil fuels' (Janardhanan 2017).

As alternative energy sector has been growing over the past several years, the equipment and service industry associated with the same has also been developing. Countries that have been investing heavily in the development have made remarkable progress developing efficient technology and equipment necessary for the implementation. Today China is the largest renewable energy producer and major exporter of equipment for the alternative energy production. As the energy equipment export has been increasing, Chinese companies seek to enter into various new markets and in some cases make investment in long term energy renewable energy projects. The $400 million investment in the Cauchari solar power station in Argentina's Puna Jujeña plateau, a super-efficient electrical substation in Kenya's volcano-strewn Rift Valley to funnel clean power from the nearby Olkaria Geothermal Plant, the upcoming, world's largest offshore wind farm in Moray East in Scotland are some of the recent examples of Chinese investment in overseas region (Campbell 2019). China is also selling equipment to several small and big renewable energy developing countries. Though this has undeniably led to the development of the domestic renewable energy in the host country, many have been raising concern that the cheap equipment from China is challenging the domestic industry's survival. While Chinese industry points out that there is no strategy to challenge the local industry in host country, the government report from the US points there has been a deliberate strategy of competition. 'China has achieved a leading position in many traditional manufacturing industries using preferential loans and below-market utility rates as well as lax and weakly enforced environmental and health and safety standards' (White House 2018). The chapters in this book elucidate the geopolitical and policy aspects of alternative energy sector and energy transition.

1.4 Energy Transition: Policies and Markets

Markets and supporting policies play a critical role in achieving any policy objective. Unless markets move decisively in the favour of any resource, that resource will not be able to penetrate significantly. This has been true for the renewable energy pathway as well. Historically, the cost of RE has been much higher than fossil fuels. Global and Asian energy systems, consequently, have been dominated by fossils. This, however, started changing in the last decade with renewable energy witnessing a much higher growth trajectory.

A large part of growth in RE came on the back of development in electricity generation technologies. Wind energy started growing in early 2000s in Asia, mainly due to support from Clean Development Mechanism (CDM), one of the market mechanisms under Kyoto Protocol. Essentially, CDM meant financial support to low-carbon technologies which otherwise were financially unviable. The cost of solar energy was very high during this period, while wind energy was much cheaper. A large part of CDM money went to support wind energy, especially in China and India. This financial support through global policy intervention was critical for developing Asian countries in the initial period of wind energy deployment.

From early 2010s, however, markets decisively shifted in favour of solar energy, mainly photovoltaic (PV) technology. Costs of PV technology has fallen significantly in the past decade, driven by cheaper materials, as well as cheaper production process due to economies of scale. Global markets have been increasingly dominated by cheaper solar panels from China which has made it possible for many Asian countries to increase the share of solar in their electricity generation portfolios.

Even though costs of solar and wind have declined continuously, the importance of domestic policies in pushing these RE technologies cannot be over emphasised. All the Asian countries have been pursuing domestic policies in one form or the other to push renewable energy. Feed in Tariffs have been used to incentivise solar and wind electricity generation. Biofuel mandates have been put in place. Countries have favoured transparent processes like auctioning to get the lowest bids. Must run status has been provided to solar and wind power plants. Dedicated infrastructure has been built to evacuate variable renewable electricity. Legal and contractual frameworks have been strengthened. Co-benefits has been an important theme assisting the penetration of RE. Particularly in China and in India, air-pollution and energy security have been important drivers of RE. Generally speaking, Asian countries have followed by and large a similar template in terms of domestic policies for pushing renewable energy. The only difference has been in terms of the fuel that has gained the most. For example, for most countries in Asia, solar power has a huge potential as compared to wind. Consequently, most of the policies in these countries have been focused on promoting solar energy, though wind energy has also got a lot of policy support. As against this, many countries in the EU region have abundant wind potential, and less of solar potential. The policies in these countries seek to maximise the penetration of wind energy.

Research and innovation have always been a critical pillar for the commercial development of any technology, same has been the case with renewable energy. However, one country that has been much more structured in terms of its approach for research and innovation has been South Korea. It had a dedicated programme, called the New and Renewable Energy Research, Development and Demonstration Programme. Within this, there were and are programs related to basic technology development, technology commercialisation, and knowledge capability and infrastructures. This is detailed in the chapter focusing on the historical evaluation of Korea's policy on renewable energy. These programs were supported by R&D implementation plan and promotion strategy focused on green technology. Funding was allocated to R & D for four strategic technologies- integrated gasification combined cycle (IGCC), wind power, solar PV, and fuel cell. Korea has always been a leader in R & D, and this has been a result of dedicated policies for promoting R&D.

Countries have also attempted following export led strategies. This is most clear for China, and increasingly being attempted by India, as discussed in the chapter on green industrialisation. China has been increasingly dominating global exports because of its labour cost advantage, administrative efficiencies, subsidies to industrial sector, as well as exchange rate management. It has extended this to the renewable energy sector as well, where it has become the biggest exporter for solar panels. India has off late been trying to emulate the same without success, because of multiple economic and administrative regions. The Chap. 5 argues that export led green industrialisation makes it easier to shift to renewable energy domestically. Many countries do envisage having some domestic manufacturing capacity for supporting domestic jobs and value addition.

The transition would be very interesting in the Gulf Cooperation Council (GCC) countries, as described in Chap. 8. These countries, traditionally, have cooperated to create a monopoly in the global oil market, hence the need of a cooperation council. In the wake of the impending transition towards renewable energy, these countries are trying to adjust their electricity markets, which in general are public monopolies with an almost 100% reliance on fossil fuels given their domestic reserves of oil. Though there is a significant potential for harnessing solar energy, these countries might need to import solar panels, or import the minerals required to manufacture panels. While the cooperation is always a source of strength, how the current cooperation framework based on oil resources evolves when (and if) oil exports reduce significantly due to climate change concerns, will be interesting to watch.

Though countries have been doing a lot in terms of domestic policies, low-cost finance has been an impediment in most developing countries of Asia. High cost of finance implies a higher perception of underlying risks related to RE projects. Risks are shaped by strong legal framework and contract enforcement process, as well as critical infrastructure like availability of land, transmission infrastructure, etc. In developed economies like Japan, Korea, or high-income countries of the middle east, as well as China which have a strong credibility to implement plans, cost of finance for RE projects is not much of an issue. However, in the developing countries of Asia, cost of finance could be the single largest component. De-risking projects in the new sectors like solar energy is critical for the pace of growth. The role of strong legal frameworks and platforms like the International Solar Alliance (ISA) becomes critical.

Legal frameworks are critical for the success of any new and upcoming sector, like RE. The RE debate, as it stands now, is largely a debate related to the electricity generation sector, though many countries also have policies related to liquid biofuels for use in other sectors. Arguably, the single most important instrument for ensuring strong legal architecture is that of Power Purchase Agreement (PPA). PPAs are long-term contracts that define the terms of engagement between the seller (RE electricity generators) and the buyer (distribution company). There are different kinds of risks that a RE generator faces- off taker risk, technology risk, infrastructure risk, demand risk, political/regulatory risk, and currency risk, as explained in Chap. 9 on power purchase agreements for risk evaluation. The PPA has to ensure that these risks are identified, priced, and allocated in the most rationale way that is conducive for the sector. As countries move from an incentive support policy (e.g. Feed in Tariff) regime to a competitive auction-based regime, the role of long-term purchase agreements becomes even more important. Ultimately, it is crucial to have a balanced understanding of risks in the markets for supporting RE in Asia.

Along with legal frameworks for addressing risk concern of investors, another crucial development is the creation of International Solar Alliance (ISA). ISA is the newest multilateral organisation, with an aim to help increase the penetration of solar energy by bringing solar rich nations together and offer a larger market, facilitating deployment of existing solar technology, reducing prices further, and promoting collaborative solar R&D and capacity building. ISA has the potential to play a decisive role in enhancing the share of solar energy in Asia through market interventions. One such instrument that is being discussed at the ISA platform is the Common Risk Mitigation Measure (CRMM) that seeks to address three categories of risks (off-taker, currency and political) through a single facility. Through appropriately reallocating risks in developing Asia, and lowering the cost of finance, ISA can ensure significant benefit for the cause of climate change mitigation. There could be many interventions related to solar mini-grids, solar roof-top, etc. that could be facilitative by ISA, as explained in Chap. 4.

1.5 Emerging Issues Shaping Renewable Energy Transition in Asia

Traditionally, policy and markets have been the most critical for the pace of uptake of a technology. Supportive and aggressive policies have managed to rapidly scale up technologies, while ill-conceived policies have distorted markets while failing to achieve policy objectives. Along with policies that focused on the core themes of supporting grid connective large investments in renewable energy, there are some emerging issues that have the potential to shape the debate in a significant way. Water-energy nexus has been at the forefront of such issues and has been in mainstream conversations since almost a decade now. Framed broadly under the food-energy-water-climate nexus, the issue seeks to highlight the critical trade-offs between water and energy, across many levels on which they interact. Literature on this issue has been growing exponentially in the last few years. Many Asian countries are water scarce, and water could become a constraint on processes related to energy production, transformation, and distribution. Similarly, energy availability and prices could impact water treatment and provision for different needs.

Some of the emerging critical nexus narratives, as highlighted in Chap. 12 are related to (i) renewable energy integration, (ii) carbon capture and storage for negative emissions, and (iii) solar pumps for irrigation. The first two narratives are critical for a low-carbon world, while the third is critical for food security and livelihoods for the farmers, along with impacting the emissions debate. The first narrative on RE integration highlights the trade-off related to the concentrated solar power (CSP) technology. This solar technology has been highlighted as an important technology, better than photovoltaic (PV) in terms of integration of variable renewable energy in the electricity grid. However, the best resource for CSP is in desert and arid regions like the middle East where water is a big constraint. The water footprint of this technology is much higher than that of PV. The second narrative highlights the significant water requirement for bioenergy crops, as well as CCS technology for power generation. The water required while growing biomass could become a constraint for many economies, which might need to import biomass from water abundant areas. CCS also requires a higher amount of water during the power generation process. Water constraint on bioenergy-CCS could impede the world's progress towards the 'well below 2 degrees' goal as enshrined in the Paris Agreement. Finally, the third nexus narrative is related to solar pumps, which are growing at a fast pace in south Asian countries that have significant area under agriculture. Solar pumps, though capital intensive, take away any incentive to conserve water as there is no marginal price of water. Unless solar pumps use is coupled with innovative arrangements and business models to incentivise water conservation, their scale-up could be detrimental to the groundwater situation of already water stressed Asian countries.

The nexus element is also an emerging challenge to central Asian countries, that are increasingly facing water related trans-boundary conflicts. The trans-boundary water resource was managed within one framework when these countries were with the Soviet Union. With the collapse of the union, conflicts have started emerging. Chapter 13 presents a unique nexus perspective for central Asian economies with a focus on hydropower and the synergistic impact of this resource on the macroeconomy as well as cooperation between these countries. The central Asian region has traditionally had a history of cooperation. Water resources are concentrated mainly in two countries in this region, Kyrgyzstan and Tajikistan, which can be used to provide low carbon power to other countries in the region through a cooperative cross-border electricity trading framework. This chapter highlights the positive benefits for the macroeconomy as well as energy-water linkages in Central Asian countries through a general equilibrium analysis. Investments in forward and backward linkages of hydropower would have significant implications for trade, investment and GDP of the region as well as impact energy related emissions of central Asian countries.

Another emerging issue has been that of solar-based mini-grids. Energy access has been a high-priority issue for economically poor countries of Asia. Energy access is one of the most important development concerns of the world. As investments in central grid expansion could be significant, many Asian countries are exploring setting up solar-based mini-grids to provide access to underserved communities. The experience has been largely positive. The critical question, as explored in Chap. 11, is what happens to a mini-grid when a community or village gets connected to the central grid. A case-study-based analysis presented in the book argues that solar mini grids could complement the central grids during peak hours, and predictable grid expansion plans are important to maximise the gains from mini-grids.

1.6 Conclusion

Asian countries are at different stages of energy transition. Japan has been a major consumer of imported fossil fuel for several decades and countries like China have emerged as major energy consumers in the recent decades. On the other hand, many of smaller economies in the South and Southeast Asian region have comparatively higher share of non-fossil fuels in their energy mix. Hence, it may be difficult to draw a common pattern and the catalysts behind the pace of energy transition in Asia. However, as described earlier in this chapter, one can notice several major elements that shape the energy transition though there is no uniformity in the magnitude of influence of each factors across the region.

The framework proposed in this chapter looks at the interplay of the key elements such as governments, geopolitical factors, political economy and business, and the role played by these elements in influencing the energy transition through policies, governance, politics, market, and technology. Undeniably the governance structure and the policy apparatus in Asian countries have been influenced by various global and regional factors. Policies of governments based on their respective national circumstances, domestic, environmental trends etc. have made remarkable steps towards the development of renewable energy sector. On the other hand, the geopolitical considerations have been two folded. The need for diversification of energy supply away from politically volatile producing regions, and the potential instances of clash of energy search by Asian countries within and outside the region have given impetus to energy transition debates.

Though Asian countries were relatively late entrants in the global renewable, the pace of development of alternative energy industry in China and India, and the increasing demand for cleaner energy sources in other developing economies mainstreamed energy transition debate in the region. Another significant factor that shaped energy transition in Asia has been the growth of domestic energy industry, especially in China, and the availability of technologies and cost-competitive equipment supply from China. As private sector investments and government funds as well as financial incentives for developing renewable energy began pouring in, China's trade of renewable energy equipment and technology to other developing economies in the region gained remarkably. While many countries have often raised concerns about the cost-effective Chinese equipment and technology hampering their respective domestic energy industry, this has undeniably given impetus to energy transition in the region.

Being at the epicentre of global consumption of commercially traded primary energy sources, the Asian region will continue to play a determinant role guiding the world energy sector in the years to come. This will be not only in the case of fossil fuel consumption but also in terms of greater investment in the alternative energy sector, technology and innovation, transborder trade of electricity, and cooperation among the countries in the region.

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PART II

Technology and Politics

CHAPTER 2

Leveraging Co-innovation Model for Energy Transition: Examining India's Engagement with Japan and China

Nandakumar Janardhanan

2.1 Introduction

The growing dependence on fossil fuels and inefficient energy usage together led to a significant increase in greenhouse gas emissions across the world. No country alone is capable of addressing the complex threats of climate change in the present-day world. To address the growing emissions and climate impacts, integration of better technologies across various energy-producing as well as energy-consuming sectors is necessary. Addressing trans-border impacts of greenhouse gas emissions, complex technical needs of mitigation and adaptation initiatives, demand for scientific knowledge and innovation capability, and so on requires greater interdependence among the countries. To meet the domestic demand for cleaner energy and for transitioning from fossil fuel-based to a clean-energy-based economy, technology remains critical for the developing countries. As the lack of availability of advanced technologies has been a

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critical impediment, developing countries often turn to overseas players for technological support. Global initiatives of climate mitigation under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) also stipulate that financial resources and technology transfer to developing economies are critical in their fight against climate change.

However, the existing predominant models of technology collaboration are often limited to the sale of finished products from technology supplier to the recipient country. This makes the recipient economies merely the market for the source country's products. Despite being the customers of imported products, many recipient economies face three critical challenges with regard to access to advanced technologies—'Affordability', 'Adaptability' and 'Market threat'.

First, with regard to affordability, one may note that the cost of the imported product always hindered the popularisation of a specific technology, thus limiting its access where it is necessary. The suppliers are keen to sell at a premium in the available markets. As there is a lack of advanced technology to meet the growing domestic needs, developing country customers end up paying a premium to access the technology supplied by the source countries. Even with regard to the technologies that are 'appropriate' (Wicklein 1998) in terms of efficiency and have the potential to play a significant role in emissions reduction, affordability remains a critical barrier. Second, in many developing economies, adapting to the advanced technology and its acceptability among consumers are other important challenges. The integration of imported technologies without adequate customisation will limit the recipient country in making full use of the imported technology. Even for those technologies, which are important in terms of environmental benefits, factors such as lack of continuous support, lack of adequate capacity in operations, and lack of adequate customisation to local conditions place serious limitations on their popularisation. Third, the supply of finished products to meet the technology needs in a developing country also adversely affects the recipient country's domestic industries. This has often pushed the domestic manufacturers out of the market or turn them into mere suppliers and resellers of the imported technology or products. On certain occasions, overseas players have been seen as *predatory* by certain domestic industries as the former's cheaper and more efficient technologies systematically oust the latter in markets where both compete. One example is the heavy dependence of India on Chinese players to meet the domestic demand for renewable equipment, especially in the solar power sector. Due to the cheaper supply of solar panels and modules from China, it has been observed that (Parliament of India 2018) India's domestic industries have been reduced to mere suppliers or resellers of Chinese products in recent years.

This chapter introduces co-innovation as a potential solution to address these multiple challenges faced by developing countries against the backdrop of their energy transition initiatives, and their efforts towards building a more sustainable society. As the chapter discusses co-innovation in the case of developing countries, it takes the example of India to explain the experiences of technology transfer and the associated opportunities and challenges. The next section focuses on the need for advanced technology in India against the backdrop of the energy transition and climate mitigation initiatives. Then the chapter discusses the collaboration between India and Japan on the low-carbon technology front. The following section discusses Indian industries losing out to overseas competition, especially to Chinese companies. In order to examine this, the chapter looks at India's dependence on Chinese equipment imports for the renewables sector and how India's players have been losing out to Chinese companies in the domestic energy market. The following section focuses on the role of co-innovation in facilitating better technology collaboration. The chapter then concludes by highlighting the role of co-innovation in the context of developing countries and the advantages it has in giving impetus to energy transition.

2.2 Role of Technology in Energy Transition

The role of technology has been highlighted as a critical element in addressing climate mitigation, originally by the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC/FCC), which was established in 1990. The committee has further recognised that Technology Transfer (ToT) is a significant step considering the 'common but differentiated responsibilities' of developed and developing countries (UNFCCC 1990). The fact that the lack of adequate technology in developing economies would continue to be a critical impediment in addressing climate change has further strengthened this perception. However, while the convention emphasises the importance of ToT and collaboration in Paragraphs 1 and 5 of Article 4 as well as in Article 10 (UNFCCC 2016), these have only resulted in shaping various market mechanisms which are yet to make any significant impacts in addressing the technology gaps in the developing countries.

The International Energy Agency's analysis shows that energy-related CO_2 emissions need to be 52% below the current level by 2040 to be on track with the Paris Agreement (IEA 2019). With regard to strengthening the energy transition in developing countries, advanced technology can undeniably play a critical role. The energy transition involves the accelerated deployment of renewable energy technologies and energy efficiency, which requires systemic change, matching and leveraging synergies in innovations across all sectors and components of the system, and involving multiple actors (IRENA 2020). This is critical for the developing economies as there is a need for an enormous change in the way these countries use environmentally damaging fuel sources to meet domestic economic growth. Facilitating the transition from fossil fuel-based to cleaner fuel-based mobility, minimising the usage of coal and fossil fuels in the industrial sector, integrating advanced systems to reduce consumption in all energy-consuming sectors, and so on require upgrades to existing technologies.

2.2.1 India's Dependence on Imported Technology

The country's renewable energy expansion plans have benefited from the cheap supply of equipment and machinery from other countries, mainly China. However, it is often noted that the over-dependency on China has also led to the vulnerability of India's renewable energy supplies, as disruptions in supply have adversely affected the growth of the sector. In order to develop alternative supply lines of equipment and machinery from within the country, the industry will need to integrate advanced technology which can facilitate cheaper and more efficient production competitive with the imports. Improving industrial energy efficiency, achieving electric mobility, and strengthening the energy efficiency in the residential and urban building sector are critical targets in order to further meet the energy transition plans of the country.

India also seeks technological assistance in controlling carbon emissions and in limiting environmental damage, using the climate negotiation platforms as well. The alarming growth of carbon emissions in the country also demands urgent action. 'Even though India has one of the lowest per capita energy consumption in comparison to other major emitting countries, the total CO_2 emissions increased by 71.4% between 2007 and 2017 and reached almost 2.3 Gt in 2018, with an annual growth of 4.9% from 2017' (IEA 2019). For India, reducing greenhouse gas emissions and increasing the renewable installed capacity demand integration of advanced technology across the sectors. However, the efficacy of technology collaboration initiatives between India and potential technology source countries faces critical hurdles. The suitability of overseas technology in Indian domestic conditions, concerns regarding royalties, legal issues related to use of a specific technology, lack of adequate customisation adaptive to local conditions, lack of adequate post-sales support and intellectual property rights, and so on are often major hurdles for strengthening technology collaboration. Hence, 'ToT' or 'collaboration' is often reduced to the sale of finished product or equipment to India from the source country which has mature technologies.

An assessment of the technology gaps in addressing climate mitigation highlights that several energy-producing and energy-consuming sectors have been facing a lack of access to efficient technologies in a sustained manner. India's Biennial Update Report also indicates that 'transfer and grounding of appropriate technologies and know-how is the key to enhancing adaptation and mitigation measures' (MoEFCC 2018). The report also presents an array of technologies that are critical for the country to meet its climate and energy goals, the most critical of which are the needs in the transport, industry, power and building sectors. The report states that by 'learning from the collective wisdom of innovators elsewhere, India can complement its efforts and fast-track the development of environmentally friendly technologies appropriate to its national circumstances and requirements' (MoEFCC 2018). However, to put this into practice, India needs to encourage alternative approaches to technology collaboration.

2.2.2 *Key Sectors and Technology Need in India*

The industrial sector especially plays a significant role in India's GDP. It is also a major contributor to the Gross Value Added (GVA2), which in 2016–17 accounted for 31% of the total. Among industries, the micro, small, and medium enterprises (MSMEs) play a significant role, not only for their contribution to the GDP but also for the fact that a significant share of the industrial workforce is employed in this particular sector.

> The Ministry of MSME, of the Indian government estimates that around 100 million jobs are generated through over 46 million units situated through-

> out the geographical expanse of the country. With 38% contribution to the nation's GDP and 40% and 45% share of the overall exports and manufacturing output, respectively, it is easy to comprehend the salience of the role they play in the social and economic restructuring of India. (Kapuria 2015)

For a country like India, the numerous industrial activities and the energy required to run these industries need to be complementary to the emissions reduction plans that have been given utmost importance over the past few years. The past 10 years indicate that a significant increase in the consumption of fossil fuels has taken place in India. 'The total consumption of raw coal by industry has increased from 462.35 MT during 2006–07 to 832.46 MT during 2015–16, while the consumption of petroleum sources, especially oil and gas increased from 146.55 MMT during 2006–07 to 232.87 MMT during 2015–16' (MoSPI 2017). This has also led to a corresponding increase in greenhouse gas emissions and has made way for direct as well as indirect damage to the environment as well as to human beings.

On the other hand, India has been equally concerned about reducing fossil fuel consumption, primarily because of the dependence of the key energy-consuming sector on these fuels. Industry and transportation heavily depend on fossil fuel usage, which is also critical in meeting the overall national economic targets. However, balancing the energy-economy-environmental targets is crucial for the long-term sustained economic development of the country. To achieve this, the transition to non-fossil fuels is being prioritised by the government with the aim that India's emissions intensity will be substantially reduced in the years ahead. A combination of measures that include supply-side as well as demand-side measures driven by advanced technology is needed in this regard.

The fact that India has massive energy-saving potential is another critical reason for integrating advanced technology in the major energy-consuming sectors. Here, industry, especially MSMEs, emerges as a natural choice with its immense energy-saving potential. India also has been aiming to promote the widespread use of electric vehicles for public transportation. Though there are existing technologies for electric mobility, their exorbitant cost has been adversely affecting their popularisation in India. In addition, the lack of efficient technologies for advanced battery storage and charging facilities and lack of vehicle designs that suit the needs of the Indian consumer also limit the popularisation of existing electric vehicle technologies.

2.3 India's Energy Transition and Technology Needs: Role of Japan and China

Japan and China have been playing an important role in advanced technology-based equipment and machinery in India. While Japan has been India's long-term partner for several decades, China's growing presence in the global equipment and machinery supply chain has benefited India's energy transition initiatives.

2.3.1 India—Japan Technology Collaboration

The progress Japan has achieved on the energy efficiency and energy conservation front is a remarkable learning opportunity for other less developed economies. The governments of Japan and India have been giving great importance to bilateral trade and technology collaboration. The two countries have 'underlined the need to intensify cooperation in technology, space, clean energy and energy sector development, infrastructure and smart cities, biotechnology, pharmaceuticals, ICT, as well as education and skills development to strengthen and deepen their Special Strategic and Global Partnership' (MoFA 2016). They have been collaborating on the technology front for several decades. Japanese technologies have gained widespread recognition as reliable and state-of-the-art technology solutions for diverse sectors. Japan's International Cooperation Agency's role in India in promoting advanced technology for heavy industry as well as various notable national projects have been some of the examples. Japanese—Indian joint efforts to develop Maruti Udyog Limited, metro rail projects that are operational in Indian cities, and the multi-city transport corridor projects are some of the examples of the use of Japanese technologies in India. In the industry sector, too, Japanese technologies play a major role both in heavy industries and the micro, small, and medium enterprises (MSMEs). India's domestic initiatives to improve energy efficiency in the industry and the key energy-consuming sectors will undoubtedly benefit from technology collaboration with Japan.

India has been the largest recipient of Japanese Official Development Assistance loans in past decades (Ministry of Foreign Affairs, Japan 2020). However, most of the technology collaboration and financial assistance to India from Japan has been directed towards supporting the transportation sector, especially metro rail projects. This is despite the fact that there is a high demand for Japanese technology and equipment in the Indian market that has a direct bearing on clean energy generation and energy efficiency. The Japanese private sector's interest in India is rising, and currently approximately 1305 Japanese companies are representing various industries that have branches in India. However, it should be noted that the actual potential of collaboration between India and Japan can be several times greater than what is happening currently.

Market options such as the Clean Development Mechanism, which spearheaded ToT in the past, have not only witnessed a fall in the rate of implementation but also faced limitations in terms of narrow geographical and sectoral coverage (Chatterjee 2011). On the other hand, bilateral mechanisms focusing on the transfer of technology in the form of subsidised sales of finished products also did not hold much appeal for the developing country stakeholders due to economic and technical factors and concerns regarding accessibility, availability, and affordability. Japan's push for a joint crediting mechanism, which also could potentially facilitate technology transfer, has not convinced the Indian policymakers of any notable advantages. Concerns regarding the operationalisation of such an agreement and the lack of information available to the stakeholders pose a critical challenge to concluding the agreement.

Despite the strong bilateral relations India and Japan enjoy, India's bilateral engagement in terms of overall trade or the sale of equipment or finished products required for the industry is remarkably low compared to that with China. To achieve the full potential of enhancing technology collaboration, the countries need to work together and eliminate all possible hurdles that limit collaboration on the technology front.

2.3.1.1 Limitations in Strengthening Technology Collaboration with Japan

Several key factors adversely affect the technology transfer or the collaboration for sharing know-how on advanced technology from Japan to India. Three main factors are listed in this chapter: cost competitiveness, compatibility, and business practices.

Indian customers in the MSME industry sector have often noted that Japanese technologies, despite their advantage in terms of energy-saving potential and durability, are not preferred especially due to their high cost. Similarly, the compatibility of advanced technology remains a key hurdle in technology collaboration. Interactions with industry experts have also highlighted that lack of acceptability of technologies from Japan to India is also because the equipment and machinery supplied in the market do not always take into account the domestic demand and local conditions that influence usage. Hence, the perception of the complexity of a particularly advanced technology/finished product limits its adoption and diffusion in the Indian market.

Technology use in industries is often influenced by regional, geographic, and climatic factors, as well as the practices of maintenance and operation. There is a clear demand for integrating local solutions to these hurdles. Necessary modifications in the equipment to fit the climatic changes, usage and load patterns, placing of equipment in the industry premises, and operation and maintenance will be critical in ensuring the adaptability of the equipment. In addition, flexibility in modifying or refurbishing the equipment is also critical in many developing country contexts. For example, some of the pilot installations of Japanese technology experts (Interviewee-A 2016) revealed that Japanese machinery and equipment are complex in design and do not allow for easy replacement of spare parts, eventually limiting their acceptability in the Indian market. For a product manufactured abroad but sold for local industries in a technology-recipient country, flexibility concerns regarding the designs remains critical. The location of the manufacturing facility, availability of spare parts, availability of locally accessible technical expertise, and so on are also key factors that are critical for successfully promoting technology collaboration.

Another major concern with regard to technology transfer is the perception of a lack of timely post-sales support. Many of the Japanese players are unable to maintain a reasonable ratio of servicing personnel to equipment installations (Interviewee-A 2016). Only in exceptional cases can Japanese players create an adequate presence in post-sales servicing. With regard to industrial refrigeration, an interviewee noted that very few overseas companies which have a long-term presence in India can meet the post-sales service requirement. For example, specifically in the refrigeration sector only one Japanese company maintains the installation to service personnel ratio at 1:20, while the rest of the other leading industry players from Japan can maintain only approximately a 1:100 ratio for installation to service personnel (Interviewee-B 2016). As Japan has achieved substantial improvement in energy-efficient technologies it has received much attention from the Indian industry players. However, the integration of these technologies in India faces serious challenges due to concerns regarding the initial capital cost (Interviewee-C 2017). These concerns continue to be critical challenges in strengthening collaboration between India and Japan.

2.3.2 China's Export of Equipment and Machinery to India: Politics vs. Technology

It is interesting to note that the Indian industry and consumers resort to the usage of cheaper equipment options, often received through imports from China. While China continues to be the major source of exports of renewable energy equipment to India, this has also adversely affected the latter's domestic industry production to a significant degree. Though the Indian industry is concerned about over-dependence on equipment supplies from Chinese manufacturers, the clean energy development targets in India have been forcing India to continue its dependence on China. In the case of the renewable energy industry, India imported (Chandrasekaran 2017) almost 87% of the total solar panels required to meet its domestic demand in 2017, of which the majority were imported from China. Recent years have witnessed a substantial increase in energy equipment imports from China. During the fiscal years 2017, 2018, and 2019, India's solar sector imports from China stood at $2817.34 million, $3418.96 million, and $1694.04 million, respectively, which is far higher than India ever imported from any other country (ETEnergyWorld 2020). Though there have been domestic manufacturers involved in solar equipment production in the past, the high influx of cheap equipment from China eventually turned the domestic manufacturer into a retailer of Chinese goods.

It can be noted that India does not consider import dependency on China as a long-term plan; rather it is to meet the immediate demand due to the domestic energy transition targets. However, one of the critical questions raised by many concerns whether or not India can build its domestic industrial production capacity if it continues to depend on imports. This points to the need to increase domestic industrial capacity and improve domestic supply lines of key equipment and machinery.

As per the Paris Agreement, India has also planned to achieve a 40% non-fossil fuel-based supply in the electricity mix. India's renewable energy targets of 175 GW by 2022 and 450 GW by 2030 demand an uninterrupted supply of key equipment and machinery to the renewable energy sector. This further adds pressure on the country to enhance renewable energy production, which inevitably leads to the demand for imported renewable energy equipment from China. However, considering the fact that domestic industry production is insufficient to meet the clean energy targets, the dependence on Chinese products has been growing substantially.

As Chinese exports to India have benefited the domestic energy transition plans, it should be noted that two main concerns have been adversely affecting the collaboration: first, China's exports of cheaper goods to the Indian market; and second, the concerns regarding Beijing's larger strategy to dominate Indian markets. The first is the domestic concern about the dumping of cheap equipment in India and thereby flushing out the domestic industries. It should also be noted that 'Chinese enterprises benefit from preferential policies that lead to subsidized overcapacity in China's domestic market, which then depresses world prices and pushes foreign rivals out of the global market' (White House 2018). While India's trade deficit with China has been widening, imports of Chinese equipment for use in the industrial sector have significantly damaged the MSME. The government has estimated that the dumping of Chinese solar panels in India has resulted in nearly 2,00,000 lost jobs in the MSME sector (TNN 2018) in the energy equipment production arena.

The second concern involves the apparent geopolitical strategy of China (Freeman 2017; Janardhanan 2017) to indirectly weaken India's domestic energy industry and make it heavily dependent on Chinese supplies. It is often noted that 'the Chinese government is implementing a comprehensive, long-term industrial strategy to ensure its global dominance. Beijing's ultimate goal is for domestic companies to replace foreign companies as designers and manufacturers of key technology and products first at home, then abroad' (US-China Economic and Security Commission 2017). It has also come to light that China uses a *predatory* 'debt trap' (White House 2018) model of economic development and finance that proffers substantial financing to developing countries in exchange for an encumbrance on their natural resources and access to markets. Even in India, some observers have noted that China has been pursuing a similar strategy which can be termed predatory. India, out of concern for over-dependency on imports, has imposed a '25% safeguard duty on solar imports from China' (Lal 2018). However, it should be noted that products made in China are often re-routed through neighbouring countries and then to the final destination: Indian markets. The 'Indian Parliamentary Committee report in 2018 found that Chinese manufacturers were also re-routing their products through the markets of other countries that India has Free Trade Agreements (FTA) with. Straddling South East Asia, underdeveloped members of ASEAN have served as hubs for Chinese exporters to circumvent anti-dumping and countervailing duties' (Waghmare and Chakraborty 2018). It is often understood that once dependency is developed on overseas supplies, conventional trade barriers will not be effective.

2.4 Strengthening India's Energy Transition Through Co-innovation

Energy transition in India is a technology-intensive process, as the existing fossil fuel-oriented energy production and consumption infrastructure will need to undergo a drastic change. Fossil fuel-based electricity-generating facilities, internal combustion-based transportation modes, hydrocarbon-based industrial activities, and so on will need to undergo changes for the country to make significant progress in energy transition. As of 2017 accounts, renewables, primarily wind and solar together, have accounted for only 1% of Total Primary Energy Supply (TPES), while coal and oil constitute roughly 44% and 25% (IEA 2020) respectively. In order to significantly improve the share of renewable energy in the TPES, innovation in energy generation is critical. This should not be limited to the technology front but must also involve information technology, policy frameworks, market design, business models, finance instruments, and enabling infrastructure (IRENA 2020). The country also needs accelerated deployment of technologies for renewable energy generation and energy efficiency. Collaboration with Japan and China can contribute to the development of technologies in India; however, the country needs to address the inherent concerns regarding collaboration with these two countries. Here, co-innovation can play a key role. India can co-innovate with Japanese players and produce the equipment and machinery domestically. The domestic policy environment supporting industrial production will also help strengthen the *business-to-business* engagement between these two countries. With regard to China, concerns pertaining to the influx of cheap Chinese goods and Indian industry losing out to its Chinese counterparts have already been adversely affecting trade relations. Co-innovation can help strengthen trade relations and build mutually beneficial collaboration pathways between the two. The subsequent sections discuss co-innovation and the approaches for operationalising this.

2.4.1 Co-innovation: A Conceptual Understanding

Co-innovation is defined as *a collaborative and iterative approach to jointly innovate, manufacture and scale-up technologies* (Janardhanan et al. 2020). While it is a relatively newer approach for discussing technology collaboration between Asian countries, it has been widely used in the context of the IT sector. It is also referred to as 'a shared work of generating innovative and exceptional design conducted by various actors from firms, customers, and collaborating partners' (Saragih and Tan 2018). Along with this concept, two other approaches are also often discussed in the context of joint production and manufacturing: 'co-creation' and 'co-development'. These terms are widely discussed in industry circles when referring to two or more stakeholders coming together to develop equipment or better technology. However, there are two prominent limitations to these concepts. First, these terminologies are used to denote collaboration without any purposive or directional aspects. However, co-innovation is discussed in the context of developing advanced technologies to achieve sustainability transition. In addition, co-creation and co-development often have limitations in recognising the innovative inputs given by various actors and stakeholders outside the product development arena. On the other hand, co-innovation highlights the contributions of various actors and stakeholders involved in the innovation stage. Co-innovation also reflects the continuous exchange of knowledge among all the stakeholders, including scientists, manufacturers, and the end-users of technology. It thereby efficiently captures the efforts of all the stakeholders in comparison to the co-creation and co-development frameworks, which only emphasise the creation and development stages, rather than the innovation stage. While 'co-development or co-creation are the economic model based on maximising the returns on design investments through product sales, co-innovation aims to generate knowledge and incorporate the same for continuous technology improvement, and thereby help the product remain competitive in markets that are constantly being redefined. Hence co-innovation is an approach that requires profound changes in the industrial world's operating rules' (Maniak and Midler 2008). In addition, Maniak and Milder point out that, 'while co-development usually involves a smaller group of partners, co-innovation indicates the cooperation of a wider set of partners outside the traditional channels'.

Another critical question concerns the relevance of co-innovation while stakeholders can depend on the conventional markets or other market-based approaches to sell advanced technology equipment. There are several factors that make co-innovation relevant. First, in the context of conventional technology transfer, the source country can often be ill-equipped to understand the demand conditions specific to the recipient country markets. These include various key factors such as cost sensitivities of the domestic market, climatic conditions under which the equipment needs to operate, and design needs of the consumers. A product or

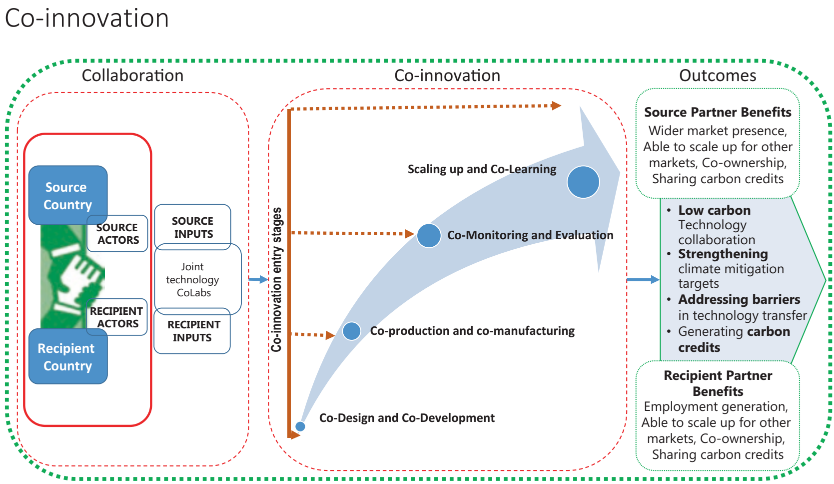

Fig. 2.1 Co-innovation: Schematic Representation. (Source: Janardhanan et al. 2021)

machine that incorporates the knowledge of the local market, consumer expectations, and the requirement by policy as well as the legal environment can perform better in the recipient market. Second, a product that is jointly developed by pooling financial and knowledge resources and by fine-tuning the innovation is likely to have a far better output than a finished product or piece of equipment imported straight from an overseas partner. These factors make co-innovation a valuable approach in redefining the traditional technology collaboration between source and recipient countries. Figure 2.1 shows the process of co-innovation.

2.4.2 *Operationalising Co-innovation*

Co-innovation is intended to promote sustainability transition. Hence, the resultant product or technology developed is expected not only to be technologically advanced, cost-effective, and adaptive to local conditions but also environmentally suitable. Co-innovation may involve multiple stakeholders, including government agencies, the private sector, business organisations, higher institutions, and financial institutions.

Flexibility remains the key to engagement in the co-innovation process. The process of co-innovation can roughly involve three stages: Collaboration, Co-innovation, and Outcome. As indicated in Fig. 2.1 in the first phase of 'Collaboration', both partners recognise the importance of jointly working together and agree on the type and depth of engagement they can have. Both the source and recipient partner can develop technology collaboration laboratories (CoLabs) or joint production facilities with the support of these institutional stakeholders or agencies. This CoLab platform will help partners exchange ideas and develop or refine the concept. With regard to the inputs, both the recipient and source country have their respective domains of expertise, which include technical knowledge that acts as the basic concept. While the key inputs from the source country are initial technical expertise as well as production and manufacturing guidance, the value added to the basic technology and the customisation is undertaken with the inputs of the recipient country. These include local knowledge, understanding the industry needs, demand conditions in the specific geography, information on the market trends, and raw materials. The recipient and the source countries also pool their financial resources at this stage.

The second stage—'Co-innovation'—remains the core segment in the process where multiple phases of collaboration can occur. These include *Co-Design and Co-Development*, *Co-production and co-manufacturing*, *Co-Monitoring and Evaluation*, and *Scaling-up and Co-Learning*. These phases are indicative of a possible collaboration trajectory under which the partners can work together. The first phase, 'co-design and co-development', focuses on the design and development of technological solutions for addressing local needs and societal challenges. In the second phase, 'co-production and co-manufacturing', the partners develop or manufacture products based on joint technological initiatives/solutions. The 'co-monitoring and evaluation' phase focuses on progress, outcomes, and problem detection, and eventually ensuring the sustainability of the technology solutions. In the last phase, the partners focus on scaling up the products to new markets.

The third stage highlights the 'Outcome' of the collaboration. As the concepts are developed and products are launched to the markets, these joint platforms can aim to expand their product lines and reach out to new markets. The key advantages for the source country are better market presence, the opportunity for jointly scaling up for other markets, cost-effective production, co-ownership of products, and above all sharing of carbon credits in the case where the technology or product can offset carbon emissions in its respective field. Specific advantages for the recipient country include employment generation, the opportunity for jointly scaling up production in newer markets, co-ownership, and sharing the carbon credits. Overall, the process of co-innovation offers climate, health, economic, and environmental co-benefits.

While highlighting the importance of co-innovation the chapter does not undermine the potential challenges in operationalising these. Aligning the interest of the source country and recipients, the capacity of the recipient in manufacturing and production, setting up adequate institutional mechanisms, securing financial resources, legal aspects, and so on will be key hurdles for operationalising co-innovation. In terms of energy transition and addressing greenhouse gas emissions or even minimising air pollution in developing countries, co-innovation can help enhance technology collaboration.

2.4.3 Role of Co-innovation in Facilitating Technology Collaboration

Energy transition is undeniably a technology-intensive process. Whether for the energy-consuming sectors or the energy-producing sectors, improving the efficiency of the equipment used will be of critical importance. As in the cases discussed above, collaboration with Japan is of significant importance for India. The challenges for traditional ToT can be addressed by facilitating policy and legal provisions to enable co-innovation, where overseas partners and Indian industry can jointly develop, fine-tune, and produce advanced technology solutions for addressing energy transition needs in the developing countries.

Unlike the conventional understanding of ToT, where technologies from one country to another are facilitated through business-to-business interactions, it is important to find options for a more sustainable approach. The issues pertaining to energy transition are dynamic and continue to evolve based on the changing economic activities, energy consumption patterns, and so on. Hence, it is important to continuously upgrade and integrate the local concerns in fine-tuning the technological solution. Co-innovation typically helps in achieving the desired targets in a specific local context and helps to make the solutions economically viable even for a larger market. In the case of views with regard to Chinese equipment supplies pushing out domestic market players and China pursuing a long-term 'predatory' strategy to capture the domestic market, one may consider revisiting these debates. Despite the historical perception of China as an aggressor preying on India, one should note that India's collaboration with the former can play an undeniably positive role in the current situation. By promoting opportunities to co-innovate within India, the domestic industry and energy equipment manufacturers also gain the opportunity to develop and learn. However, to what extent co-innovation as a business model will be appealing to China will depend on the policy tools and financial mechanisms India can roll out in support of this. Co-innovation would not only help the external players in pooling resources to produce more efficiently but will also give the source and recipient partners opportunities to explore the market in other economies using their diplomatic and economic ties.

2.5 Conclusion

Taking India's case as an example, this chapter describes collaboration with two countries. First, Japanese clean energy technology companies have not been able to make substantial inroads into the Indian market, despite the two countries enjoying one of the healthiest bilateral relationships in the region. Even though Japanese technologies could potentially support India in its low-carbon development plans, they remain a relatively low-key partner compared to the Chinese companies in India. The high capital cost of technologies and the differences in business practices often pose additional hurdles for Japanese companies reaching out to Indian end-users. Co-innovation is proposed here as a way to bring together the Japanese and Indian industry players to jointly develop technologies and manufacturing in India. It can also provide multiple benefits for Japanese industry, in terms of gaining access to a wider consumer network in India and being able to reach out to other developing country markets. Availability of skilled manpower, natural resources, and the existing policy mechanisms such as Make in India also open up opportunities for building joint manufacturing facilities in India. Indian customers in turn can access world-class technology and equipment and locally adaptive technologies.

The second case discussed in the chapter concerns India's China engagement in the energy technology front. For the past several decades India—China engagement has witnessed political differences taking the driver's seat. The conventional energy sector has also witnessed India and China competing to secure overseas oil and gas assets, which has often paved the way for geopolitical frictions. However, India's over-dependency on China to meet the domestic demand for renewable energy equipment to cater to the energy transition targets has been a concern. With the influx of cheap Chinese equipment and products for the renewable energy sector, Indian producers have faced a serious threat to their survival. As the renewable energy industry is highly dependent on Chinese supplies, policy circles as well as industry are concerned about Chinese players dominating the domestic market. The chapter proposes co-innovation as a possible way for building collaboration in this context. As Chinese companies offer strong advantages in terms of cost-effective products and advanced technologies, Indian companies collaborating with them to manufacture in India will be a win-win situation for both.

Co-innovation offers an opportunity to explore the alternative pathways for strengthening technology collaboration between the source country and the recipient country. It provides opportunities for long-term development, piloting, and commercialisation of technology from the concept to marketable product with the joint efforts of supplier and recipient partners. The chapter highlights that co-innovation will not only help develop locally adaptive technologies but also help strengthen the domestic industry. Technology collaboration or transfer of technology from one country to another is not a new phenomenon. The objective of this chapter is not to reinvent the wheel but to examine the feasibility of technology collaboration in a manner that enhances the long-term partnership between the players. In this sense, the objective of this chapter is to present a potential new platform to supplement the technology collaborations to address climate change impacts.

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CHAPTER 3

India's Renewables Commitments: A Political Risk Assessment

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3.1 Introduction

The world has been witnessing the changing nature of political risk since the age of coal and steam in the eighteenth and nineteenth centuries and subsequent emergence of petroleum from the end of the nineteenth to the early twenty-first centuries. Consequently, the field of political risk

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surrounding energy has evolved substantially in the past hundred years, albeit with an overt and unwavering disposition towards oil and gas. As the world was settling down with the political risk narrative synonymous with the geopolitics of oil and gas, shale discoveries in the USA and the prolific push for renewables combined with the twenty-first century political risk view that involves non-state actors in international relations (Rice and Zegart 2018) have reconfigured the conversations surrounding energy political risk. India is in the midst of this very interesting transformation. While its import dependency on conventional energy continues unabated, it is investing heavily in renewable energy with a goal of installing 175 gigawatts (GW) of renewable capacity by 2022 to support its submission towards Intended Nationally Determined Contribution (INDC). Embedded in this is a profound manoeuvring that India has to manage: on the one hand, the changing nature of conventional energy supplier countries and their accompanying leverage needs to be internalized. On the other hand, because of intrinsic nature of factor inputs i.e. land, and output i.e. electricity from renewable being state subjects (though electricity is a concurrent subject in India but mostly driven by states), states within India now exercise more leverage than the centre for renewable energy projects. The political-economy surrounding the spirit of collaborative and cooperative federalism, whereby various central and state entities in the Indian electricity sector can work on common narratives is going to be focal to understanding the geopolitics of renewable energy from an Indian perspective.

We find that while there exist vibrant academic debates on political risk of conventional energy, scant attention has been given to the political risk of renewable energy (Overland 2019); predominant focus so far has been on the conflict potential of rare earth materials in international energy dependencies (as cited in Scholten and Bosman 2016). Consequently, the literature is significantly silent when it comes to explicating if and how centre-state political risk within a country can sustain the renewable energy growth. A common framework with which to explore the issue is lacking and wanting. While we propose an extension of the current typology surrounding the conventional energy geopolitics and how it relates to the renewable energy, the main thrust of this chapter however will be to propose a framework that can help understand the relationship between centre-state surrounding energy political risk in the Indian context. Our model posits that the idiosyncratic centre-state India specific conditions entailing socio-cultural and political-institutional environments strongly influence the renewable energy political risk. This is in contrast to the nuanced political risk focus on positions of countries in the international system of dependency on critical raw materials and technologies that may follow from the rise of renewables. Our work definitely is not fully representative of renewable political risk faced by all countries in all situations and hence, should certainly not be seen as the generalizable work on the subject. Quite the contrary, it invokes a first inroad to a new theme, one that refurbishes an already existing phenomenon and acts as a food for thought for future works.

The remainder of this chapter presents a literature review that maps the field of the political risk of conventional energy and the changing nature of it as applied to renewables. Combining insights from international relations with external-geopolitics perspective on the one hand and renewable energy as seen from political-economy of centre-state relationship (internal-geopolitics perspective) on the other, it seeks to clarify key concepts and their relation. It then constructs an analytical framework that revolves the transition. Finally, the conclusion summarizes the core arguments we have been able to make shaping the geopolitics of renewables.

3.2 Literature Review

Historically, energy issues have been closely related to regional and global geopolitics (Akiner 2004; Amineh and Guang 2012; Andrews-Speed 2008; Correlje and van der Linde 2006; Friedman 2006; Eisen 2011) as traditional energy sources such as oil, natural gas and coal are strategically significant spatial variables (Francés et al. 2013; Scholtena and Bosman 2016; Sovacool 2011). According to Keppler (2007), the global energy policy and the relationship existing between suppliers, customers and the transit countries are important factors influencing international relations. As observed by Paltsev (2016), the power balance is now shifting away from the countries rich in fossil-fuel to countries who are efficient in developing sources of low-carbon energy. For countries heavily dependent on oil imports, the alternative technologies like solar and wind power will lead to diversification and improved energy security and as a consequence reduce the power yielded by the traditional energy producers (Larson 2007; Scholten and Bosman 2016; Criekemans 2011, 2018). However, renewable energy geopolitics is a very complex issue with many distributed players (Paltsev 2016) with varied dependence on multiple inputs like access to rare earth elements, patents, storage, and technology (Scholten and Bosman 2016).

Scholten and Bosman (2016) has important observations on the shift in emphasis from getting access to the resources as in the case of fossil energy geopolitics, to management of strategic infrastructure as in renewable energy geopolitics. Since renewables are most easily converted into electricity, electricity is expected to become the prevalent energy carrier in a renewable energy-powered world with significant consequences (Ellabban et al. 2014). The renewable energy electricity grid would be a physically interconnected system that links consumer and producer countries via a single integrated grid (Battaglini et al. 2009). As with fossil fuels where transit countries have a vital role to play, renewable energy would also have power in the hands of those who manage major power lines (Paltsev 2016) and endowed with rare earth elements often known as critical components of equipment for renewable energy (De Ridder 2013; Golev et al. 2014; Hurd et al. 2012). Since almost all mining, production and processing of rare earths is done in China today (Dutta et al. 2016; Wübbeke 2013), this overwhelming dependence on China as the dominant supplier of rare earths materials could potentially lead to geopolitical tensions and cartelization (O'Sullivan et al. 2017). Interestingly, provisions such as small renewable energy producers returning electricity to the grid could possibly shift the power balance among citizens, local authorities and national governments (Schleicher-Tappeser 2012).

Despite the egalitarian narrative underlying the argument that each nation has access to at least one or another type of renewable energy such as sun, hydro, wind and geothermal energy, neither the opportunity nor the potential for generating energy is the same for all renewable energy sources (Sathaye et al. 2011). As a consequence, solar and wind energy costs would be significantly differing from region to region thus potentially creating a situation similar to the world dominated by fossil fuels (Palmer and Burtraw 2005). Similarly, Overland (2019) tries to invalidate four emerging concerns i.e. competition over critical materials; resource curse; transboundary electricity cut-offs; and cyber-security risks.

3.3 India's Renewable Energy Sector

Renewable energy push has started taking the centre stage in India's pursue towards not just the low carbon development path but also towards providing energy access, reducing consumption of fossil fuels, and augmenting grid power. As per Global Status Report-2018 of Renewable Energy Policy Network for the 21st Century, India ranked 5th in Renewable Power Capacity (including hydropower) and 4th (not including hydropower), as of end 2017. India's ambitious submission of Intended Nationally Determined Contribution (INDC) to the UNFCCC is contingent upon installation of 175 gigawatts (GW) of renewable power capacity which includes 100 GW from solar, 60 GW from wind, 10 GW from Biomass and 5 GW from Small Hydro power by 2022. Over the years, India's steadfastness towards renewable sector has paid off by successfully creating a positive outlook necessary to promote both investment and demand.

In India, a total of 80.04 GW of renewable energy capacity has been installed in the country till May 2019. The state-wise and source-wise details of the power generated through renewable energy sources in the country during each of the last three years are given in Annexure I.

The strategy adopted by the government for achieving renewable energy target includes the following:-

1. Waiver of Inter State Transmission System (ISTS) charges and losses for inter-state sale of solar and wind power for projects to be commissioned up to March, 2022.
2. Permitting Foreign Direct Investment (FDI) up to 100 percent under the automatic route.
3. Notification of standard bidding guidelines to enable distribution licensee to procure solar and wind power at competitive rates in cost effective manner.
4. Declaration of trajectory for Renewable Purchase Obligation (RPO) up to the year 2022.
5. Viability Gap Funding (VGF) and permitting Foreign Direct Investment up to 100 per cent under the automatic route
6. Implementation of Green Energy Corridor project to facilitate grid integration of large-scale renewable energy capacity addition.
7. Notification of standards for deployment of solar photovoltaic systems/devices
8. Launch of new scheme for farmers, Central Public Sector Undertaking (CPSU) Phase II and Solar Rooftop Phase II program.
9. The government has requested the Reserve Bank of India to consider segregating the exposure in Renewable Energy (RE) sector

from Power Sector and defining new category ‘RE sector’ so that flow of capital for RE sector is not hampered.

The National Solar Mission (NSM), launched in January 2010, was the first mission to be operationalized under the National Action Plan on Climate Change (NAPCC). Through a range of policy instruments and mandates such as building by-laws and its incorporation in the National Building Code, the initial target of the mission of installing 20 GW grid-connected solar power plants by the year 2022 was enhanced to 100 GW to be achieved by the same target year. However, major areas of concern remaining are strengthening of the planned infrastructure, protocols and power grid infrastructure for evacuation of renewable energy.

The International Solar Alliance (ISA) was launched in 2015 as a treaty-based alliance between countries that are Members of the United Nations, and aims at accelerating development and deployment of solar energy globally. In 2017, the ISA became a treaty based international intergovernmental organization in which 75 prospective Member countries have signed the Framework Agreement of the ISA and 54 of these countries have ratified the same.

Against the estimated wind potential of the country (see Annexure) is around 302GW at 100m above ground level, capacity installed as of 2018 is 35.01GW. To facilitate the development of wind power projects in an efficient, cost effective and environmentally benign manner, the government has issued a detailed ‘Guidelines for Development of Onshore Wind Power Projects’ that prescribes the requirement of site feasibility, type and quality certified wind turbines, micro-siting criteria, compliance of grid regulations, real time monitoring, online registry and performance reporting, health and safety provisions, decommissioning plan, etc. However, the key challenges in harnessing wind energy are availability of land, logistics in transporting turbine blades and power evacuation infrastructure at potential wind sites.

Most of renewable energy projects in the country are being set up by the private sector developers selected through transparent bidding process. The government has issued standard bidding guidelines to enable the distribution licensees to procure power at competitive rates in cost effective manner. In order to protect the interest of small developers, states and union territories can procure power from solar projects (less than 5 MW capacity) and wind projects (less than 25 MW capacity) bypassing competitive bidding guidelines through Feed-in-Tariff (FiT) mechanism as determined by the respective State Electricity Regulatory Commission (SERC).

3.4 A Framework of Analysis

In this section, our interest lies in unpacking political risk, broadly defined as the impact of politics on markets (Bremmer 2005), in the context of renewable energy in India. In order to have a granular understanding of it, we disentangle political risk to two things: first, risk associated with geopolitics – a term that is associated with the political geography and international relations (Scholten 2018), which we label as external-geopolitics perspective (Criekemans 2018); and second, risk embedded with the political economy, a term broadly indicates how political forces within a country or a state interact with institutions that eventually influences functioning of market (Victor and Heller 2007), which we label in this study as internal-geopolitics perspective (Criekemans 2018). Going forward, we take the perspective that the study of the geopolitics of renewables has at its core the strategic realities and policy considerations of producer and consumer countries investing in renewable energy. Sources and technology may become the dominant geopolitical players or victims of cooperation and conflict. Similarly, the study of the political economy of renewables is at its very essence about empowerment of region or states because of decentralisation of the energy generation impacts, centre-state relationship and eventually the political economic fabric within a country, India in this case.

We operationalize the two core concepts i.e. external-geopolitics (Fig. 3.1) and internal-geopolitics by further breaking it down into distinguishable and actionable pieces to aid the understanding of the relationship between renewables and political risk and make it as a toolkit to readers (see Annex I and II). Before delving deeper into the subject, it is beneficial to contextualize the understanding of these two core concepts as applied to India. Since external-geopolitics and internal-geopolitics are generally associated with fossil fuels, especially oil, coal and natural gas because of their dominance in the global energy mix it is natural to start the discussion by delineating the changing nature of the concepts as applied to conventional as well as renewable energy. A simple representation as depicted in the below continuum would help simplify the ideas.

Based on our understanding, conventional and renewable energy may be depicted on a spectrum that represents one possible combination of

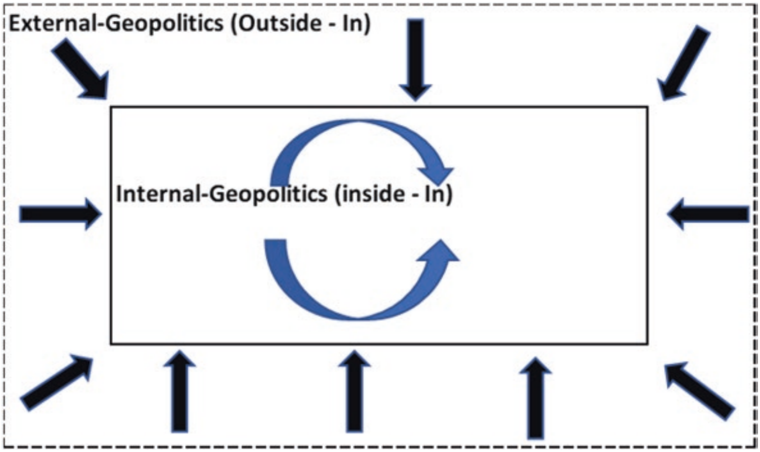

Fig. 3.1 External and Internal Geopolitics. (Source: Author's description)

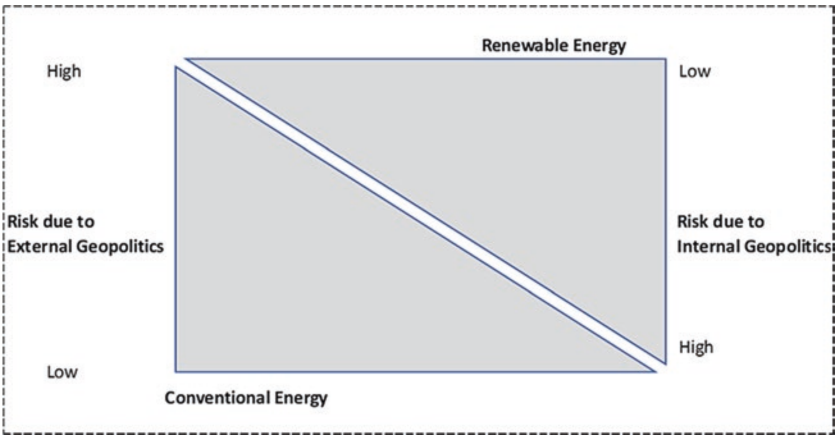

Fig. 3.2 External and Internal Geopolitics: Energy Type versus Risks. (Source: Author's description)

external-geopolitics and internal-geopolitics involvement in conventional and renewable energy delivery, classified according to the risk allocation between them (see Fig. 3.2 below). Except for the nation-state and authoritarian case where the same government is responsible for the interactions and execution of contracts outside as well as inside, all other case would involve multiple levels of interactions by federal or central, and provincial or regional or state governments while finalizing and operationalising the contract. In India, since conventional energy resources such as oil, gas, and coal are central subject, most of the risk associated with it are linked to central government's relation with outside world. But when it comes to renewables, the division of interaction and subsequent emergence risk is explicit. As electricity is the energy carrier and the final product of most renewables—as opposed to physical commodity in case of conventional—local and regional governments exercise more levers vis-à-vis their central counterparts because state-controlled electricity distribution companies (discoms) are the ultimate off-taker of electricity. Further, the critical factor inputs for renewable project i.e. land is a state subject in India. Consequently, this combination of state dominance over renewable projects changes the geopolitical power relations between the central and state government in future geopolitics.

Next, to understand how the rise of renewables is transforming energy-geopolitics landscape, we are tempted to examine key shifts associated with the move from conventional energy to renewable energy (Table 3.1).

By introducing this analytical framework above, we have laid the groundwork for a comprehensive overview of the great transition. As evident from the above table, the coming energy transition towards renewable energy will engender far-reaching consequences though the jury is still out on how fundamental this change will be especially with regards to centre-state relationship—the core focus of the next section. Though we do not strive to be exhaustive in our endeavour to present the centre-state debate next, but rather aim to showcase the key triggers in which renewables are reshaping political economy of centre-state relationship and old-new government within a state.

3.4.1 State Versus Centre Debate I (Internal Geopolitics)

India has become one of the top renewable producers with a target of 175 GW of installed capacity for which it would require investment of around $80 billion till 2022. Unfortunately, concerns about India's ability to reach that milestone now being raised when a spate of issues related to delays in payments by state-run distribution companies (DISCOMS), and Andhra Pradesh and Uttar Pradesh's decision to renegotiate tariffs of solar and wind projects have surfaced. As of July 2019, distribution companies (Table 3.2)- long been under financial strain—across India owed

Table 3.1 Examining Geopolitical Shifts: Conventional and Non-conventional Energy

Conventional energy ➡	*Renewable energy*
Resources finite, depleting, and geographically concentrated	Resources abundant, replenishable, evenly spread, and intermittent
Business models dominated by economies of scale: high capacity, centralized facilities	Increasingly decentralized nature of energy production by and for a more varied set of local actors
Oligopolistic markets where producers such as Russia and the OPEC countries hold considerable market power	Increasingly becoming competitive markets
Energy geopolitics generally revolve around depleting and geographically concentrated oil and gas reserves in politically unstable countries in the Middle East and North-Africa (MENA) and Central Asia and Caspian Region (CACR).	Energy geopolitics to centre around competition for rare earth materials and clean tech know-how between countries like US, Germany, and China that aspire to become industrial leaders
Clear demarcation between net-exporters and net-importers	Countries essentially face a make-or-buy decision (security versus affordability)
Commoditization of energy systems, as commodity like coal, oil and gas physically move around	Electrification of energy systems, as electricity is the energy carrier
Concerns revolve around import-dependence, climate change, and transport bottlenecks, continuity of commodity supply	Concerns over supergrids, system integration, spot emergency response to prevent blackouts, continuity of service supply, strict managerial oversight for grid management
Price volatility due to political instability or supply disruptions	Price volatility because of intermittency
Globalization of environmental impacts	Localization of environmental impacts and land related issues spiralling into food versus fuel, and community land debates
Individual country engages in oil or gas diplomacy	Possibility of individual region or states initiating energy diplomacy like California in the USA
Militarization of energy strategy	Limited chances of future use of electricity as a 'weapon' in a world where resources are expected to be spread evenly

(*continued*)

Table 3.1 (continued)

Conventional energy →	*Renewable energy*
Primary focus on resource control or endowment; internal optimization; supplier -receiver relationship;	May be visualised as a platform ecosystem where the primary focus would be resource synchronization; external interaction; ecosystem relationship
Producer and consumer countries usually remain fixed	Consumers and producers can swap roles, for example through net metering
High entry barriers because of huge upfront investment	Works like an open architecture as long as consumer has a place to install a solar or wind panel/equipment

Source: Authors own interpretations from Criekemans (2018), Scholten (2018), Van Alstyne et al. (2016)

Table 3.2 Power Utility Ownership by Companies and States

State/Utility	*Sum of Amount (in Crore)*
Andhra Pradesh	2509.21
Tamil Nadu	2413.47
Telangana	1580.84
Karnataka	937.75
Madhya Pradesh	832.65
Rajasthan	722.23
Maharashtra	629.40
IREDA	22.42
Punjab	19.80
DPL	19.03
Gujarat	18.16
Uttar Pradesh	11.74
Bihar	8.13
Sikkim	6.36
Uttarakhand	3.37
Andaman Nicobar	0.75
Torrent Power	0.31
Grand Total	**9735.6**

Source: CEA (2019)

renewable power producers INR 9,736 crore (refer table below) of which around three-quarters of that were owed by four southern states—Andhra Pradesh, Tamil Nadu, Telangana and Karnataka.

Interestingly, the state of Andhra Pradesh that owes over a quarter of the combined dues of all DISCOMS has been trying to renegotiate Power Purchase Agreements (PPAs) raising investors' concerns about the sanctity of PPAs. While the renewable energy companies approached the Andhra Pradesh High Court against the state government intention to revise the PPA, the court directed the power producers to go to the state electricity regulatory commission. Subsequent to this event, the state of Uttar Pradesh government stopped procuring electricity from 650 MW of wind power plants. While the states may have appealing reason to do this as fierce competition in solar and wind power auctions in recent times along with falling prices of equipment have helped tariffs tumble to record lows, making older projects look very costly. However, when facing request for renegotiation of contracts competitively won, the sanctity of the bid must be upheld. State's misdemeanour like this might make investors wary and inactive. Given that all renewable generation is a must-dispatch scenario as per the law, any political interference will only lead to depletion of the confidence of investors jeopardizing the overall business sentiment of the country.

3.4.2 State Versus Centre Debate II

Post Paris negotiations, Indian government's focus on renewable energy (RE) implementation for climate change mitigation has been proposed and this message has been conveyed to all Indian states (Dubash and Jogesh 2014). States comply with targets mandated under NAPCC and set up incremental targets. The initial thought of RE as a tool to reduce energy deficits, decrease electricity imports and provide quality energy services to underserved is lost. This can be attributed to lack of institutions, barriers to high priced renewables, challenges with grid integration and lack of suitable interstate power off-take mechanisms.

The Karnataka Renewable Energy Development Ltd. (KREDL) as the state nodal agency has been allocated 67% (19,772 MW) of the state's RE potential, but only 17% (4887 MW) has been commissioned (KREDL 2016). Struggle lies in getting permits and clearances – the process is tedious and time taking. The other hurdle is land-use uncertainty. RE targets are not integrated with land-use planning at district level and the growth/failure depends on land acquisition for individual projects. Renewable energy infrastructure and technology cannot expand in silos. It needs to be integrated with states development agenda and inter-related factors as land use, rural development and environmental sustainability.

Karnataka has a good solar and wind resource, but the solar developers are cautious in setting up plants in northern Karnataka, envisaging grid evacuation challenges as in Tamil Nadu (Sushma 2014). State bears the cost of infrastructure and although open access regime and FiT is attractive for states, but the costs are more than the profits. Customers do not want to bear the brunt of these charges (Ramamurthi 2016). Therefore, Central government intervention can help state governments take full advantage of their RE resources.

The problem rests in dearth of institutional mechanisms that can integrate RE investment with conventional power sector planning. Due to this, severe electricity deficit states are unable to utilize RE resources to meet their needs (Ramamurthi 2016). Need of the hour is to build on integrative institutional mechanisms with clean energy financial support to the states.

Central schemes are inadequate to cover the subnational electrification. The commitment by central government at international arenas, can only be implemented if the conventional energy route is withdrawn and local context specific action road maps for RE are redrawn. A paradigm shift in financial and technical models are a requisite for adoption of RE technologies, to which central support is paramount. India's high renewable targets are a step in the right direction. However, how well India will fare eventually boils down to the extent to which central and state actors' priorities and institutional mechanisms are aligned.

3.5 Discussion

India has taken a stand on energy system transformation and its renewable policy is an inspiring example for many countries around the world. Data shows that India is all set to cross the 100GW renewable energy capacity mark in 2020. Provided the government deals with some of the key issues, India will rapidly stride towards the ambitious 175 GW renewable energy target by 2022.

The key issues afflicting renewable energy generation, distribution and storage are categorized in this chapter into institutional, structural, financial and regulatory for better comprehension. Moreover, these issues also highlight the rift between centre and state political economy with respect to renewable energy dynamics. Though these categories are not water-tight, and issues overlap, nevertheless it brings clarity in the role of various actors and a scope to cater to policy uncertainty.

The key challenges in energy system transformation are:

3.5.1 *Institutional Challenges*

The institutional structure for renewable energy development in India clearly shows a division between centre and state level institutions (Fig. 3.3). A common reform roadmap is required among a broad range of central government agencies, state authorities, system operators and utilities.

On the left side of renewable energy development arrow are the policy makers on a national level and on the right side are the implementers/producers and regulators of renewable energy at state level.

As per various reports, the distribution companies or discoms in most of the states are under performing. The reason for that is the financial stress discoms are undergoing due to high capital cost for renewable

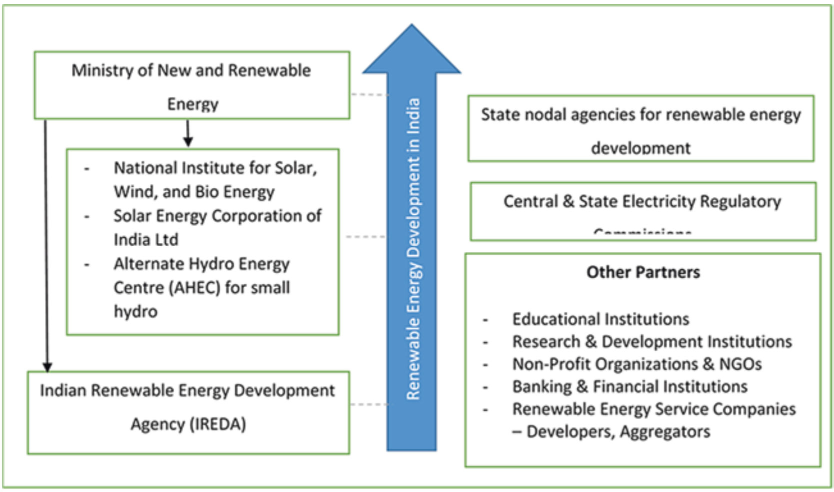

Fig. 3.3 Institutional Structure of Renewable Energy Development (Source: Author's description)

energy and prevailing policy uncertainties. The RPO regime on the one hand stimulates renewable energy investment but has proven to be a cause of failure of discoms because of lack of harmonization between national and state level targets.

There is a need to evolve the age-old discom model by changing from a centralized model to a more distributed system (e.g. roof top solar model for energy generation). Most of the schemes are tied to extending the grid and connecting un-electrified households to centralized distribution and transmission networks. Managing this centralized system has become unworkable.

The SPDA listed issues impacting the segment which includes uncertainty over GST rates for SPGS (solar power generating systems), forecasting and scheduling mechanism, continued safeguard duty on imported solar cell/modules, provisional anti-dumping duty on import of material for module mounting structures, grid curtailment etc.

3.5.2 Structural Challenges

Structural level changes require cost, which leads to increase in cost of renewable energy projects and hence the expansion of the projects is difficult. The characteristics of renewable energy make it variable and affect the degree of its predictability. So the requirement is to integrate renewables into the grid by taking measures like renewable energy generation forecasting, coordinated project development, grid planning and grid strengthening; thereby reducing the variability and uncertainty of RE generation through aggregation over broader geographic regions, creating flexible capacity, spinning reserves and ancillary services market, and properly defining RE grid integration standards and regulations. Development of storage systems is necessary in order to ensure uninterrupted power supply using RE sources like solar and wind.

3.5.3 Financial Challenges

Lack of interest of financial institution to fund renewable energy projects is perceptibly a risk averse move. So, a high cost and low availability of debt have increased the cost of such projects and hence creates hurdles in expansion of renewable sector. Most of the discoms are not in a good financial health. Weak financials of discoms will keep them from meeting commitments and affects the effectiveness of instruments that have been put in place for deployment of renewables.

Safeguard duty on imported solar panels, ambiguity over GST on solar equipment are some of the hurdles in clearly defining the financials for the project. Payment delays for developers, cancellation of auction and lack of enforcement of contracts dampens the investor confidence and developer's interest. Need of the hour is to institutionalize Renewable energy and streamline it with the existing grids.

3.5.4 Regulatory Challenges

A robust regulatory framework is required. The state discoms will have to start taking RPOs seriously and state regulatory authorities will have to hold the discoms responsible and penalize them for failing to comply on purchase obligations. Recently the Electricity Regulatory Commission of Uttarakhand imposed a penalty on its discom for not complying with its renewable power obligation (RPO) target. Instead, the states are allowing the obligated entities as Discoms and captive consumers to 'carry forward' deficits to the next financial year.

Another regulatory challenge is to streamline, accelerate, and standardize the acquisition of permits, clearances and other administrative hurdles that the developer must cross. These relate particularly to land acquisition and environmental permitting. Lack of coordination among key organizations like revenue department, state pollution control board, grid operators has led to time and cost overruns resulting in high transaction costs.

3.6 Conclusion

This chapter strives to achieve three main goals that we believe would contribute to an enriching understanding of the political risk surrounding renewable energy. The first objective has been to briefly discuss the extant narratives on the political risk. We observe that current framework provides plausible explanations of how countries (both importer as well as exporter) are able to reconcile their external-geopolitics, albeit from a conventional energy perspective. However, they are of little help in explaining how countries are able to sustain the internal-geopolitics, especially with respect to renewable energy. This is particularly troublesome when the success of impetus to renewable energy of any country in general and India in particular, is not based on privileged control of critical resources and technologies but on managing the centre (federal)-state (region or province) equation within the country.

We address the second objective i.e. to provide explanations to flesh out the conventional to renewable transition and what it means for political risk—by proposing a framework that delineates how geopolitical world of renewable energy is different or similar compared to the geopolitics of conventional energy. We think the applicability of this framework would help rekindle interests and as a consequence, the dearth of research on this topic could be a thing of the past.

Our third objective was to provide evidence to support the importance of internal-geopolitics i.e. political economy of centre- state in Indian context. By providing factual story of recent events, we make an attempt to drive the point that how renewable energy is aiding the changing power relation, with states in India disposing of more levers vis-à-vis centre, ostensibly towards creating an egalitarian economic landscape.

Annexes

Annex I

External-Geopolitics (Outside – In) – possible manifestations	*Example*
Resource Nationalism and expropriations	In Venezuela, resource nationalism was an important feature of the 'Bolivarian Revolution' under the Chávez presidency. As per Maplecroft Resource Nationalism Index (RNI), countries now rated 'extreme risk' include: Venezuela and the Democratic Republic of Congo; Tanzania; Russia; North Korea and Zimbabwe; Swaziland; Papua New Guinea
Host government reneging on contracts with a focus on shifting a larger share of commodity revenues from international to domestic hands thereby increasing the host government's fiscal take	Kazakhstan in the super-giant Kashagan project; Mongolia in Oyu Tolgoi copper project; Chile's state-owned Codelco versus Anglo America; Repsol in Argentina; Gazprom in Sakhalin-II
Great power shifts	Russia's annexation of Crimea, the invasion of eastern Ukraine and the shooting down of a passenger airliner; Brexit; decline of US intervention in global order

(*continued*)

(continued)

External-Geopolitics (Outside – In) – possible manifestations	*Example*
Increase in south-south trade	Chinese commercial clout over Africa; flow of commerce among emerging countries bypassing the West as intermediary
Interstate wars (including proxy wars)	Physical as well as cyber and data wars
Multilateral economic and trade sanctions	USA and EU sanctions on Russia, Iran; U.S.-China trade war
Opening up of new sea routes debottlenecking strategic maritime passages chokepoints	Panama Canal Expansion; Northern Sear Route (NSR) connecting Northwest Europe with Northeast Asia via the Arctic Ocean

Source: Authors own interpretations from Rice and Zegart (2018)

Annex II

Internal-Geopolitics (Inside – In) – possible manifestations (India Specific)	*Example*
Individual Province/region/State's control over factor input like land, labour, capital, and infrastructure	Renewable energy projects leading to significant land-use change rendering lands now used for occupational purpose, Ecological importance and cultural significance being labelled as wastelands.
Centre-state relationship (federal cooperatism)	State-wise Central assistance; FDI equity flows into various states; Conventional (Oil/gas/coal) energy contracts-Centrally controlled versus Renewables (Electricity)—State controlled through PPAs
Host provincial/state government reneging on electricity contracts (Power purchase/sales agreement)	Electoral cycles driving renegotiation of PPA contract as the new government often seek to reinforce their support by exploiting the populist appeal, a phenomenon recently observed in many states

Source: Authors own interpretations

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PART III

Policy and Markets

CHAPTER 4

The Role of International Solar Alliance in Advancing the Energy Transition in Asia

Arunabha Ghosh and Kanika Chawla

4.1 Introduction

Globally, investments in renewables-based electricity capacity have beaten fossil fuels consecutively for the past three years. In India renewables have dominated power sector investments since 2015. Since then, much of the power sector investment in India and around the world has been in renewable energy. Yet, investors continue to remain circumspect about renewable energy. Developing countries have a lot of untapped solar and wind energy resources, but their markets are perceived to be risky and challenging.

For more than two decades of climate negotiations, developing countries have been demanding technology and finance for a transition to a low-carbon future. Even after technology costs have fallen, investments in clean technologies are largely bypassing the bulk of developing countries.

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In 2015, at the start of the Paris climate summit, India and France offered an alternative in the form of the International Solar Alliance (ISA). ISA was conceived as a platform to bring together countries with rich solar potential (along with solar innovators, developers, and financiers) to aggregate demand, create a global buyers' market for solar energy, reduce prices, facilitate deployment of existing solar technologies at scale, and promote collaborative solar R&D and capacity.

As the world's newest intergovernmental organisation (ISA became a legal entity on 6 December 2017), so far the ISA has 79 signatories to its Framework Agreement, 57 of which have also ratified the Agreement (International Solar Alliance 2019). At a time, when global collective action on climate change is under threat of backsliding, ISA has the potential to facilitate climate action across the developing world, and particularly in Asia, if it can catalyse innovations in finance, technology and deployment of solar at scale. Building on the lessons that have emerged from previous treaty-based institutions, that have played an important role but have been constrained by their operational structures or political paymasters, the ISA has been designed as a lean, nimble, financially independent entity with responsiveness and support to member countries being its primary objective.

This chapter begins by exploring two themes. First, energy demand and growth in Asia, establishing why the energy transition in fast growing economies in Asia would be central to the global energy transition. Secondly, the premise and the purpose of the ISA, and how its value proposition is contingent on a bias for action since its design is different from that of a traditional intergovernmental institution. In this regard, the ISA has a role in aggregating demand, facilitating technology collaborations, and enabling experiments with new business models or in training and building capacity in Asian countries. Thereafter, the chapter's focus turns to the most difficult challenge facing many emerging economies: How to lower the cost of finance associated with investments in clean energy? In particular, the chapter outlines the design of an innovative financial solution—the Common Risk Mitigation Mechanism—which the ISA has facilitated but which still requires implementation in its true spirit. The chapter ends with specific recommendations for the ISA to demonstrate its value to its member countries.

4.2 What Is Holding Back the Energy Transition in Asia?

There are currently over six billion energy consumers in the developing world whose demand is projected to grow another 30 per cent over the next 15 years, up from 7000 million tonnes of oil equivalent (Mtoe) in 2015 to 9100 Mtoe in 2030 (Benoit 2019). Powered in large part by rapidly expanding economies, specifically industrial growth and rising standards of living, the energy options available to developing countries and the choices they make are issues of global concern.

The growth in energy demand worldwide has been driven by fast-growing developing economies since the early 2000s, especially led by India and China. In 1990, members of the Organisation for Economic Cooperation and Development (OECD) accounted for almost two-thirds of energy demand, with developing countries consuming just one-third. However, energy transition projections for the mid-century shows reversed positions, with non-OECD countries accounting for over two-thirds of the demand.

4.2.1 Asia's Role in Driving Global Energy Demand

Much of this rise in energy demand in concentrated in developing Asian economies (India, China, Vietnam, Thailand, Malaysia and Indonesia), where improving living standards and prosperity will support this rise in consumption demand (BP Energy 2019). Primary demand (Fig. 4.1) in Asia is expected to grow annually at 2.5 per cent until 2035, reaching 7.3 btoe (billion tons of oil equivalent). This will be 42 per cent of global primary energy demand (RECAP Asia 2012). Figure 4.1 showcases the global energy transition highlighting the heightened role that developing economies will play in the energy market.

Currently Asia (including China and India) accounts for more than 41 per cent of global energy demand (Ritchie and Roser 2018a, b). This growth has been driven by the booming economies of China and India, which led to energy demand growth rates of 5.5 per cent and 6 per cent, respectively (RECAP Asia 2012).

Excluding India and China, however, other Asian economies will observe a gradual rise in energy consumption from less than 1 btoe in 1990 to nearly 2 btoe by 2040 (Fig. 4.1). Unlike China, this growth is a lot more gradual than the sudden boom in consumption that China

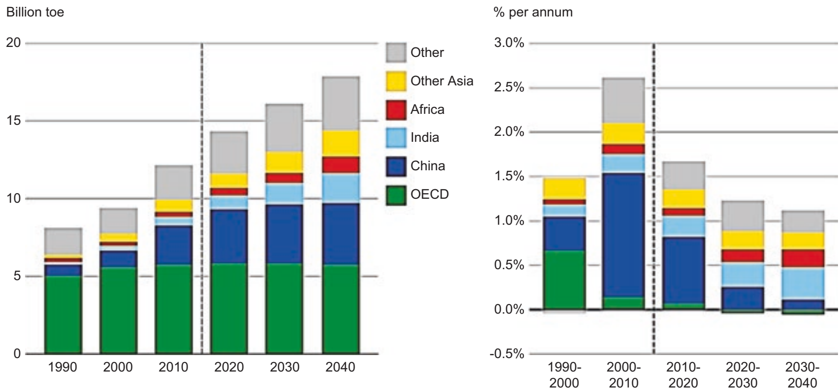

Fig. 4.1 Primary energy consumption by region (left); Primary energy growth and regional contribution (right). (Source: BP Energy (2019). BP Energy Outlook: 2019 Edition. BP PLC. Note: There is a global energy transition underway with developing countries increasing their role as the main market for energy consumption)

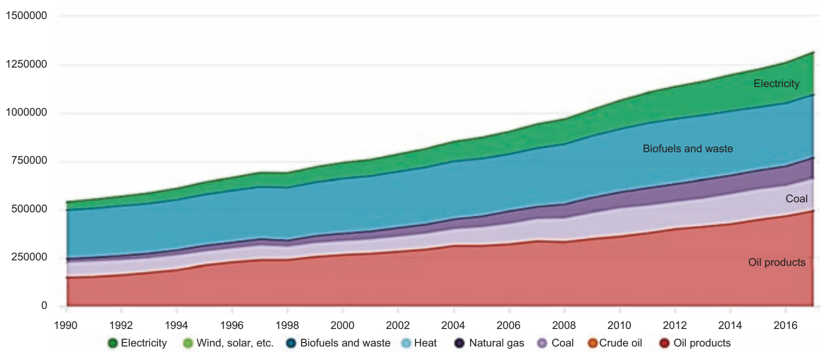

Fig. 4.2 Total final consumption by source for Asia (excluding China) from 1990–2017. (Source: Ritchie and Roser 2018a, b)

observed during 2000–2010. Figure 4.2 shows the total energy consumption for Asia (excluding China) from 1990–2017, highlighting the steady rise in all sources of energy.

Primary energy demand in Southeast Asia grew by 7 per cent during 2000–2016. Fossil fuels dominated the energy mix, accounting for nearly

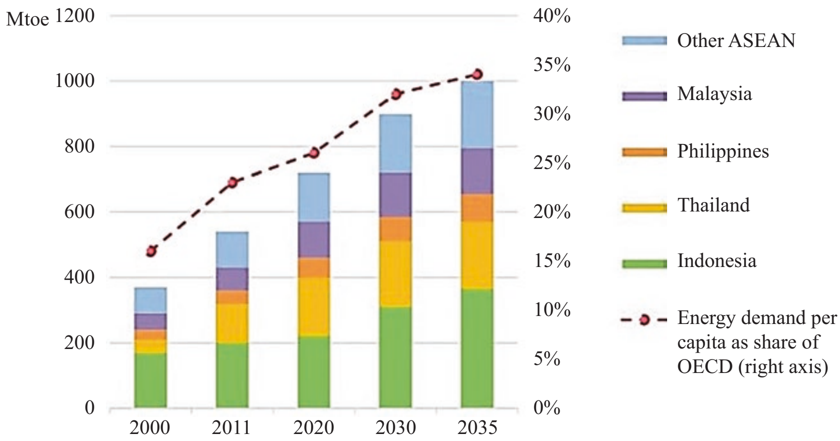

Fig. 4.3 Energy demand for ASEAN countries from 2000–2035. (Source: Ito et al. 2006)

75 per cent of the total share in 2016. Among members of the Association of South East Asian Nations (ASEAN), Indonesia has the highest energy demand, more than 35 per cent of the region's total, followed by Thailand (IEA 2017a, b). Figure 4.3 shows the role of key emerging economies in ASEAN's energy growth. Indonesia, Thailand, Philippines and Malaysia collectively accounted for 87 per cent of the total primary energy demand for ASEAN in 2016, and are projected to have a similar share until 2035.

As has been the case with China and India, ASEAN countries will also see the share of agriculture fall. Meanwhile, rising urbanisation will continue to boost the construction sector. As a result, industrial energy consumption in other non-OECD Asian countries, excluding China and India, is projected to increase by 60 per cent between 2015 and 2040, with demand for natural gas and renewables steadily increasing and demand for coal increasing and then tapering off at about 11–13 per cent by 2030 (Fig. 4.4) (IEA 2017a, b). Total transportation energy consumption among the other non-OECD Asia nations is likely to grow from 7.6 quadrillion Btu in 2012 to 17.0 quadrillion Btu by 2040 (U.S. Energy Information Administration 2016).

With rising living standards in non-OECD countries, there will also be growing need for energy in new segments, such as home appliances, industrial equipment or commercial services. Coal use in residential and

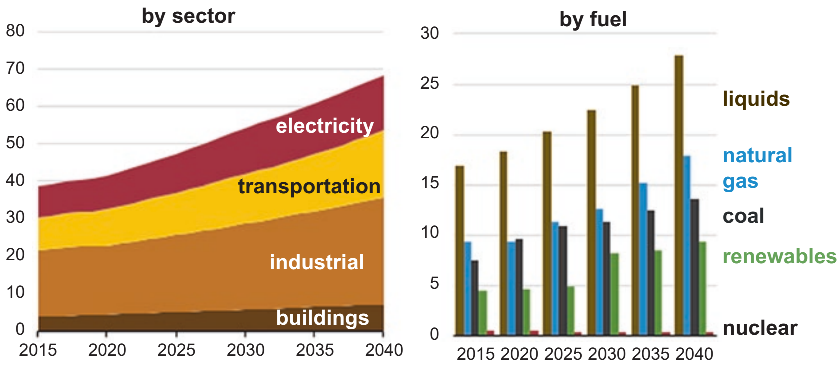

Fig. 4.4 Energy consumption (quadrillion British thermal units) for non-OECD Asia, excluding China and India from 2015–2040. (Source: Energy Information Administration 2017)

commercial sectors remains relatively low, and natural gas will be used more for cooking and heating.

Burgeoning energy demand in Asian economies underscores the opportunity to leapfrog to a cleaner energy mix, rather than having to retrofit legacy infrastructure in fossil fuel-based energy. As Fig. 4.4 shows, energy consumption in the electricity, transportation and buildings sectors will be about the same as for industry. These three sectors lend themselves to a shift to clean energy sooner than heavy industries, where greenhouse emissions are relatively harder (but not impossible) to abate. If Asian countries (not just China and India) shifted to clean energy, a double energy transition would unfold: growing access to modern energy to drive economic growth in emerging economies combined with a greater role for clean energy in driving global energy demand in the first half of the twenty-first century.

4.3 International Solar Alliance's Premise and Promise

In the lead up to the Paris Climate Summit in 2015 it had become clear that earlier approaches to clean energy technology cooperation had not worked. Several climate/energy technology partnerships had been initiated across the world, with many emerging during 2005–2015. Many of these were discussion forums, with a few concentrating on research and policy matters. While targeted technologies formed the basis of some partnerships, others had a geographical approach towards cities and regions. Despite more than 30 initiatives that had been launched, very few extended beyond sharing knowledge and some preliminary R&D activities (Ghosh et al. 2015). There was seldom any actual transfer of technology, nor any explicit mandate to deploy advanced clean technologies.

Moreover, the global energy landscape was dominated by groups of countries, which controlled the supply of energy (Ghosh and Chawla 2018). The Organization of Petroleum Exporting Countries (OPEC) served as the oil cartel. The Nuclear Suppliers Group controlled access to uranium in nuclear power plants. Even coal exports were dominated by just five countries. In contrast the International Energy Agency, while a group of major energy demanding countries, was a club of OECD member states, excluding the major new energy demanders in developing countries, particularly Asia.

ISA was conceived against this background. The countries between the tropics were mostly developing nations, were experiencing or going to experience rapid increase in energy demand, were not part of any major energy demanding group or association, and had high potential for generating solar power thanks to abundant sunshine. Therefore, when the ISA was designed, it had three main aims: To aggregate demand across countries to reduce solar technology costs; to lower the cost of finance for rapid solar deployment of existing technologies; and to pool resources for research and development (R&D) for the next generation of solar and related technologies.

This promise of an aggregated solar energy market excited many countries in Paris in 2015. When India and France proposed this new alliance, 121 countries expressed interest in being part of the grouping. Against the standards of the glacial pace of global diplomacy, ISA charted an accelerated path. By November 2016 its Framework Agreement had been opened for signature and by December 2017 (just two years after being proposed) ISA had enough ratified signatories that it was born as the world's newest intergovernmental organisation. At the ISA Founding Conference in New Delhi on 11 March 2018, senior representatives of 46 countries (including many heads of state) attended along with the senior membership of 10 multilateral development banks.

The ISA also demonstrates an important shift in the geopolitics that will emerge from a global energy transition. India's diplomatic tact and political leadership was clear when it joined hands with France to launch the ISA. India's actions on climate change are currencies for its soft power. It has used shifts in domestic policies, pursued values of equity and justice to manoeuvre in international negotiations, and upended received wisdom on the ability of developing countries to conceptualise and lead international institutions (Ghosh 2016). These are significant examples of soft power, in principle and in practice; with the writing on the wall—the geopolitics resulting from an emerging energy world will be more dissipated, with several countries playing a role, rather the highly polarised energy markets of the present. With enhanced energy security and energy independence, the levers in play will be controlled by demand groups more than by supply groups, putting emerging economies that are the growing demand centres of energy at the heart of the energy markets of the future.

The Government of India has supported the ISA since inception, allocating 5 acres of land for the construction of its headquarters, and an additional USD 27 million (INR 175 crore) for building infrastructure, creating a corpus, and supporting the costs of the ISA Secretariat for the first five years. The Government of France has also committed EUR 700 million to support the ISA and its activities in member countries.

The ISA is governed by its Assembly, comprising all member countries. It is a member-driven organisation and its activities are divided into work programmes, approved annually by the Assembly. In order to encourage cooperation between countries, any ISA work programme requires at least two-member states to jointly propose it, while allowing for any other member to voluntarily join the programme. This arrangement allows for only those programmes to be launched in which several countries find common interest and avoids the pitfall of any one country dominating the agenda. Any ISA programme should be ultimately respectful of national sovereignty, applicable in various regulatory environments, and yield maximum returns on limited amounts of public funds.

A number of work programmes have been launched since 2016. These include: scaling solar applications for agricultural use; mobilising affordable finance at scale; scaling solar mini-grids; scaling solar rooftops; and scaling solar e-mobility and storage.

But the ISA is also expected to be an action-oriented organisation. Therefore, any work programme is only as good as the actions it catalyses and the investments it is able to attract. This means that the ISA has to act in collaboration with other stakeholders. It has a small Secretariat, whose role is intended to be to bring together the right set of actors (from industry, financial institutions and civil society) to ensure that the objectives of any work programme are fulfilled. A lean ISA Secretariat will be effective only if it is strong in diplomacy, clear in its communications, and inspires confidence by the mastery of content related to solar technologies, policies, finance and markets.

4.3.1 Building Demand and Stimulating R&D

Four ideas could demonstrate how ISA can deliver on its promise of being an action-oriented organisation.

First, creating credible demand. In principle, if solar-rich but capital-poor developing countries aggregated plans for solar power, a big global market would emerge. ISA could work with its members towards a coordinated tender for large-scale solar deployment. For instance, one of its programmes plans to deploy 500,000 solar irrigation pumps, amounting to as much as 2500 megawatts of capacity.

But ISA is not a power utility. It cannot sign power purchase agreements. Technology suppliers and project developers do not respond to political announcements as well as they do to enforceable contracts. For a synchronised pumps programme to be credible, it has to be backed by business and financial models that generate maximum returns on investment.

ISA should bring together policymakers, rural enterprises, pump manufacturers, and commercial lenders to respond to this call for products and services for scaling solar applications in agriculture. In work done by the ISA secretariat in recent months, it has worked closely to facilitate a global tender that aggregates demand from all ISA member countries, in order to drive down prices for the collective demand pipeline. In the next phase, it would be valuable to work with individual member countries to streamline contracts such that contracts across countries are bankable, and standardised to some extent so as to reflect similar clauses. This will be critical to addressing the challenge of high cost of due diligence of these individual country level contracts. If unaddressed, the transaction cost of evaluating these contracts could undo the cost advantages discovered through aggregation.

Secondly, facilitating targeted innovation. Developing countries cannot afford to invest vast sums in solar R&D. Pooling resources, in cash and kind, makes eminent sense, but for what purpose? Targeted innovation is needed for technology challenges specific to developing countries. These include: efficiency of solar cells in dusty environments; solar applications in income generating activities in the rural economy; renewables for small and medium industries; sturdy batteries for rough ambient conditions.

But ISA is not a technology laboratory. It should, instead, design targeted and time-bound innovation prizes for the developing world. For each research area, ISA must define specific parameters. For instance, the ISA could coordinate with the G20, OECD, major Asian powers and other emerging economies in the ASEAN region to launch a multi-billion-dollar five-year programme for R&D in energy and other low-carbon technologies (Ghosh et al. 2019). Such a multi-institutional approach should have specified timelines, objects and metrics to measure progress, such as (a) efficient solar cells; (b) reducing the cost of production of solar modules; and (c) energy storage solutions for large-scale and decentralised energy projects.

For this programme to succeed, participating entities would have to necessarily include commercial enterprises. It would be co-financed by partnering ISA member countries up to 49 per cent with private enterprises contributing the remainder. For cash-strapped developing countries, contributions in kind (laboratory facilities and research personnel) should be permitted. Any technology resulting from the collaboration would have jointly owned intellectual property. Advanced market commitments from governments to procure new products that meet specified parameters would give an added incentive for private investment to invest in R&D and manufacturing facilities at scale, to bring down the costs of emerging technologies.

Thirdly, ISA has a role in promoting new business models in distributed solar energy in Asian economies. For rapidly urbanising Asian countries, energy demand in residential buildings, commercial enterprises and transportation networks will grow. Distributed generation of energy reduces the need to build additional capacity, reduces transmission and distribution losses for electricity utilities, allows for new business lines to be created utilities, and enables the integration of rooftop power and charging of electric vehicles (Kuldeep et al. 2018). New business models for rooftop solar are being developed in India, Indonesia, Singapore, Thailand and other Asian economies. These business models allow for deployment even when roof space is limited for individual households or where their credit histories make it hard for them to access capital.

In rural areas, distributed solar energy can support income generating activities. Examples include solar-based irrigation, food processing units, milk chilling plants, cold storages, small manufacturing such as textiles, and so forth. India, alone, has a market of more than USD 50 billion in using distributed renewables in farm and non-farm activities in rural areas (Waray et al. 2018).

ISA could catalyse these business models and technologies for distributed solar power by creating a cross-learning platform, supporting business delegation visits and investor meets in different Asian countries, and helping to create a warehousing facility to aggregate demand for distributed generation projects across many geographies.

Fourthly, ISA can support technical capacity building of energy and finance officials in Asian economies. As discussed earlier, many of these countries are experiencing rapid energy growth but have legacy infrastructure embedded in fossil fuels. They require training in clean energy technologies and opportunities. Moreover, officials in finance ministries are more conservative and wary of infrastructure investments in renewables when there is a risk of stranded fossil fuel assets. Training on how to manage the energy transition, how to finance renewable energy infrastructure, how to aggregated demand and offer portfolios of projects, or how to create solar parks are among the topics for which there is likely to be significant interest in many Asian economies. ISA should facilitate such training programmes drawing on the expertise in think-tanks working in the region with a knowledge of technologies, regulatory frameworks, and business conditions in many countries.

4.4 The Real Barrier: Cost of Finance

In 2018, global energy investment stabilised at more than USD 1.8 trillion (IEA 2019) and power sector investments exceeded those in oil and gas. The road to decarbonisation starts with greater electrification. Moreover, investment in low-carbon energy, both in supply and demand side measures, amounted to a third of total investment at USD 620 billion (IEA 2019). Nearly half of clean energy investment came from investments in renewable energy (BNEF 2019), with investments in electricity grids, energy efficiency, battery storage, etc. contributing the rest. And the amount invested in renewable power capacity globally in 2018 (USD 289 billion) was three times as much as the investment in coal- and gas-fired power generation capacity (BNEF 2019).

This good news is shrouded by the fact that low-carbon investment needs to ramp up significantly—by 250 per cent by 2030—if the goals enshrined in the Paris Agreement have to be met (IPCC 2018). But mobilising of large volumes of capital that can be invested in deploying or developing low-carbon energy solutions has proven to be the main stumbling block to the energy transition in emerging economies.

There is no dearth of capital. Estimates based on publicly available data suggest that there is nearly USD 250 trillion of commercial capital (Hewlett Foundation 2017) available globally in five primary capital pools: Asset Owners; Retail Bank Deposits; Development Finance Institutions (DFI) and Multilateral Development Banks (MDB); Private Equity; and Venture Capital. More than USD 200 trillion worth of assets are under management in the world's pension funds, insurance firms and sovereign wealth funds. But the capital is not flowing to where it is needed the most.

4.4.1 Availability and Affordability of Capital

Energy investment and income levels are highly correlated. High-income countries, home to just over 15 per cent of the world's population but where energy demand is not growing much, got more than 40 per cent of energy investment in 2018. Lower-middle and low-income countries, which account for 40 per cent of the world's population and where energy deficits are huge, received less than 15 per cent of energy investment (Chawla and Ghosh 2019).

To be sure, some large emerging economies do receive a lot of renewable investments. Excluding large hydropower, out of USD 2.6 trillion invested globally during 2010–2019, only China, India, Brazil, Mexico and South Africa had investments of more than USD 20 billion over the entire decade (UN Environment, Frankfurt School and BNEF 2019). Further, since 2010 the total number of emerging markets recording investments in excess of USD 100 million in any one year has stagnated at 27 countries annually (BNEF Climatescope 2018).

China is the clear leader, accounting for 31 per cent of global renewable energy investment. Other regions have also seen steep expansions. For instance, renewable energy capacity in the Middle East and Africa increased from 3 gigawatt (GW) to 45 GW between 2010 and 2019. In 2018, developing economies invested more in renewables than developed countries, skewed due to the large investments being made in renewables in China and India. Barring investments in the two Asian giants, investments in other developing economies stood at a record USD 47.5 billion, higher than previous years but a small share of the total of USD 272.9 billion invested in 2018.

The concentration of absolute investments in a few economies is not the only challenge. Compounding this is the limited amount of foreign capital available even in the leading developing countries. The share of foreign capital in renewable asset financing in China, Brazil or India is well below that in developed countries like Canada, United Kingdom or United States.

Despite deepening energy markets in Asian countries, many investors remain wary of investing in renewable energy in developing countries. Technology costs are no longer a barrier to the energy transition in developing countries. In 2017, tariffs for solar and wind fell to record lows. A project in Saudi Arabia invited a bid of just 1.78 cents/kilowatt-hour (¢/kWh). The price of onshore wind fell to 1.86 ¢/kWh in Mexico. In India, solar and wind tariffs reached 3.8 and 4.1 cents per unit, respectively. But prices will not fall further if several risks are not mitigated.

The determinants of renewable energy tariffs include land, equipment-related factors and financing costs (costs of debt and equity). And the financing costs account for the largest component—between 50 and 65 per cent—of current renewable energy tariffs in India (Chawla, Aggarwal, and Dutt 2020). This share is even higher in other developing countries where the risk premium is higher.

In other words, the real reason for lower foreign investment is the cost of finance i.e. return on equity and debt servicing. Whereas it accounted for about 50 per cent for bids in Dubai, for instance, it was 66 per cent in the lowest solar bid India has achieved. Cost of capital for solar projects in India is at times twice as much, in dollar value, as the cost of finance for projects in the Middle East.

This poses a twin challenge for renewable energy markets in emerging economies: renewable energy projects face both an availability and an affordability constraint. Several investors, especially those with limited risk appetites such as institutional investors, do not even consider investing in most developing economies. Capital that is willing to move into these markets is often priced at prohibitively high rates thanks to the combination of real and perceived risks. Lack of low-cost finance is now the main barrier to rapid deployment of solar technologies.

4.4.2 Real Versus Perceived Risks

Why do many emerging economies in Asia face high cost of finance for renewable energy projects? Some real risks are unique to the sector itself, such as technology risk or integration of infirm power supply into the grid without destabilising the grid. Other risks are economy-wide, such as currency fluctuation risk, counterparty risk, policy and political risk, etc.

However, there is a third risk category that is playing spoilsport for clean energy markets in emerging economies: the perception of risk. Specifically, in the case of renewables, there is often a delta between perceived risk and actual recorded risk. Left unmitigated, this delta deters investment. The delta exists because of a paucity of adequate data on actual ground realities, resulting in a lack of coherence among various stakeholders in clean energy markets.

Take India as an example. Renewable energy is no longer a fringe player in India's electricity system. More than 80 gigawatts (GW) have been installed and India is making progress (albeit haltingly) towards its target of 175 GW of renewable energy capacity by 2022. With variable renewables expected to contribute as much as 20 per cent of generation capacity by 2022 (much higher shares if all renewable energy sources, including large hydropower, were considered), there is a growing need to better understand the project-level performance of renewable energy assets and identify impediments that can retard progress. Continuous tracking of the sector and a strong data regime would be central for energy planning in the future, as well as for cost-effective monitoring and management of the grid. This would help to reduce information asymmetries regarding renewable energy, and support better decision-making by system operators, policymakers, project developers, and investors.

Information asymmetry can be bridged, with dedicated efforts to monitor market activity and increase transparency. Recent analysis indicates rising levels of market consolidation in the Indian renewable energy sector (Chawla et al. 2018). Firms with access to financing on favourable terms dominated solar photovoltaic and wind auctions in 2018. The top 10 developers in the solar and wind sectors accounted for over 80 per cent of the capacity awarded. This kind of information helps both existing and potential investors.

Further, growing familiarity with renewables has also boosted confidence among lenders, resulting in a decline in interest rate spreads over benchmark bank lending rates for both wind and solar PV by 75–125 basis points during 2014–2018 (Dutt et al. 2019a, b). The reduction in interest rate spreads, coupled with improved bankability of projects, and improved debt-to-equity ratios for solar PV (80:20), and wind energy (75:25), is a significant contributor to rapidly reducing renewable energy tariffs in India to among the lowest in the world.

Tracking on-ground activity shines a light on the effectiveness of government actions to make it easy to do business. The risks of land acquisition, access to evacuation infrastructure, and licenses etc. have reduced thanks to solar parks. In 2017, 54 per cent of total capacity added was in solar parks, driving down tariffs and attracting international power producers. The share dropped to 24 per cent in 2018 due to a slowdown in solar park development, although absolute capacity awarded at solar parks remained largely unchanged.

Without this kind of market information, perceived risks will tend to dominate real risks on the ground, holding back investments in clean energy sectors. But even in India, despite rapid progress in renewables since 2010, information barriers persist. For other emerging economies in Asia, where the renewable energy sector is less developed, these perception-based risks are even greater.

4.4.3 But Investors Also Perceive Risks Beyond the Projects

Some risks are inherent to project development. Transmission uncertainties are major risks for RE projects. Once upfront capital costs have been incurred, the power generated must be sold, without payment delay or default, in order to avoid recurring losses. The technical capacity of the grid to absorb renewable power is critical. Even with plans to install transmission infrastructure, RE capacity gets installed faster, increasing the risk of curtailment of power procured thanks to technical reasons.

Further, delays in land acquisition add to construction and commissioning risks, adding to the cost of finance. The difficulty of securing large, contiguous tracts of land has made developers intentionally scale down projects.

But there are other risks, well beyond the control of individual project developers. The most significant is offtaker risk, resulting in delayed payments or altogether default in payments. Project developers find it harder to predict curtailment when the financial health of distribution companies is at play. The power purchase agreements (PPAs) might oblige distribution companies to offtake power, but enforcement of contract varies from country to country and from province to province.

A second major non-project risk is associated with foreign exchange. If a developing country has a currency whose value fluctuates frequently, the burden of debt denominated in foreign currency could greatly increase with currency devaluation. Moreover, many developing countries also have the risk of currency inconvertibility, which makes foreign investors wary of locking in their money in jurisdictions from which they cannot withdraw easily.

A third major systemic risk is political and policy uncertainty. Much premium is still placed on the political commitment to renewable energy and the overall low-carbon transition. If political support dissipates, or is perceived as uncertain, investors hold back from making long-term investments.

This problem is especially true in countries where the complex political economy of the power sector makes investments in clean energy prohibitive. Indonesia is a good example (Dutt et al. 2019a, b). Despite having considerable solar and wind power generation potential, 208 GW and 61 GW respectively, and both latent unmet energy demand as well as growing demand on some islands, renewable energy sources remain largely untapped. Solar and wind tariffs realised in other countries are much lower than Indonesia's average generation costs of US cents 7.66/kWh. These compare unfavourably against US cents 4/kWh in India and with lowest tariffs achieved globally standing at US cents 2/kWh and US cents 3/kWh for solar and wind, respectively.

There is recognition of this opportunity that renewable energy presents, with Indonesia's National Energy Policy (NEP) 2014 targeting at least 23 per cent of new and renewable energy (NRE)[1] in the energy mix by 2025. The Indonesian electricity utility PLN (which is a vertically integrated behemoth) also targets 23 per cent renewable energy in the electricity generation mix by 2025, and a planned renewable energy capacity addition of 16.7 GW over the period 2019–2028. However, planned solar and wind capacity addition over the 2019–2028 period so far stands at a meagre 908 MW and 855 MW respectively (PLN, RUPTL 2019–2028, 2019).

Multiple interests and the complex governing mechanisms have resulted in heightened risks for investors, thereby constraining the growth of

[1] This includes hydro, geothermal, solar, wind, biomass and other renewable sources.

renewable energy investments in Indonesia. These include: uncertainty over a pipeline of projects, regulatory provisions impacting project viability and bankability, transmission related risks, challenges in land allotment and acquisition, and absence of strong and clear policy ambition for variable renewable energy.

4.5 ISA's Role in Reducing the Cost of Finance

The non-project risks are where the role of the ISA becomes particularly important. Institutional investors remain wary of high-risk renewable energy projects in poor countries. ISA is not a multilateral bank. Its role would be best demonstrated if it facilitated market-ready financial instruments, which crowded in large volumes of private investment. ISA members should politically signal their readiness to work with existing public and private institutions (Chawla 2018). Together they could build a platform that works as an efficient clearing house for portfolios of pooled projects.

4.5.1 Common Risk Mitigation Mechanism

Whereas renewable energy investments need large upfront capital, have long payback periods, and create assets that last a long time. These factors build in an inherent conservatism among investors. The modest credit ratings of most renewable energy projects make it harder for them to attract such investment.

The trouble is that existing options to hedge against risks are either narrow in scope or too expensive. An alternative route is possible. This is to combine various types of risks and spread them across several countries. The premise is that a multi-risk and multi-country approach reduces the exposure for any single country, investor or project developer. At least three such categories of risks—offtaker risk, currency risk, and political risk—could be handled through a single facility, the Common Risk Mitigation Mechanism (CRMM).

On 18 May 2017, the governments of Argentina, Australia, Brazil, Burkina Faso, Cameroon, Chad, France, India, Ivory Coast, Mali, Namibia, Niger, Nigeria, Senegal, Seychelles, Uganda and Yemen (all of which are now members of ISA) gave the mandate to a taskforce of institutions to develop and design a mechanism, which could help to de-risk solar energy investments. The taskforce comprised the Council on Energy, Environment and Water (CEEW), the Currency Exchange Fund (TCX), the Terawatt Initiative (TWI), and the Confederation of Indian Industry (CII).

The taskforce conducted extensive consultations in New Delhi, Abu Dhabi, Paris, New York, Buenos Aires, etc. The range of stakeholders included solar developers, private capital markets, insurers and re-insurers, and development finance institutions (DFIs). Dedicated briefings were given to government officials, in Paris and Delhi—and to diplomatic representatives in those cities. The taskforce, then, presented its study at the Twenty-third Conference of the Parties to the UN Framework Convention on Climate Change (COP 23) in Bonn in November 2017.

Discussions continued between ISA member countries and relevant stakeholders and a pilot version was announced on the occasion of the ISA Summit held in New Delhi on 11 March 2018. The pilot would use the CRMM as a means to leverage public funds, underwrite risks across countries, and crowd in private capital investment by a multiple of at least 15 times.

4.5.2 Need for a Platform

The Common Risk Mitigation Mechanism (CRMM) is designed as a solar project insurance scheme for members of the ISA. Its main idea is to offer countries with rich solar potential a voluntary option to participate in a joint instrument, which would hold the promise of faster and cheaper capital in larger volumes. This joint approach could begin with an instalment of 15 GW of solar capacity, deployed over five years across 20 countries. This would translate to channelling and de-risking about USD 10 billion of senior debt into these countries. Given the growing demand for energy in Asia, the CRMM could act as the trigger to make the adoption of solar solutions to meet this demand significantly more attractive for investors, industry, and counterparties alike in these markets.

If the initiative were driven by ISA, the accelerated route would have the following components:

– A digital platform, whose role would be to pool demand but also create a marketplace or clearinghouse to match investors, project developers and insurers, and create competition among them to secure the best deals.

- A common guarantee, which would be necessary to lower the risks, which have not been removed altogether.
- A common regulatory and contractual framework, so that market participants would have lower transaction costs in identifying, evaluating and closing deals.

The common guarantee, in turn, would also have an instrument to transfer risks, necessary to offer dedicated swaps and guarantees against a listing of the main risks. The entity offering the guarantee would have very low capital requirements if it managed to transfer a substantial portion of the subscribed risk to risk hedging instruments already being offered by various multilateral and regional development banks (including World Bank Group, European Investment Bank, European Bank for Reconstruction and Development, Inter-American Development Bank, Asian Development Bank), or development finance institutions (such as Agence Française de Développement, KfW, Netherlands Development Finance Company, CDC Group, and Overseas Private Investment Corporation), and even to public-private or private insurance and re-insurance entities (TCX, GuarantCo, ATI, AXA, etc.). In fact, the extant measures to de-risk investments could now have a longer pipeline of solar projects in more diverse markets and would be provided with bundled risk packages that are more easily manageable.

4.5.3 How Would ISA Members Benefit?

ISA member countries could benefit from such a mechanism in at least five ways.

First, risk mitigation. Solar projects in developing countries would have access to a 'one stop shop' guarantee mechanism at an affordable price, through competition between insurers. This would further bring down the price of solar electricity, as risks relating to delay in payments or foreign currency fluctuations are removed.

Secondly, foreign investment. CRMM-insured projects would have a rating of AA and above (investment grade globally). This would attract foreign investment, including institutional investment from low-cost sources of capital such as pension funds, sovereign funds, etc. This would further drive down the cost of solar electricity, as the cost of finance continues to account for at least two-thirds of the per-unit cost of solar electricity.

Thirdly, new consolidated markets. The CRMM would leverage public money, which if used to underwrite risks could lower the cost of private finance, and increase the quantity of capital accessible to developing countries. In short, it would create a large aggregated global market for solar projects, especially where the potential is the greatest. This would enable project developers to take build on their lessons in their home country and access new markets and expand their business footprint in other ISA countries. The CRMM would allow them to be covered against non-project risks in these overseas markets.

Fourthly, NDC commitments. In 2018 pressure began to mount on countries to ratchet up their climate commitments, as stated in their Nationally Determined Contributions. The ripple effect of scaling up solar in ISA member countries, aided by CRMM, could help many developing countries present a strong case against the mounting pressure. Despite very limited climate finance made available to them, they would have demonstrated real action on the ground.

Fifthly, climate leadership. With the exit of the United States from the Paris Agreement on Climate Change, a seat has opened up at the global head table on climate change. India with its domestic action and ambition in renewable energy is well placed to take that seat. Through the CRMM, and as a potential key backer of the initiative, India could share its lessons on solar energy with other developing countries, and make a larger impact. Other developing countries could contribute to this effort and showcase their climate leadership as well.

4.5.4 How Would ISA Benefit?

For an institution in infancy, established not to mimic other energy-related institutions, a successful CRMM pilot, which mobilises private capital into markets that are found wanting for investments at scale, would yield tremendous returns in the form of creating value for.

First, signalling action. ISA's unique value proposition is its focus on being an action-oriented organisation. As a market instrument that could mobilise finance for solar deployment, the CRMM could support ISA in signalling its commitment to practical solutions, with the potential to transform markets. This would give ISA an early win, and establish ISA as an institution of great value.

Second, responsive to member states. The CRMM would respond directly to the objectives identified by ISA member states. The CRMM responds directly to the current needs of countries struggling to harness their solar resource due to limited availability of affordable finance. In the process, CRMM also supports the development of harmonised solar markets in participating countries.

Third, collaboration with the private sector. A noteworthy feature of the ISA is its commitment to engage with the private sector to increase the development and deployment of solar in member countries. The CRMM would create a marketplace for existing and new private and public insurers to access new and consolidated bundles of solar projects. Further, it would also facilitate the creation of new markets for solar developers in countries with abundant solar potential.

Fourth, expanding membership. Through the CRMM, the ISA could successfully support countries in accessing new and affordable finance for solar projects, and develop an integrated global solar market. As a result, more countries would see the benefits of being associated with the ISA. This could support the ISA's endeavours in expanding its membership base and achieving its broader vision.

Implementing the CRMM pilot would require:

– The capitalisation of a guarantee entity up to USD 1 billion in cash and sovereign guarantees. This amount would have to be pooled together from international sources including the Green Climate Fund and other DFIs. Furthermore, those countries that seek to take advantage of the de-risking facility could contribute to the guarantee entity via mutual capital deposits but only in proportion of their target volumes.
– Five years of funding for the first phase of the digital platform, which would have to aggregate demand as well as the guarantees. The platform could be financed by private capital, impact investors and strategic philanthropies.

For the expansion and transition in the energy system of countries across Asia, policymakers and markets need to turn their attention to the financing of renewables, rather than merely celebrate the lower costs of solar panels and wind turbines. The CRMM, as conceptualised, could offer a way out and could, in the long run, create a sustainable solar market, which would be less and less reliant on public investment. The sun would, indeed, shine more brightly if the risks don't cloud it.

4.6 Recommendations and Conclusion

The key recommendations are:

4.6.1 Implement a De-risking Facility

Solar projects get unfavourable risk ratings when they face political instability, or electricity utilities with weak balance sheets, cannot resort to legal adjudication easily, and fluctuating exchange rates. For CRMM to function effectively and offer lower premiums for members, ISA must support member countries to develop robust policies and regulations, build strong dispute resolution mechanisms, and reduce policy uncertainty. ISA should demonstrate the potential by facilitating de-risked investment into a major solar project in a member state.

4.6.2 Design Solar Irrigation Programmes for At Least Five Member Countries

India's experience of driving down prices of solar pumps by offering a large aggregated market to manufacturers has lessons for ISA member countries. ISA would need to create a global marketplace, synchronise procurement, and recognise opportunities in extended manufacturing value chains. Thus far, it has asked member countries to outline their demand for such technologies. But this is not an accurate approach as the real demand can only be estimated after examining available finances, the appropriate applications for different kinds of agricultural activities, and the impact on the power sector overall. Support on this estimation and aggregation could add significant value to the member countries.

4.6.3 Develop a Model Rooftop-Solar-cum-e-Mobility Initiative

Rooftop solar combined with charging stations for electric vehicles create new business opportunities for cash-strapped power utilities. ISA can facilitate a coalition in two- or three-member countries to design and pilot such projects.

4.6.4 Productive Mini-grid Investment Facility for Small Island States

The viability of mini-grids and distributed solar is greater when linked to productive, income-generating activities. ISA could design and pilot a dedicated facility for small island member states to attract distributed solar investment into tourism, handicrafts and food processing industries in such countries.

4.6.5 Consistently Assess Progress Against Work Programmes

In order to do so, ISA must have three priorities cutting across all programmes. First, it must be able to lend assistance to member countries to design policy and set targets based on evidence. Secondly, it should be in the lead in establishing a global marketplace, whereby member countries (thanks to their aggregate demand and economies of scale) would be able to bring down prices. Thirdly, ISA can support the financial community and entrepreneurs by building their capacity, in understanding the technologies, the deployment opportunities and the differing market conditions in member countries.

The reputation of a results-oriented institution hinges not only on what it claims to be but also on what it is not. It need not replicate what other institutions do. In fulfilling niche but strategic roles, ISA must work closely with industry, investors and civil society. This is a tall order for any international organisation. As a nimble young entrant on the international block, ISA could chart a new course (Chawla 2018).

Business is combination of realism and sentiment. Bridging gaps between perception and reality can bring the two fuels in an economy—energy and finance—closer. This is necessary to lower the chances of investor sentiment swinging wildly between exuberance and vapidity. This is also necessary to ensure that policymakers make evidence-based decisions rather than keep developers on tenterhooks. The energy transition in Asia is already underway, and continuing. The ISA could play a pivotal role in accelerating its pace.

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CHAPTER 5

Renewable Energy Development, Export-Led Industrialisation, and Its Implications for Climate Strategies in Asian Developing Countries

Eri Ikeda

5.1 Introduction

Industrialisation is indispensable to economic growth, but at the same time, it has had not only damaging consequences for the environment, but also threatening the welfare gains arising from the growth process (see Kaldor 1967; Steckel and Floud 1997). It is now the common understanding that the modern industrialisation process, heavily relying on the fossil fuel energy system that currently accounts for two-thirds of the total

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global GHG (Greenhouse Gas) emission, is the major cause of the climate change, which is the top global risk in the recent years (see IRENA 2017; World Economic Forum 2020).

Increasing numbers of developing countries are following the industrialisation and economic development path of advanced economies, yet, there is a growing awareness that their pathways need not be as polluting as those in the past. One of the key reasons of this view is the rapid expansion of the renewable energy, driving the *energy transition* at the global level (see, for example, Matthews 2014; OECD 2017).[1,2] According to the report by IEA (2019a), the expected expansion of the renewable energy capacity between 2019 and 2024 is 50%.[3] What is notable is that the renewable energy investment in developing countries has already surpassed that of developed countries in around 2014 (IRENA 2019a), and some of the developing countries, especially China, are already leading the global renewable energy market (see Sect. 5.3 below). In addition, developing countries have started to mainstream the climate in their developmental policy agenda, attempting to balance the economic growth and environmental protection.[4] Against this background, this chapter seeks to investigate the possibilities for countries seeking to develop and industrialise to make use of the current focus on renewables in order to meet climate change targets while continuing with their growth strategies, with a particular focus on Asian developing countries who are one of the fastest growing and industrialising economies.

The remainder of this chapter is organised as follows. The following section addresses the existing literature regarding the key aspects of renewable energy development, with a particular focus on developing country context. Section 5.3 will provide an overview of the current status of the global renewable energy market to aid the analyses in the following sections. The analysis necessarily begins with the global market because of the view that it conditions the renewable energy development of any specific region or country. Section 5.4 will investigate the renewable energy deployment in developing countries in Asia as a whole, aiming to help to locate the subsequent analyses of the case studies into a context. It will

[1] The main aim of the energy transition is to achieve the zero-carbon by 2050.

[2] Other possible solutions at present include energy efficiency improvement and utilisation of CCUS (Carbon Capture, Utilisation and Storage).

[3] 60% of this will be accounted by the solar PV followed by 25% of onshore wind.

[4] A large number of co-benefits are foreseen by addressing the climate change, such as the improving access to the energy, eradication of energy poverty and increasing health benefits, which are often linking with SDGs.

begin by briefly situating Asian developing countries in the world renewable energy market in general, followed by the major analysis of the relationship between the export structure and renewable energy development in the region. Section 5.5 will examine two country cases of India and Lao People's Democratic Republic (Lao PDR hereafter), to further examine the necessary and sufficient conditions for shifting towards renewables, while achieving the economic growth and development. The last section will summarise the findings and discuss the implication of this study.

5.2 Key factors of renewable energy development - Literature Review

This section reviews the existing literature in three areas; technologies, finance, and enabling conditions for switching energy sources from non-renewables to renewables, mainly with a view to situating the current renewable energy development discussion in developing countries.

5.2.1 Technologies

There is a general agreement that renewable energy is produced by wind (offshore and onshore), marine (tidal, wave), hydro, solar (PV, thermal), biomass, and geothermal technologies.[5] The life cycle GHG emission by these energy sources is seen as much lower than that of traditional fossil fuels (i.e., oil, coal, and natural gas), thus considered as 'greener' (see Amponsah et al. 2014). Increasing numbers of reports are available to provide overviews and trends, highlighting the strategic and rapid expansion of renewable energy in the energy mix (see, for example, IRENA 2019a; REN21 2019). These studies generally look at the global trend but do not typically take the implication of level of development and economic structure on renewable deployment into consideration.

With regards to the suitability of the technologies in developing countries, increasing number of literature argue that the off-grid and smaller system are preferable for the developing countries, rather than traditional large-scale infrastructure-based system (see, for example, Griffith-Jones et al. 2012; Louie 2019; Yüksel 2019) . The former including small-scale hydropower and solar (plus wind sometimes) are seen as more flexible to

[5] There is a debate whether nuclear can also be regarded as renewables or not. This chapter excludes nuclear, mainly due to the data availability.

adapt in various local conditions and upgrade over the change in technologies and renewable energy markets, while the latter most notably hydropower requires large-scale and long-term investment in power generation and transmission. (see also Sect. 5.2.3 below). However, there is a general consensus that developing countries lack local technologies to take advantage of rich natural resources. Thus, the focus of the existing studies is typically technology transfer/imports from advanced countries and increasingly China, and generally discuss the barriers for developing countries in adopting foreign technologies (see, for example, Kirchherr and Matthews 2018; Urban 2018). The studies show such barriers include; lack of domestic capacities including the knowledge, technical expertise, and legal framework, difficulty in changing the existing system, difference in socio-economic and natural conditions, and limited available finance (see, for example, de Coninck and Sager 2015; Luthra et al. 2015; Pueyo and Linares 2012). Given that these barriers outweigh the benefit of technology transfer, although limited numbers of studies present the successful cases of technology transfer and find that the enabling factors, notably the local capacity as well as the government policies that facilitate the renewable deployment, the existing literature commonly recommends the technological development and production in the domestic renewable sector and localisation of technologies as the key solution. Yet, such discussion is typically independent of *how*, including the possibility of industrialisation, while some recognise its potential (see, for example, Matthews 2014). In recent years, there is an emerging theme of 'green industrialisation' or 'green manufacturing', but the focus is limited to the incorporation of the environmental consideration in the domestic industrial process, such as the lesser and sustainable use of materials, lowering GHG emission, and environmentally friendly product development (see, for example, Kothawade 2017; Okerere et al. 2019; Rodrik 2014).

5.2.2 Financing Renewables

Looking at literature that analyses the financing for renewables, these generally cover financing gap, tools and instruments, and source of finance.

Regarding the financing gap on renewables, the focus used to be largely on developing countries, but there is a growing consensus that large-scale finance and investment are required to be mobilised at the global scale (see Foley 1992; World Resources Institute 2019).[6] Such discussion has been

[6] For example, under the UNFCCC, the Parties agreed to set the collective goal of 100 billion USD per year by 2020.

led by the international policy arena, with the emerging terms of 'green finance', 'climate finance' and ESG (Environmental, Social and Governance) investment that promote the shift the global financial flow gearing towards meeting climate change targets especially under the Paris Agreement (see OECD 2019; Sachs et al. 2019).

Almost all the literature on the tools and source of finance highlight that developing countries do not have a viable domestic financing scheme in both public and private sectors. The perceived problems in the domestic system include high-interest rates, lack of long-term finance, immature financial system, and uncertainty in and low profitability of renewables (see Briscore 1999; Mazzucato and Semieniuk 2018; Sarangi 2018). The literature suggests that it has resulted in the heavy dependency on the external sources, especially the bilateral or multilateral assistances such as international loans, aid, and project finances, rather than utilising the market-based instruments (see, for example, Donastorg et al. 2017; Foley 1992; Hussain 2013[7]). The majority of such finance has been directed to the hydropower projects since the early stage of renewable installation, and it has been increasingly diverted to other types of technologies over the years (see Kozloff, 1995). It is apparent that such dependency has been causing many problems in developing economies, especially high-cost debt issues leading unsustainable of renewable installation and hindering economic development (see Hussain 2013; Sovacool and Walter 2019).

5.2.3 Necessary Conditions for Switching to Renewables

When considering the necessary condition for shifting towards renewables, the existing literature generally focuses on economic, environmental, and socio-economic factors. More attention is paid on the economic factor, and the discussion often links with the choice of appropriate renewable technologies (see also Sect.5.2.1 above). Among the perceived economic factors, most emphasis appears to be placed to the cost of renewables, generally electricity/energy cost (kWh, operating cost) and capital cost,[8] as one of the primary determinants of renewable installation (see, for example, Qurashi and Hussain 2012). It is the general recognition that

[7] The financial instruments available include grants, debt, equity, green bond, FIT (Feed-in-tariffs) and guarantees.

[8] It is also referred as the total overnight cost.

the cost of renewables has increasingly competitive relative to fossil fuels (see, for example, Brown et al. 2018).[9] The recent studies by EIA (2020) and IRENA (2019a, b) show that, among the renewable technologies, solar and wind are catching up hydropower that has been the cheapest option, although the former two are more capital intensive than the latter (see Best 2017). In developing country context, however, fossil fuels are argued to retain the cost competitiveness, mainly because of the higher capital cost than advanced economies (see Arnold 2018; Luthra et al. 2015; Steffen 2019). It is suggested that developing countries need an intervention in pricing, an increase in subsidies, and improve return on renewables (see Griffith-Jones et al. 2012).

While it appears that environmental and socio-economic factors are generally seen as the secondary to the economic factors, a large number of literature already exist in this area. The literature is generally critical of the blind-expansion of renewables without considering the negative consequences on the environment, local livelihood, and biodiversity, from the point of external and social costs (see, for example, EIA 2019; Grumbine and Xie 2011).

5.3 The Current State of Renewables: Overview of the Global Market

As of 2018, the share of renewable energy remains marginal relative to that of fossil fuels. For primary energy supply and demand, fossil fuels account for approximately 80% and 85% of total energy shares, respectively (REN21 2019; author's calculation[10]). On supply side, the startling fact is that the increase in the share of renewables relative to fossil fuels is merely less than 1% between 2000 and 2018. Among the fossil fuel resources, coal is the only resource that showed a decline in supply since 2015, possibly reflecting the fall in the coal in the energy mix of advanced economies. Yet, this decline is merely 1%, and coal remains the second-largest energy source after oil. In fact, coal supply has increased 60% between 2000 and 2018, and this trend is expected to continue to meet the increasing electricity demand from developing countries, especially in Asia (see IEA 2019b). These clearly suggest that the renewables are not

[9] The majority of studies typically estimate the cost with the levelised cost of electricity (LCOE), taking the capital cost also into consideration.

[10] Data is from "Total primary energy supply (TPES) by source, World 1990–2017" (see IEA, database).

yet substitute, for fossil fuels thus, for the energy transition, the challenge also lie on the reduction of the use of fossil fuels.

One of the reasons of this dominance of the fossil fuels is the subsidies. According to REN21 (2019), fossil fuel subsidies are more than double of renewables globally (115 countries), and more than 60% of countries provide subsidies over 100 million USD each. Nonetheless, in the U.S., the subsidies for solar and wind have exceeded those of fossil fuels in FY2016, and among renewable sources, solar and wind account for half and 30% of total subsidies respectively (EIA 2018). This change in composition of subsidies is in line with the increasing cost competitiveness in renewables, which suggests that the lowering cost of capital-intensive technologies driven by government support cannot be undermined.

Figure 5.1 shows the renewable electricity generation (GWh) between 2000 and 2017 for the clusters of countries[11] based on the level of development, i.e., income level, and China.[12] What is observed is that, at all the income levels, the electricity generation by renewable energy source is on

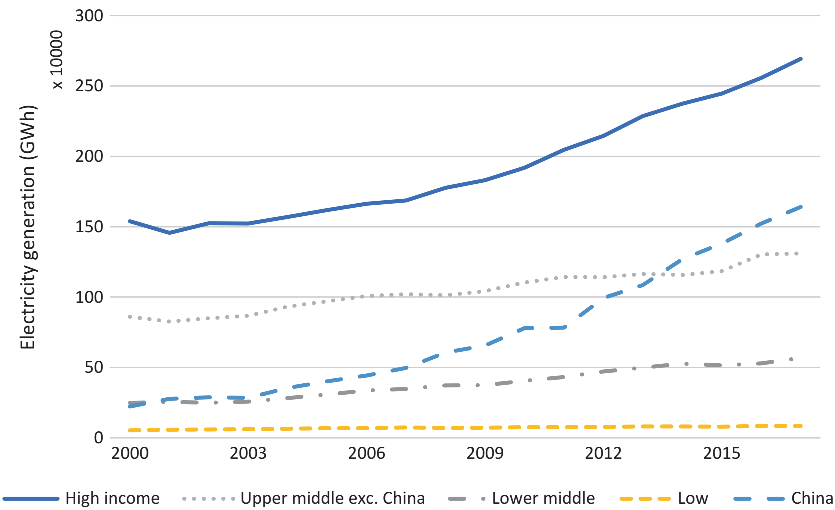

Fig. 5.1 Renewable electricity generation by income levels and China: 2000–2017. (Source: IRENA, World Bank; author's calculation)

[11] Similar trend is also seen in electricity capacity.

[12] The countries are classified based on the World Bank's per capita income levels as of 2019. Following the widely used classification, high income countries are regarded as advanced countries, and the rest consisted of upper middle-, lower middle-, and low- income

the rise, while the size of output and the rate of growth varies. In particular, the figure suggests that the income level and the renewable electricity generation size generally show a strong positive correlation; the higher the income level, the larger the renewable energy generation. It needs highlighting, however, that this relationship holds if China is excluded from the cluster of the upper-middle-income countries. With China, the renewable electricity generation by this cluster of countries has already surpassed that of high-income countries around 2010s. For the rate of growth in renewable installation, the high-income countries have been showing the relatively stable and high growth, while developing countries largely fluctuates.

Table 5.1 presents the share of total renewable energy generation grouped based on the different types of technologies, corresponding to the level of development.[13] A number of observations are made as follows. Firstly, hydropower has been accounting for by far the biggest share for renewable electricity generation and remains to be the dominant source for all the income levels.[14] This is most evident in low-income countries, whose dependency on hydropower has been close to 100%. Secondly, the hydropower share, however, has been experiencing a decline in the last 20 years or so across the income levels. This fall in share of hydropower is bigger for higher-income countries relative to lower-income countries.

Table 5.1 Share of the renewable energy generation: 2000 and 2017

	Advanced countries		*Developing countries*					
	High-income		*Upper-middle*		*Lower-middle*		*Low*	
	2000	*2017*	*2000*	*2017*	*2000*	*2017*	*2000*	*2017*
Hydropower	89	52	98	76	88	73	100	98
Wind	2	25	0	13	1	10	0	1
Solar	0	10	0	5	0	4	0	1
Bioenergy	7	11	2	5	4	6	0	1
Geothermal	2	2	1	0	7	5	0	0

Source: IRENA, World Bank; author's calculation

countries are classified as developing countries. The composite is developed for the countries that data is available by both IRENA and World Bank (see database section).

[13] Marine energy is excluded from the table as the rounded figure is zero for all the income levels.

[14] No data is provided for the small hydropower.

That is; the former is 37%, and the latter consisted of upper middle-, lower-middle-, and low- income countries are 22%, 15% and 2% respectively. Thirdly, the decline in the share of hydropower is mostly taken up by wind, solar, and bioenergy. The expansion of wind and solar are relatively significant, as in 2000 there was hardly any electricity generation by these two sources. In terms of the speed of growth, solar shows the fastest increase among different technology options, followed by wind, regardless of the perceived weaknesses including the lack of battery facility and time variation in electricity generation. This faster growth of solar deployment is seen in driven by the developing countries, most notably China.

Table 5.2 shows the top ten countries for the global share of renewable electricity generation, GDP (Gross Domestic Product), manufacturing production and its export in 2017 (latest available data). The interesting aspect of this table is that half of countries who have large renewable electricity generation are those who have not only the higher GDP but also the manufacturing value and export at the global level. These relationships are manifested by China, Germany, Italy, Japan, and the U.S. This suggests that more industrialised economies tend to utilise the renewables than those who are not. The other notable point from this table is that the

Table 5.2 Ranking in renewables electricity generation, GDP, manufacturing production and export in 2017

	Renewable electricity generation (GWh)	*GDP (current USD)*	*Manufacturing production (current USD)*	*Manufacturing export (current USD)*
1	China	United States	China	China
2	United States	China	United States	Germany
3	Brazil	Japan	Japan	United States
4	Canada	Germany	Germany	Japan
5	Germany	India	Korea, Rep.	Hong Kong SAR, China
6	India	United Kingdom	India	Korea, Rep.
7	Russia	France	Italy	France
8	Japan	Brazil	France	The Netherlands
9	Norway	Italy	United Kingdom	Italy
10	Italy	Canada	Brazil	United Kingdom

Source: IRENA, World Bank; author's calculation fast-growing economies, i.e., India, Brazil, and Russia, also ranked high in renewable electricity generation. While Russia is out of ranking for the rest of the segments, India and Brazil are high in GDP and manufacturing production. For Brazil and Russia, the large portion of renewables is generated by hydropower (100% and 80% respectively), thus less diversification in renewable technologies is observed (see also the sections below).

5.4 Renewable Energy Deployment in Asian Developing Countries: Focus on Export Structure

The renewable energy generation by the Asian developing countries[15] accounts for 35% of the world total in 2017, increased from 14% in 2000. This strong presence of Asian developing countries in the world renewable energy market evidently owes to China. China has been the biggest renewable energy supplier since 2005 in the world, accounting for 26% share of the world renewable energy generation in 2017. Within the Asian developing countries, China and India alone account for more than 85% of total renewable energy generation in 2017 (China for 77% and India for 10%). Between 2000 and 2017, while the renewable energy generation has increased more than 5 times in Asian developing countries as a whole, but without China and India, the increase is merely 2.6 times.

For the analysis of the industrialisation and renewable energy development, Asian developing countries are classified into manufacturing- or non-manufacturing export-based economies. The former is the countries that export the manufacturing products the most in the total merchandise exports, while the latter is the countries whose export is dominant in primary commodities, which is the sum of the exports in agricultural raw materials, food, fuels, and ores and metals. It needs highlighting that the reason for this focus of export rather than the composition of the GDP or production is to examine the role of drivers and dynamism underlying the economies to the renewable energy deployment. Table 5.3 below shows the country classification for Asian developing countries.[16] What is clearly

[15] It consists of South East, East, and South Asian countries, excluding the high-income countries. High income countries are Brunei Darussalam, Hong Kong SAR, Japan, Korea Rep., Macau SAR, and Singapore.

[16] Author's composite. Countries are classified based on the availability of renewable electricity generation in IRENA, and per capita income and merchandise export by World Bank in 2017, except Afghanistan, Cambodia, and Lao PDR. For these three countries, 2016 data is used for export data as a proxy.

evident is that manufacturing export-based economies and higher-income countries have larger electricity generation by renewable than those of non-manufacturing export-based economies and lower-income countries (see also the previous section). The total electricity generation of renewables by manufacturing export-based countries is 28 times larger than that of non-manufacturing export-based economies in 2017, mainly because of China. Thus, without China, this difference between these clusters narrowed down to 6 times.

Figures 5.2 and 5.3 are the plot of total renewable electricity generation by manufacturing- and non-manufacturing export-based Asian developing countries respectively.[17] China is excluded from the former group given their extremely large size of the renewable energy generation, in order to accurately capture the renewable trend of the rest of Asian developing countries. A number of observations are derived from these figures.[18] Firstly, the hydropower generation remains dominating for both

Table 5.3 Country classification based on the level of income and export structure, and renewable electricity generation in 2017

	Manufacturing export-base	*Non-manufacturing export-base*	*N/A*	*Renewable electricity generation (GWh)*
Upper middle	China, Malaysia, Sri Lanka, Thailand	Maldives	N/A	1,737,321 GWh
Lower middle	Cambodia, India, Pakistan, Philippines, Vietnam	Lao PDR, Indonesia, Mongolia, Myanmar, Timor-Leste	Bangladesh, Bhutan, Papua New Guinea	428,400 GWh
Low	Nepal	Afghanistan	Korea DPR	17,607 GWh
Renewable electricity generation (GWh)	2,086,248 GWh	74,801 GWh	22,279 GWh	2,183,328 GWh

Source: IRENA, World Bank; author's calculation

[17] Marine technology is excluded from both figures as the figure is zero.
[18] The analysis in developing countries as a whole also derived the similar results in general.

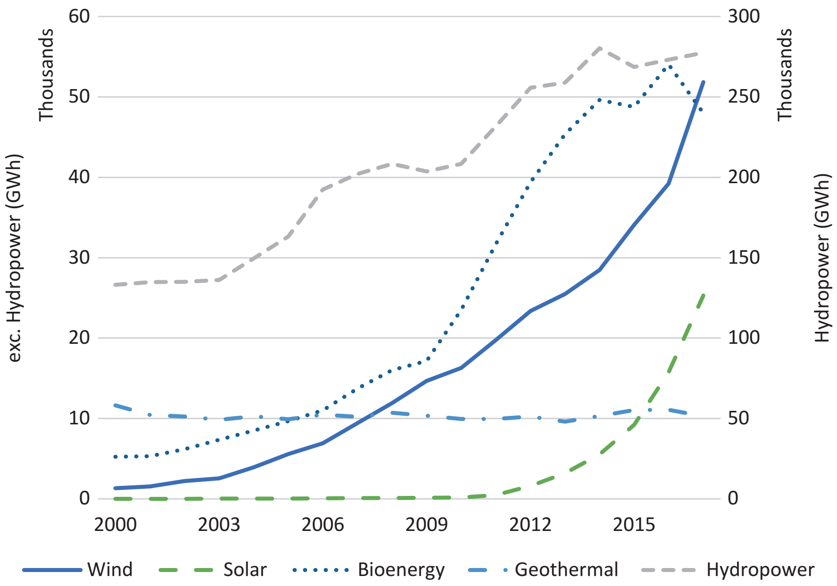

Fig. 5.2 Renewable electricity generation for manufacturing export-based Asian developing countries excluding China: 2000–2017. (Source: IRENA, World Bank; author's calculation)

clusters, and the share of hydropower in non-manufacturing based-economies (69%) is slightly larger than manufacturing based-economies (67%) in 2017. Yet, it needs highlighting that the share of the former increased 6% since 2000, while that of latter has fallen about 20% from 88% in 2000. Secondly, for manufacturing export-based economies, wind and solar (and bioenergy) show a rapid and strong increase, especially since around 2010 (see Fig. 5.2), while hardly any change is observed for non-manufacturing export-based economies and the size of these remain near zero (see Fig. 5.3). It is of note that wind and solar markets are almost monopolised by China and India in Asian developing countries. The share of these two countries for wind generation is 99% and for solar is 95%.[19] Thirdly, the use of bioenergy remains to be fairly large in Asian developing countries in general (and geothermal in particular for non-manufacturing export-based economies). For manufacturing export-based

[19] In 2017, Asia's solar generation accounts for roughly half of the world.

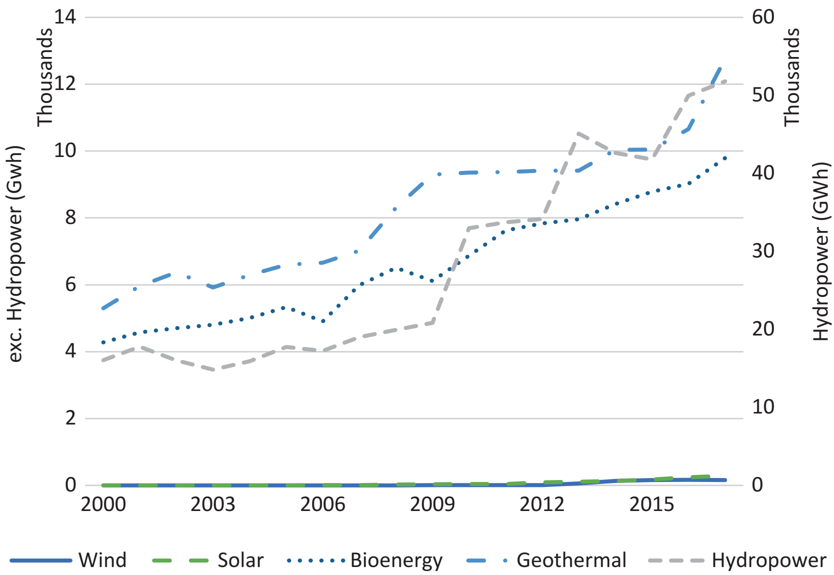

Fig. 5.3 Renewable electricity generation for non-manufacturing export-based Asian developing countries: 2000–2017. (Source: IRENA, World Bank; author's calculation)

economies, bioenergy has been the largest renewable energy source apart from hydropower until 2017 (wind surpassed its size), and the share of bioenergy has risen from 3% in 2000 to 12% in 2017 (see Figs. 5.2 and 5.3), mainly due to India and Thailand. For non-manufacturing export-based economies, bioenergy has been one of the main renewable technologies used together with hydropower and geothermal. The main contribution is from Indonesia, whose share is nearly 100% in this cluster (see also Junginger et al. 2019).[20] Above-mentioned observed differences in two clusters suggest that the dependency on hydropower become less and the diversification of technologies increases, more on capital-intensive ones, as exports shifts towards manufacturing base, while non-manufacturing export-based economies tend to utilise locally available the natural resources.

[20] For developing countries as a whole, Brazil and Indonesia account for 71% and 13% of total bioenergy generation in non-manufacturing export-based economies respectively.

5.5 Case Studies: Lao PDR and India

This section will discuss two specific cases from Asian developing countries to further elaborate the points made in the sections above. Of particular importance in the analysis are (1) the role of industrialisation and manufacturing exports, and (2) the cost considerations for renewable installation. To aid comparison in these areas of analyses, the countries selected are India and Lao PDR. These countries differ in type and size of renewables deployed, export structure, and income level, which are used as the selection criteria. Both countries confirm the observations made in the previous sections. India as an upper-middle-income and manufacturing export-based economy,[21] accelerating diversifying in their renewable towards solar and wind away from hydropower (and bioenergy). It is also important to highlight that the total renewable energy generation in India is the second largest after China, accounting for about 10% of the total in Asian developing countries. In contrast, Lao PDR is the poorest country in South East Asia, classified as a lower middle-income and non-manufacturing export-based economy. The electricity generation by renewables is about the middle size among Asian developing countries, but remains heavily dependent on hydropower, nearly 100% of the total renewable energy electricity generation. It needs noting again that the export structure does not necessarily correspond with the general perception on the country's economic structure drawn from the GDP composition.[22] Yet, to reiterate, the aim of the analysis of this section is to discuss the key driver of the economy, i.e., export, in the renewable energy development.

5.5.1 Role of Industrialisation and Manufacturing Export

While the renewable installation growth is one of the fastest in the world, India's domestic manufacturing industries for the renewables, especially solar (and wind), are at infancy level. As are other developing countries, discussed in Sect. 5.2, India too has been heavily dependent on the foreign

[21] India's export has been dominated by the manufacturing products since 1980s, which account for around 70% of total merchandise exports.

[22] Both India and Lao PDR are considered as service-based economies based on GDP composition. The shares of service, industry and agriculture sectors are 50%, 32% and 16% respectively for Lao PDR, and roughly 50%, 27% and 15% of GDP respectively for India in 2017 (see WDI database).

technology and finance,[23] and upgrading, increasing R&D and investment in this sector have long been the main issues (see, for example, Khare et al. 2013). Under such circumstances, the recent move by the government on the promotion of domestic solar PV industry is, on one hand, welcomed, imposing the safe-guard tariff on the solar-cell and modules imports, on the other hand, has shown the hampering impact on the domestic solar market. The sector suffered from the shortage of supply, increase in cost, and sudden-shortage of the investment. The problem is that the current policy gears towards the import substitution industrialisation strategies, without a tie to the economy-wide and sector-specific export-oriented strategies. As the comprehensive study on the successful East Asian industrialisation process by Storm and Naastepad (2005) for example argue, the import substitution does aid industrial development and technological upgrading at the early stage, but should be implemented complementary to export-oriented policy to ensure the reciprocation of export in relation to import, and promote more export-oriented strategies. In this regard, the recent key growth strategies consisted of aggressive and full-fledged domestic industrialisation policies across the sectors under 'Make in India' and 'Make for World', accompanied by a wide range of export promotion schemes,[24] and a clear target of tripling the export in next five years, can be a game-changer. Although the past attempts of shifting towards industrial economy are generally viewed as unsuccessful (see Chaudhuri 2013; Felipe et al. 2013), the data has already shown that India's export share of the world is expanding and the recent report by the Reserve Bank of India (2019) suggests the welcoming fact of shifting export towards higher value-added products in recent years, providing the resilience in export demand.[25] These country's macroeconomic trends show a large potential for domestic renewable energy development as well, by way of channelling financial surplus and technological resources from the other industrial and

[23] For example, the solar PV industry imports 90% of the solar cell from China. The concessional loans for the solar project come from Germany, the U.S., and World Bank (see Bloomberg NEF 2019).

[24] See Indian Trade Portal for more details; https://www.indiantradeportal.in/vs.jsp?lang=0&id=0,25,857,3901

[25] The recent COVID-19 outbreak and the subsequent lockdown has posed a greater challenge in India, through disruption of the supply chain, halting the production process, and fall in the global demand. India is attempting not only to increase domestic production but also to attract more foreign investment as one of the destinations for the relocation of supply chain away from China by creating a favourable business environment.

exporting activities, as a so-called 'trickle-down effect'. This increasing availability of resources will facilitate to develop the competitive domestic manufacturing base for renewables, also in a manner of green manufacturing as discussed in Sect. 5.2, even continuing the import substitution until the industry matures.

The expansion of the specialised renewable source of hydropower, as endowed by the rich Mekong River,[26] and primary commodity production are largely the synonym with Lao PDR's growth strategies. Thus, the major source of revenue to the country is the energy export to the neighbouring countries and primary commodity export (about 70% of total as of 2018). As is widely studied, however, the dependency on the commodity export typically results in supressed or weak growth, mainly due to the depressed price levels for the exported products (see, for example, Meizels 2000). In fact, the commodity price has been suppressed since the recovery from the 2007–9 crisis, impacting negatively on Lao PDR's balance of payment. The additional aggravating factors for their revenue are the lowest price of hydropower electricity among the various renewable technologies, the limited fall in hydroelectric cost, and the higher re-importing electricity price from neighbouring countries. This is not to say that Lao PDR does not have the industrialisation strategies. One of the key policies since early 2000s is the attraction of FDI for foreign capital, finance, and technologies by setting up several Special Economic Zones (SEZs) across the country. However, about a half of FDI is flowing into the hydropower and mining from 2006 to 2016, a limited number of SEZs are active, and investment concentrates in low-value added segments outsourced by the neighbouring countries (see OECD/Economic Research Institute for ASEAN and East Asia 2018). Yet, recently, the share of manufacturing export products is surging, from merely less than 10% of total merchandise exports in 2012 to nearly 30% in 2016, mainly seen as due to the contribution by the electric and telecom products (see Gnanasagaran 2018). This diversification of export products as well as shift from food and beverage processing manufacturing are a positive signal that Lao PDR is embarking on the industrialisation path. Unlike the case of India, trickle-down effect from industrial activities to renewable development, i.e., hydropower, is not likely to occur at present, simply because of the small scale and infancy level of manufacturing industry and exports. The industrialisation strategies also do not include the production of renewable alternative such as

[26] Electricity export accounts for 26% of total exports in 2017 (OECD 2018).

solar and wind. Yet, promoting hydropower coupling with the manufacturing industry developments evidently could contribute to the growth process, and the trend of manufacturing export growth might show some potential in transforming the economic structure and diversification of renewables as well in long run.

5.5.2 Economic Cost and Finance

The focus on non-hydropower-based renewables, i.e., solar (and wind), allows India to shift less costly option in long-term. While India is facing a drawback of import tariff in solar market in short run as is mentioned above, the solar cost in India is already the cheapest in the world and the investment trend, scale, lower labour cost and land availability show that the reduction of cost is expected to accelerate further (see Bloomberg NEF 2019). Although the cost competitiveness is seen as one of the key factors to accelerate the renewable installation as reviewed in Sect. 5.2, in the case of India, it is also seen as having an hampering effect to the investment due to the low tariff resulted from the lower cost (see Gupta 2020). Under such environment, the government finance and concessional finance from multilateral agencies are seen as playing a key role in the sector development, especially at the initial stage. The funding supports and incentive mechanisms that the government has been setting since 1990s is quite extensive, and seen as successful in boosting investment. It includes preferential low interest loans, preferential FIT, accelerated depreciation, power purchase obligation, tax holidays, capital subsidies, to name a few (see, for example, Altenburg and Engelmeier 2013). In recent years, the share of private finance in both banking and non-banking institutions in renewable investment is rapidly increasing, while multilateral loans show a slight decrease (see Gupta 2020). As one of the most attractive markets for renewables, India has been attracting an increasing amount of FDI and raising the funds through the capital markets, due to which the equity investment in clean energy sector has reached 1.02 billion USD in 2018 (see Bhaskar 2019). Yet, this availability of finance is not seen as a panacea because of the high cost debt and short-term availability of the finance, as is the developing countries in general. This implies that the state support on long-term and low interest finance remains crucial to facilitate the sector development.

Along with the national growth strategy mentioned above, Lao PDR has been expanding the construction of dams and planned to build more than 70 additional ones.[27] Given the lack of domestic and export dynamisms, unsustainable export income revenue, and low foreign reserves, the dam construction has been financed through the external sources (mostly concessional loans and foreign funded projects).[28] The consequence is the debt trap. International Debt Statistics shows that including other infrastructure projects, the debt to GNI ratio (%) and external debt stocks to exports (%) of Lao PDR are on average 85% and 258% respectively between 2000 and 2018 (see also IMF 2019). Most notably, in recent years, the borrowing from China to energy sector has reached to more than 40% of the external debt (Ibid.). It is projected that by 2030 the financially viable hydropower will reach the limit (OECD 2019), and hardly any room is left for hydropower cost to fall due to the technological saturation. These imply that Lao PDR will face the stoppage in expanding the source of revenue shortly, expecting the worsening financial condition, deterioration of balance of payment, and more pressure on debt repayment. In this regard, Lao PDR's aspiration for expanding renewables, focusing on hydropower, is unsustainable, without generating the domestic dynamism and developing the solid and alternative source of income, i.e., strong manufacturing export base.

5.6 Conclusion

Developing countries are undergoing the rapid economic growth and structural shift towards industrialised economies, while being expected to meet the GHG reduction targets. This is the preliminary study and a lot more has to be done to fully answer the questions on how to facilitate the energy transition through industrialisation, and why some developing countries are able to adopt renewables better than others. Nonetheless, the present study argued that a shift to renewable energy is not inconsistent with an industrialisation process, provided that the industrialisation process is export-oriented and some or most of the initial costs of switching to renewable energy technologies are borne by the state. The main findings in this regard are, firstly, more industrialised economies that are

[27] Negative environmental consequences and the impact of livelihood and biosphere by the construction of dams have been well-reported (see, for example, Blake and Barney 2018).

[28] The governments suffer from budget deficit since 2000, and persistent current account trade deficit since 1980s (OECD/Economic Research Institute for ASEAN and East Asia 2018).

generally higher income and their dominant export in manufacturing products typically utilise the renewable energy than the less industrialised economies whose characteristics are lower income and their dominant export in primary commodities. Secondly, manufacturing export-based economies tend to diversify the electricity generation source of renewables, in comparison to non-manufacturing, i.e., the commodity, export-based economies. It has argued that the former is generally shifting away from the conventional large-scale hydropower and putting more weight on wind and solar. Thirdly, from the case study, it has argued that export-led industrialisation could facilitate the renewable sector development, through channelling the trade surplus and other resources towards investment and R&D expenditure in domestic renewable sector. This is more likely the case in India than Lao PDR, while both countries are embarking on the industrialisation path. It has argued that in India, the rapid expansion of the renewable energy deployment coincides with the process of full-fledged industrialisation under 'Make in India' policy, and India already shows a sign of the trade shifting high value-added products and rapid expansion in export, and this could well be complementing the import substitution policy on solar PV development. In addition, the strong back up by the government finance and intervention remains available, and facilitating the participation of private sector. In contrast, Lao PDR's case shows that the heavy reliance on commodity and energy exports will continue to make the country's financial condition vulnerable and be trapped into the existing pathways of the development. Yet, the manufacturing export has started to take off, and that in long run, if the country is successful developing further the manufacturing and export base, there is a possibility for the country to generate the sustainable income source to finance debt payment and diversify the renewable sources.

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CHAPTER 6

Dynamics of Renewable Energy in China: Drivers and Challenges

Qing Tan and Sha Yu

6.1 Introduction

China has the world's largest renewable energy market. It has one-third of the global wind power capacity and a quarter of the global solar capacity. The Chinese government is continuing to expand its investment in renewables and is expecting to add $360 billion investment on renewable power generation between 2017 and 2020. Meanwhile, the demand for energy in China grows rapidly, and the impact of renewable energy is still small in the overall energy mix. Non-fossil energy, including non-hydro renewables, hydro, and nuclear, only accounts for 12% of China's primary energy consumption today.

In this chapter, we will investigate the future growth of renewable energy in China, with a focus on solar and wind energy. On the one hand, China is accelerating its renewable deployment on several fronts:

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alleviating air pollution and phasing out coal, reducing dependence on imported fossil energy and improving energy security, and further expanding its clean energy industry. These factors, along with proactive climate policies such as the national cap-and-trade system, create favourable conditions to further advance renewable energy deployment in China. On the other hand, China still lacks adequate regulatory structures to support the clean energy transition, which could become bottlenecks to renewable deployment in the future. The Chinese government is considering phasing out renewable subsidies. Renewable power generators in China face the worst curtailment rates in the world, with the national average curtailment rate at 17% for wind and 10% for solar in 2016. This raises several questions about the growth in renewable energy in the future. How would the market perform when the government removes subsidies for renewables? How would the current power sector reform in China improve electricity dispatch and reduce curtailment? Moreover, the majority of China's large-scale wind and solar projects are in the resource-rich northern and western regions with low electricity demand. How would China develop inter-regional transmission capacity to allow for further growth in renewable energy? This chapter will discuss the dynamics of renewable energy in China and how different drivers and policies interact and shape the future of renewable energy in China. In addition, it will examine the current power sector reform and how improved regulatory structures can create enabling conditions for renewable deployment in China.

6.2 Background

This section describes what the renewable energy landscape is in China and how the policy framework has evolved to support the Chinese renewable industry, with examples of challenges to be discussed in later sections.

6.2.1 Renewable Energy in China

China has considerable potentials in renewable energy, where hydropower, biomass, wind power and solar energy are the four technologies of the most promise. By the end of 2018, installed renewable capacity in China, including hydro, marine, wind, solar, bioenergy and others, reached 729 GW, which takes 38.4% of the country's total generating capacity and around 30% of the world's total renewable capacity. Of China's renewable capacity, 184.3 GW is from wind, accounting for 32.8% of global wind capacity; and 174.5 GW is from solar, which is 36.3% of the world's total solar capacity (China Renewable Energy Engineering Institute 2019; IRENA 2019).

Behind China's large renewable capacity is its fast growth. Between 2009 and 2018, China more than tripled, while the world only doubled, its renewable capacity (Fig. 6.1). Wind and solar capacity of China in 2018 are over ten times and 400 times than those in 2009, respectively (Fig. 6.2). By comparison, the world increased by around four and 21 times during the same period of time in wind and solar capacity, respectively. In 2018, more than 40% of the world's additions in wind, solar and total renewable capacity came from China (IRENA 2019).

There is substantial demand as well as potential for China to continue expanding its renewable capacity. In its nationally determined contribution (NDC), China is committed to lowering the emissions intensity by

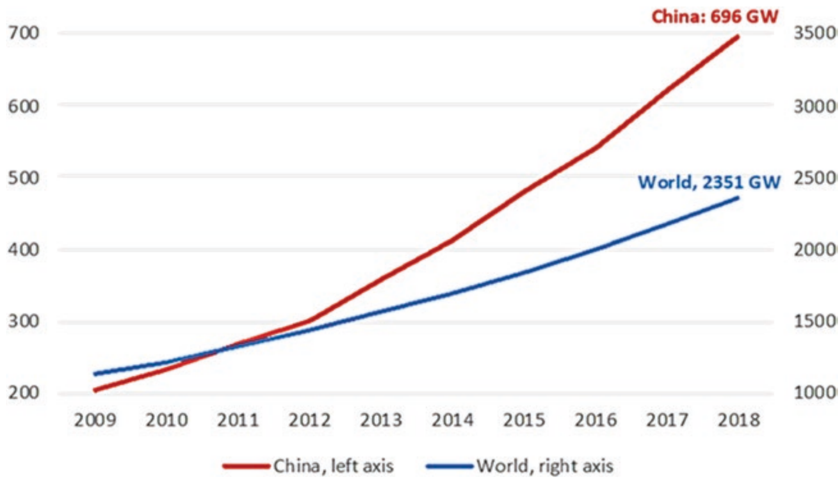

Fig. 6.1 Chinese and global RE capacity in GW, 2009–2018. (Source: IRENA 2019. Note: RE stands for renewable energy. The left and right axes start with non-zero values, and are different yet presented in proportion in order to compare the growth instead of the value of the renewable capacity of China and the world. For the China, there are two sources of data on 2018 capacity, namely 729 GW from the China Renewable Energy Engineering Institute and 696 GW from IRENA. For consistency with other data in the comparison figure, the IRENA data is used here)

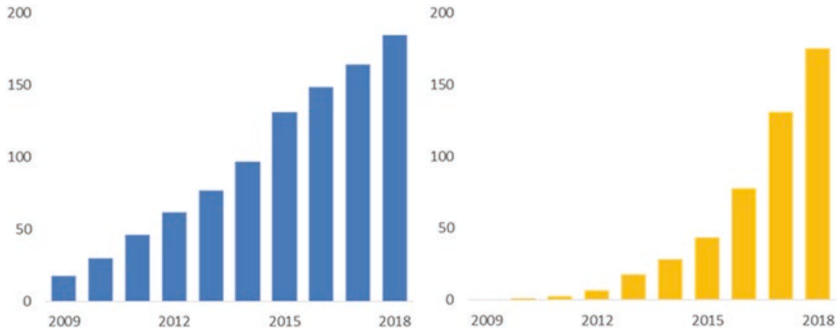

Fig. 6.2 China wind (left) and solar (right) capacity in GW, 2009–2018. (Source: IRENA 2019)

60–65% compared with 2005 levels and increasing the share of non-fossil fuels in primary energy to 20% by 2030 (National Development and Reform Commission of China 2015). These would all require further rise of renewables. It is estimated that wind energy available in China totals 1.0 TW, more than forty times the size of the Three Georges Project (i.e. the world's largest power station with installed capacity of 22,500 MW). In terms of solar, over two thirds of the Chinese land enjoys an annual sunshine time of 2200 hours or more, where gross radiation intensity reaches 5000 MJ/m^2 (National Development and Reform Commission of China 2007; Hou and Li 2018).

China's energy consumption structure, however, does not correspond to that of its power generation. By the end of 2018, renewables supply 13.8% of primary energy in China, below its 2020 commitment of 15% (Chen and Zhang 2018). The national average curtailment rates for wind and solar PV in 2018 are 7% and 3%, respectively, whereas in Europe the curtailment rate was normally below 1% when wind and solar PV generated around 10% of power (Zhu 2019).

There are several challenges. For example, a large proportion of renewables in China locates in the west (National Development and Reform Commission of China 2007), which is less developed. On the one hand, local demand is relatively low; on the other hand, it is expensive to transmit the renewable power generated in the west to the developed east where demand is high. Besides that, existing energy system and regulatory structure do not work with China's renewable transition, causing conflicts of interests and barriers against wider employment of renewables. Moreover, as subsidies phase out, non-technical costs may play a more important role in renewable projects. The lags in land policy and financing mechanisms, for instance, could lead to the postponing or even cancellation of a wind or solar project. Finally, the scaling up of renewables with volatile nature requires larger extent of system flexibility as well as reliability, which also raises the costs (Zhu 2019).

Given China's great renewable potential, capacity and growth, it is having and will continue to have substantial impact on global renewable energy. Adding China's significance in global climate change mitigation and how renewables would contribute to it, Chinese renewables also have a role to play in global climate actions. Therefore, how China addresses these challenges draws much attention from all over the world. The following Section summarizes key strategies China has been taking to promote renewable energy.

6.2.2 Policies on Renewables

In 1995, the Chinese government developed the *Outline for New and Renewable Energy Development between 1996 and 2010*, setting development targets for new and renewable energy with tasks and measures during the 9th, 10th and the 11th Five-Year Plans (FYPs). Yet at that time, there was no independent and self-sustained renewable industry in China due to the non-market nature of renewables and the absence of a renewable energy law. For a period of time, provisions to promote renewables scattered in relevant laws such as the Power Law, the Energy Conservation Law, the Buildings Law and the Air Pollution Prevention and Treatment Law (National Energy Administration of China; Energy Research Institute; Chinese Renewable Energy Industries Association; China Renewable Energy Society Industry Committee 2007).

The policy framework for renewables in China (Fig. 6.3) started to form with the establishment of the *Renewable Energy Law* of February 2005, which went into effect in 2006. This Law set basic principles and infrastructure for renewable development on a large scale in China. Key principles put out in this Law include (1) setting renewable capacity targets, (2) mandatory purchase and connection (which requires grid companies to purchase power generated by renewable sources and provide grid-connection services), (3) differentiated pricing, (4) cost allocation, (5) special fund for renewable development and others (National Energy

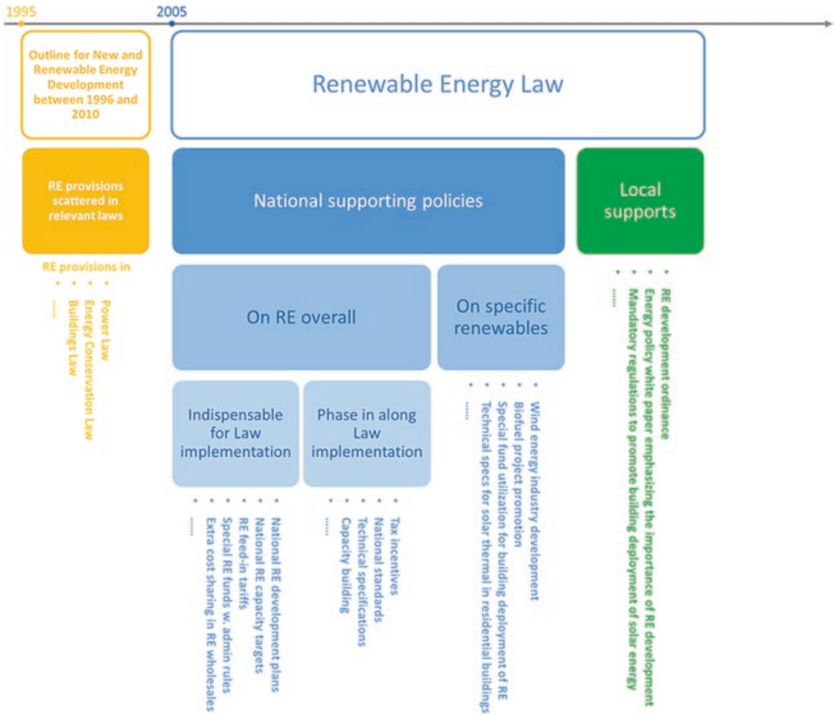

Fig. 6.3 Policy framework for renewable energy in China. (Source: Author's description. Note: RE stands for renewable energy; w. is in short of "with"; admin is in short of "administration"; "specs" is short for "specifications")

Administration of China; Energy Research Institute; Chinese Renewable Energy Industries Association; China Renewable Energy Society Industry Committee 2007).

To ensure concrete enforcement of the Renewable Energy Law and realization of the principles above, the Chinese government designed 12 supporting tasks for the implementation of the Law in April, 2005, and assigned these tasks to specific national departments. Most of the tasks resulted in specific, supporting policies for the Law. These policies can be categorized into two groups. One includes the policies without which the Law cannot be feasibly implemented, such as policies on the plans and capacity targets for the national renewable development, feed-in tariffs, establishing special funds for renewables with corresponding administrative rules, and how to share the extra costs in wholesales of renewable capacity compared with conventional power. The other includes the policies that could be absent at the very beginning of the implementation of the Law, yet to phase in along its enforcement; for example, the policies on tax incentives, national standards and technical protocols and capacity building (National Energy Administration of China; Energy Research Institute; Chinese Renewable Energy Industries Association; China Renewable Energy Society Industry Committee 2007).

In addition to the policies mentioned above on the overall development of renewable energy in China, there are policies by the national government on the development and utilization of specific renewables, like the policy to promote wind energy industry, the rules on how to use the special fund for renewable deployment in buildings and the technical specifications for solar thermal systems in residential buildings, for instance. In provinces and cities such as Shanghai, Shenzhen, the Yunnan Province and the Hainan Province, the local governments accommodated requirements of the Law and other national renewable policies to their local situations, coming up with local regulations that comply with the national Renewable Energy Law and national policies with local feasibility (National Energy Administration of China; Energy Research Institute; Chinese Renewable Energy Industries Association; China Renewable Energy Society Industry Committee 2007).

Despite the Renewable Energy Law and supporting policies, renewable energy has served only as complements to fossil fuels for a long period of time. The three FYPs between 2000 and 2015, i.e. the 10th to 12th FYPs, valued fossil fuels as major impetus for the Chinese economy. The Chinese economy expanded rapidly with the leap in coal consumption, bringing up issues such as environmental problems, lack of energy efficiency and energy security. This was when China turned to renewables and started to develop them on a large scale, yet only as a clean complement to the existing fossil fuel-based energy system (Energy Research Institute; China National Renewable Energy Center 2018).

This trend lasted till around 2015 as China takes lead in addressing climate change and specified renewable energy targets as part of its climate mitigation strategies in its NDC (discussed in the previous section). The 13th FYP specified the long-term development goal for the energy system of China as “establishing a clean, low-carbon, secure and efficient energy system and ensuring energy security”. In 2017, the Chinese government published the Energy Production and Consumption Revolution Strategy (2016–2030), calling for energy revolutions in terms of consumption, supply, technology and institutions. Renewables play a significant role in the energy supply revolution, which aims for the decarbonization of the existing energy system as well as the Chinese economy with alternative energy sources. In late 2017, the Chinese president Xi Jinping pointed out in the 19th National Congress of the Communist Party of China, that the Chinese economy needs sustainable transition with ecological civilization and clean energy industry. These together mark a new era for renewable energy in China when it is becoming mainstream in the energy system (Energy Research Institute; China National Renewable Energy Center 2018).

By comparison, there was only one Renewable Energy Development Plan during the 11th FYP; in the 12th FYP, the national government added four specific plans on hydro, wind, solar and biomass; now in the 13th FYP, there is one overall renewable development plan, six specific plans with the two additions on geothermal and rural biogas, plus one on the power sector specifying the target energy structure for China in the near future. In the overall Renewable Energy Development Plan during the 13th FYP Period, it is consistent with NDC goals and requires the share of non-fossil fuels (mostly renewables) in primary energy reaching 15% and 20% by 2020 and 2030, respectively. Specifically, the installed renewable capacity by 2020 should take 27% of the country's total capacity (National Development and Reform Commission of China 2016a, b).

Compared with two decades ago, there are now renewable industries of scale in China, which was largely due to government support. Moving forward, however, China needs a better regulatory structure (discussed in the following sections), including utilization mechanism for the renewable capacity produced, and further, a self-sustained renewable market with healthy pricing, purchase and competitions, for example. The Chinese government has started targeting these issues with several policies. For instance, the *Renewable Energy Law Amendment of 2009* features guaranteed purchase among others (The Central Government of China 2009); the *Renewable Energy Development Plan during the 13th FYP Period* sets objectives to address curtailment of hydro and reduce curtailment of wind and solar by 2020 (National Development and Reform Commission of China 2016a, b); and *the Action Plan on Clean Energy Utilization (2018–2020)* deals specially the problems that renewable capacity cannot be sufficiently utilized (National Development and Reform Commission of China 2018). The government is changing the name of the "benchmark price" into the "guide price", giving way to market functioning. Policymakers are turning their eyes to the near future when subsidies phase out, and thinking of solutions.

6.3 Drivers and Barriers to Renewable Energy Deployment

This section focuses on the key drivers that have contributed to the increase of renewable energy deployment in China, and analyses possible barriers that may hinder further growth and therefore need to be addressed.

6.3.1 Drivers of Renewable Energy Deployment in China

One of the most important drivers for growth in renewables in China is alleviating air pollution. Coal-dominant energy system has resulted in significant environmental issues and health concerns. The *Action Plan on Prevention and Control of Air Pollution* released in 2013 initiated policy discussion on coal retirement and transition to clean energy. Currently, advanced end-of-pipe control technologies have already been widely applied, but in 2018 the majority of Chinese cities still exceeded the national $PM_{2.5}$ standard of annual average emissions of 35 μg m^{-3} in 2018. To further improve air quality and prevent adverse health impact of air pollution, energy system transition and renewable energy expansion are essential (Wang et al. 2015).

Climate change mitigation also helps promote renewable energy development in China. As discussed above, China sets targets of non-fossil energy use in its NDC and is expected to continue enhancing these targets in its mid-century strategy for deep decarbonization and 14th FYP.

Energy security concern can also prompt transition to renewable energy. As China continues to expand its economy and energy consumption, it would become increasingly dependent on fossil fuel imports and more vulnerable to price fluctuations in the international market. Using indigenous renewable energy becomes important for supporting China's growth and energy security.

China is also restructuring its economy, transitioning from low-value added manufacturing facilities to high-value added manufacture. Renewable investment and expansion in China allow new industries to scale up and reduce costs, which creates favourable conditions for Chinese renewable industries to compete in the international market. China has expanded its share in global solar panel manufacture dramatically in the past decade, growing from 15% in 2006 to more than 70% in 2017, and eight out of top 10 solar manufacturers in 2019 are Chinese enterprises (Hanada 2019).

6.3.2 Barriers Preventing Large-Scale Renewable Energy Deployment

Although there are favourable conditions to facilitate renewable energy deployment in China, there are still substantial real-world constraints limiting renewable expansion. High social cost is one of the barriers. China is heavily dependent on coal. Replacing coal with renewable energy could face social trade-offs and negatively affect local economy. Shutting down coal power plants could contribute to local job losses and increase unemployment rate. In addition, shifting away from coal might impact local government's budget in a negative way, as it could reduce financial revenue from industrial taxes (de Oliveira Vasconcelos 2018). The social impact could be even more substantial against the backdrop of a slowing Chinese economy.

The more imminent barrier preventing large-scale renewable deployment is the current power system setup in China. One of the most pressing challenges for renewable energy in China is the mismatch between renewable energy supply and demand – while most renewable capacity is located in resource-rich western provinces, demand centres are in eastern provinces. How to improve grid integration and stability and develop transmission infrastructure to effectively connect supply and demand is critical to renewable energy expansion. The electricity market reform is currently underway in China, with a focus on increasing grid integration and stability. The next Section focuses on the power system reform and how the two critical issues – grid integration and transmission are addressed by Chinese policies.

6.4 Issues Need to Be Addressed for Extensive RE Growth

In response to the barriers that prevent the renewable energy deployment in China from further and better growth, key challenges for China include marketization and curtailment reduction. This section examines three approaches that China has been taking, namely the power sector reform, integration of distributed capacity with grids and inter-regional transmission capacity expansion.

6.4.1 Power Sector Reform

The power sector in China has experienced complex evolution. It used to be fully administered by the government and planned by the Chinese Ministry of Power Industry (hereinafter referred to as "the Ministry")[1] before people found such planning-centred mechanism no longer worked with China's leaping growth and soaring power demand. The Chinese government then decided to let the market in following successive steps; in the 1980s, it started to open power generation to multiple players like local governments and enterprises (rather than the national government alone), and to allow for conditional tariff variations.[2] In 1997, the government founded the State Power Corporation of China (hereinafter referred to as "the State Power").[3] This was a giant state-owned power company that had both generation and grid capacities, meaning it covered the power industry in China almost from head to toe (Wang and Chen 2015; Zhang 2018).

Since late 1990s, people have been discussing about further marketization of the power sector and addressing issues like monopoly of the State Power, for instance. Meanwhile, the Ertan Hydropower Station, the most attention-drawing hydro station of that time, faced an unexpectedly high

[1] The name of the Ministry changed several times, but the most commonly mentioned one is the Ministry of Power Industry.

[2] The power tariff in China had used to be fully set by the national government; conditional tariff variations allowed for price setting from the power company side under certain circumstances, yet the price needed review and approval by government departments.

[3] The State Power was initially staffed with workforce from the Ministry, i.e. a state-owned power company with some government administrative functions, but one year later the national government revoked the Ministry, separating government functions from enterprise management of the State Power.

curtailment rate, which pushed further the existing discussion on power sector institution. These, together with other concerns, contributed to Phase I of China's power sector reform, marked by the release of the *Power Sector Institutional Reform Plan* (hereinafter referred to as "the Plan") in 2002 (Zhang 2018).

Phase I of the reform features breaking the monopoly and partially introducing market competition in the power sector. To achieve these objectives, the Plan set tasks to (1) separate generation, grid and ancillary services from the State Power, (2) break power tariff into the on-grid tariff, transmission and distribution tariff and the retail tariff and (3) to explore possibility of on-grid tariff bidding by generation companies[4] (State Council of China 2002). In 2014 at the end of Phase I, there were five generation corporations and two grid corporations (the State Grid and the Southern Grid) in China. Phase I of the reform broke up the monopoly landscape in China's power sector and prepared basic infrastructure for a competitive power market (Zhang 2018).

The marketization in Phase I, however, was not enough. First, there is a lack of direct trading mechanism between power suppliers and consumers, causing inefficient allocation of the power resource and high curtailment rate of wind and solar energy, for example. Second, the pricing mechanism, especially the transmission and distribution tariff, is not transparent. Existing government-led power pricing does not correctly and/or timely reflect costs, demand-supply relationships, and environmental externalities and so on. It also creates difficulties for the clarification of cross subsidization. Third, existing power infrastructure does not work with the distributed and unstable nature of renewables like wind and solar, making it hard to generate and utilize power out of these energy sources. China therefore carried out Phase II of its power sector reform since 2005, when the national government published *the Chinese Communist Party Central Committee's and the State Council's Opinions on Further Deepening the Power Sector Institutional Reform*, to transform the power sector in China for further marketization (hereinafter referred to as "the Opinions")

[4] During Phase I of the reform, a pilot on-grid tariff bidding system was implemented in the northeast of China, yet stopped due to deficits of generation companies. Policymakers decided to postpone the bidding plan as it might not be the right timing, so the majority in the power market traded at the government benchmark price on the supply side, with some variations such as the step tariff, differential tariff and punitive tariff on the demand side. During this period, the government also piloted direct power purchase (from generation companies) by large power users.

(Chinese Communist Party Central Committee; State Council of China 2015).

In the Opinions, the government plans to (1) gradually introduce bidding for the on-grid and retail tariffs while examining and revising the transmission and distribution tariff[5] (known as "open up the two ends and regulate the middle"), (2) gradually open up non-public power generation and consumption plans (i.e. minimize the role of government plans), and let in the private sector in power selling business with additions of local distribution grids, (3) build independent exchanges and thorough trading mechanisms in the power market and (4) ensure adequate and fair grid access to promote distributed energy (Chinese Communist Party Central Committee; State Council of China 2015).

Different from the Plan, the Opinions is more of an instructive guide rather than a concrete action plan. Following the Opinions, various supporting actions and policies have come out and been taking effect:

- Since 2016, the Chinese government has launched four batches of pilot additions of local distribution grids to engage more players on the distribution and demand side (National Development and Reform Commission of China; National Energy Administration of China 2019a, b).
- By 2017, the government completed the first-round examination and revision of the transmission and distribution tariffs in provinces and regions. The revised transmission and distribution tariffs will be in practice since 2019, hopefully contributing to a more market-reflective power price (Liu 2019).
- In 2018, China piloted spot power markets in eight regions for the first time (TrendForce Corp 2019).
- Having tested the water in four power-consuming industries, the national government published a notice in June 2019 to fully let go of government control on the generation and utilization plans of non-public power consumers, contributing to the increase in power market turnover (TrendForce Corp 2019; National Development and Reform Commission of China 2019).
- Chinese power market exchanges, both national (i.e. belonging to the State Grid) and local ones, are undergoing shareholding

[5] The transmission and distribution tariff has long been set by the grid companies with the retail tariff minus the on-grid tariff, creating a fuzzy zone in the pricing mechanism.

transformation with non-grid enterprises sharing no fewer than 20% of the capital stock (TrendForce Corp 2019).

As a result of all the efforts, 30% of China's total capacity is tradable by the end of 2018, compared with 19% in 2016 (Liu 2019).Throughout the reform, the regulatory structure of the Chinese power sector has also evolved along the progress. Before the 1990s, there was only one regulation – the *Regulations on the Protection of Power Facilities* of 1987, which focuses on the infrastructure as a reflection of power sector development stage at that time. Entering the 1990s when discussions over the power sector reform started, several regulations on different facets of the power sector, including dispatch, supply and utilization, were put in force. Most importantly, China enforced its first power sector framework law, the *Electric Power Law*, in 1996. It sets basic principles for the power sector to facilitate power industry development, ensure secure operation of the power system and protect rights of stakeholders. Nearly a decade later in 2005, the by-far last piece of the regulatory structure – the *Regulations on Electric Power Supervision* – was implemented as a regulatory complement to the marketization reform and aims to regulate the power market (Li and Dai 2006). Meanwhile, the Electric Power Law and other regulations have gone through several amendments to reflect development and updates in the power sector, including those due to the power sector reform, of course, and thus created an enabling policy environment for the marketization reform. The most recent amendment was to the Electric Power Law in December 2018.

Renewables benefited from the reform for sure. Although renewable energy is rarely a focus in Phase I,[6] it is within roughly the same period from 2005 to 2015 that renewables rapidly developed and formed its own industry in China. Along with the breakup of monopoly and the engagement of more players on the generation side, there grew more opportunities for renewables. Generation companies were thinking of ways to enhance their competitiveness and get equipped for the upcoming competitive market; they explored new, clean, sustainable energy sources (renewables included) and pushed for technology advancement to lower

[6] The only provision in the Plan that relates to renewables is to work out a new pricing mechanism that internalizes environmental costs of power generation and encourages clean energy development.

the costs. As a matter of fact, the renewable industry benefited from Phase I of the power sector reform.

There are two critical moves for renewables in Phase II of the reform, namely the *Administrative Regulation on Guaranteed Full Purchase of Renewable Generation Capacity* (herein after referred to as "the guaranteed purchase") in 2016, and the *Notice to Establish and Strengthen the Guaranteed Power Utilization Mechanism for Renewable Energy* (hereinafter referred to as "the guaranteed utilization mechanism") in 2019.

The guaranteed purchase makes sure that non-hydro renewable power has priority over other-sourced power to be purchased by grid companies within their capacities (National Development and Reform Commission of China 2016a, b). This policy fostered renewable energy development in the power sector reform and pushed forward the transition of energy structure in China, by mandating grid companies to purchase as much renewable energy as they could. In other words, renewable generators had no worry about the buyer, though grid companies might need to think where to sell the renewable capacities.

The guaranteed utilization mechanism later serves a similar purpose, but in a smarter way; it sets a five-year timeframe when the national government mandatorily assigns a minimum proportion of renewable energy in the total energy demand to each province[7] (National Development and Reform Commission of China; National Energy Administration of China 2019a, b). This is more of a habit cultivation policy for province consumers to switch their energy structure and consumption behaviour. This way, renewables are not to neglect when a province is making its next-year energy strategy and plan. The guaranteed utilization mechanism, though just put into implementation for a short time year, is expected to have profound impact on renewable energy utilization.

Entitling privileges to renewables is in line with the principles stated in the Opinions, yet as the power sector reform goes on, there are more challenges for renewables. First, existing power sector reform does not yet reflect explicit environmental and ecological consideration, meaning there is limited support that renewables could gain. This is also reflected in the *Electric Power Law,* which was born as a power sector facilitation law, then turned into a marketization law (Huang and He 2019a, b), and may evolve to be a renewable supporting law. Second, there is still a gap to

[7] Renewable energy proportions may vary with provinces. And provinces may get incentives for consuming more renewable energy than their assigned proportions.

bridge towards a highly marketized power sector (e.g. the power industry still relies on the transmission and distribution tariff to make profits), as well as a lack in effective regulatory structure that does not only follow the reform, but also lead it by cultivating a competitive market (Huang and He 2019a, b). Only in a competitive market can distributed, naturally unstable renewables be efficiently utilized, through flexible loads and demand response for example. Third, as the reform moves forward, the role of government would be minimized, where comes the tricky part for renewables – renewables do need a flexible market, but are still benefiting from government support; whether the renewable industry in China could prepare itself to be self-sustained remains the key. After years of development, generation is barely a problem for renewables, yet utilization is quite tough – the high curtailment rate. Apart from the guaranteed utilization policy and other policies to shift China's energy structure and social energy consumption behaviour, technologies like smart grid, smart metering and Internet of Things may also help to allocate renewable capacity efficiently according to real-time demands across regions – grid additions and integration necessary. This is a long way to go for both renewables and the power sector in China, yet also a tremendous opportunity.

6.4.2 Integration of Distributed Capacity with Grids

It is among the most pressing challenges for renewable energy in China that part of its generation capacity cannot reach the demand side. Wind farms and solar PV power stations are in most cases distributed due to the nature of wind and solar energy, whereas regions rich in energy sources may not always be consumers with high demand, causing spare or waste in generated renewable capacity. Grid integration is therefore the first step as the solution to this issue – to connect distributed renewable energy power plants, also known as independent[8] plants, with power grids.

Grid integration provides a solution to both excess (flexibility after meeting local demand) and fluctuations of distributed renewable energy. The electricity grid has new sources of excessive energy (i.e. flexible loads) from distributed renewable plants, and can dispatch them to regions in need. It also allows for the backup of local supply with other in-grid capacity when renewable capacity fluctuates and becomes insufficient, and stabilizes the grid overall in terms of power quality, generating efficiency

[8] Supplying only local energy demand as opposed to connected to grids.

and others. This way, distributed renewable energy also helps the grid achieve its renewable utilization assignment (e.g. as in the guaranteed purchase and guaranteed utilization mechanism) mentioned in Sect. 6.4.1.

Government support for grid integration dates back to the *Renewable Energy Law*, which explicitly encourages grid integration of distributed renewables and urges the development of relevant technical standards (The Central Government of China 2009). Following the Renewable Energy Law there are by far 16 enterprise standards, eight industry standards and eight national standards on grid integration of specific renewables and distributed energy as a whole, as well as toolkits like contract templates between the grid and distributed energy. In 2013, the State Grid published an official document on providing better services for grid integration of distributed energy, to clarify actions the company would take to ensure better grid integration (State Grid Corporation of China 2013). In the national policy document (referred to as "the Opinions" in Sect. 6.4.1) that marks the start of Chinese power sector reform, Phase II, there are provisions about improving grid integration of renewables as well (Chinese Communist Party Central Committee; State Council of China 2015). By 2018, grid-connected (including both centralized and distributed) wind and solar PV installed capacity in China amount to 184 GW and 174 GW (124 GW centralized and 50 GW distributed); national average curtailment rates for wind and solar are 7% and 3%, 5 and 2.8 percentage points lower than the last year, respectively (National Energy Administration of China 2019a, b).

In spite of all the efforts and progress, there are obstacles. For grid companies, grid integration requires extra costs for grid construction and management. In order to coordinate with unstable wind or solar PV and to ensure reliable power supply all the time, the grid company has to make preliminary preparations before integration. The fluctuations in wind and solar energy also create additional difficulties for grids in peak shaving. In the meantime, rapid growth in wind and solar PV asks the grids for long-distance, large-capacity transmission (discussed in the next Section), which requires extra efforts (Gao 2012; Li 2012). All of these concerns have been hindering grid companies from willingly expanding integration of distributed energy. For the distributed players, things are not smooth, either. For example, solar PVs have to first raise its voltage in order to connect to the grid, and then lower it back to the original level to sell and be used by consumers, having to increase their investment in power transformation and transmission (Wang 2012). For further improvement and scale-up of grid integration, and finally for more efficient utilization of renewables and the energy system as a whole, these issues are to address by motivating grid companies, promoting technology innovations, developing a facilitating regulatory framework and so on.

6.4.3 Inter-regional Transmission Capacity Expansion

With in-grid renewable capacity either from centralized plants or through grid integration by distributed plants, the next step to utilize it efficiently is to transmit it across provinces and regions within the grid. As explained earlier, there is a mismatch between renewable resources (and thus supply) and demand; most Chinese renewables, especially wind and solar, are found in the north and west, whereas the central and eastern China need them more (Zhao 2016; State-owned Assets Supervision and Administration Commission of the State Council 2018). Inter-regional transmission copes with such situation (after grid integration) and helps to keep the national supply-demand balance overall. The West-to-East Power Transmission Project is a most famous practice. To some extent, it is the inter-regional transmission capacity that determines how much China could adjust the geographical supply-demand imbalance and how efficiently China could make use of its abundant renewable potential.

In 2003, the second year in Phase I of the power sector reform, the Chinese government released a document to regulate inter-regional and –provincial energy dispatch (former State Electricity Regulatory Commission of China 2003). The document sets basic principles for power distribution across regions and since created more need for inter-regional transmission. Later in 2017, China aims to add 130 GW of inter-regional transmission capacity in the 13th FYP period (2016–2020), accumulating to 270 GW by 2020 (National Development and Reform Commission of China 2017a, b). Phase II of the power sector reform also put a focus on inter-regional transmission. In November 2017, the national government called for efficient use and further development of existing inter-regional transmission infrastructure in the *Implementation Plan of Addressing Hydro, Wind and Solar Curtailment* (National Development and Reform Commission of China; National Energy Administration of China 2017). Just one month later, the *Provisional Rules on Setting Transmission Tariff of Inter-regional Transmission Projects* was published to complete the system with a pricing mechanism (National Development and Reform Commission of China 2017a, b). In 2018, another policy document, *the*

Guiding Opinion on Improving Self-adjusting of the Power System, proposes to increase the share of renewables in total inter-regional transmission capacity, and sets a target to utilize 70 GW of new and renewable energy during the 13th FYP, of which 40 GW or more should be renewables from northern China. It also reminds to enhance the grid infrastructure for reliable inter-regional transmission (National Development and Reform Commission of China; National Energy Administration of China 2018).

By the end of 2018, inter-regional transmission capacity in China reached 140 GW (China Electricity Council 2019a, b), attributing to proactive policies and actions mentioned above. The capacity transmitted across regions and provinces in 2018 was 481 TWh and 1294 TWh, respectively, 13.5% and 14.6% more than the previous year (China Electricity Council 2019a, b). However, to achieve the 270 GW goal by 2020, the inter-regional transmission capacity needs to double in the next two years, posing pressure on the government and grids. Looking further, China sets targets to reach 680 GW of installed renewable capacity by 2020 and 20% of non-fossil share in primary energy demand by 2030 (National Development and Reform Commission of China 2015, 2016a, b) both requiring the country to continuously speed up expanding its inter-regional transmission capacity while reinforcing other utilization mechanisms. Moving forward with ongoing growth in economy and energy consumption, north-to-south transmission may be prompted on the agenda while stabilizing the West-to-East Power Transmission Project, as northern China is rich in wind energy and could add to inter-regional transmission sources with necessary capacity expansion (Wang 2019).

6.5 Conclusions

China has started its transition to a cleaner economy in the past decade and has been accelerating the deployment of renewable energy ever since. It now has the world's largest renewable energy market and top manufacturers for solar panels and wind turbines. China is also leading in new installations of renewable energy.

The domestic needs for improving air quality, ensuring energy security, and developing renewable energy industry could sustain the growth in renewable energy. Meanwhile, there are emerging issues associated with increasing renewable energy deployment. The most substantial one is the mismatch between energy supply and demand, which lead to high curtailment rates. If issues on grid integration and inter-regional transmission could be fully addressed in the current power sector reform, it could significantly accelerate renewable energy deployment in China in the near future.

Power system flexibility is critical to renewable energy integration. Intermittent renewable energy technologies could create short-term supply fluctuations and pose challenges to the power grid. Having load-following services to the grid could help balance electricity supply and demand. Coal-fired power plants could be retrofitted to provide such services, and cleaner, more efficient options, such as gas fired power plants, can also be used for load following.

Demand side response and electricity storage are also crucial for unlocking grid flexibility. The Chinese government has developed several pilots on demand side management/response and tested out several measures, such as demand-side distributed energy storage system, load shifting, time-variant electricity prices, and different electricity prices by sector. To further improve power system flexibility and increase the share of renewable energy, more active demand response measures, beyond traditional demand side management and energy efficiency improvement, are needed. This would include dynamic load shifting and curtailment, as well as structural changes in electricity demand.

Accelerated deployment of renewable energy in China could bring significant benefits to China and the world. Expanding renewable power generation could help reduce greenhouse gases and air pollutant emissions in China and contribute to the Paris Agreement goals. It can also facilitate China's transition towards low-carbon economy and high-quality growth, while lowering costs of clean energy technologies globally.

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CHAPTER 7

Historical Evaluation of Korean New and Renewable Energy Policy

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7.1 Introduction

The Republic of Korea is now facing grand energy transition as the new administration pursues the long-term phase-out of nuclear and coal, offset by the rapid deployment of renewables, which is unprecedented from the

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path-dependent energy policy history in Korea. The new administration announced in 2017 the Renewable Energy 3020 Implementation Plan (RE2030) whose principal goal is to supply 20% of electricity from renewable sources by 2030 (The Ministry of Trade, Industry and Energy 2017), and more recently in 2019 the 3rd National Energy Master Plan (3rd EMP) where the renewable share in power generation is upwardly targeted at 30% ~35% by 2040 (The Ministry of Trade, Industry and Energy 2019).

The proposed energy transition raises a heated debate. On the one hand, the plans were embraced as an appropriate policy response to ever-worsening local air pollution such as particulate matter, climate change as well as safety and radioactive waste issue of nuclear power generation. On the other hand, the plans were blamed for the reason that expanding renewable would not be economical and would undermine the domestic nuclear industry's foundation and its just-blossoming international competitiveness. Both sides, however, raise the same concern of whether the seemingly ambitious target is feasible in the suggested timeline given the laggard deployment of renewable energy throughout the past decade even with much energy and environmental policy attention and initiative to the low-carbon green growth and sustainable development.

In this context, this chapter articulates the Korean New and Renewable Energy Policy (the NRE policy), reviewing its historical development and background in terms of its objectives and instruments, evaluating its overall and program-specific performance, and identifying possible enabling factors and barriers to the effective implementation of the policy. This chapter also draws general lessons applicable to other countries in the burgeoning stage of renewable energy policy.

7.2 Overview of New and Renewable Energy

In the Korean energy policy arena, the terminology of new and renewable energy (NRE) has been more familiar and widely used than renewable energy (RE) up to recently. The "new" includes energy produced from unconventional technologies such as fuel cells, integrated gasification of combined cycle (IGCC). Even the "renewable" includes some energy sources such as waste, which is not commonly regarded as renewable sources.[1]

[1] According to the IEA standard, only 3% of electricity generation from waste in 2016 in Korea can be categorized as the renewable energy (http://www.koenergy.co.kr/news/articleView.html?idxno=104352).

NRE capacity for electricity generation is about 16 GW in 2017, accounting for 13% of the total power capacity. The NRE share in electricity generation is about 8% in 2017, which has been rising since the early 2010s. By the IEA standard the RE[2] capacity shrinks to 11.3 GW with its generation share to 3.5% in 2017. During the past 12 years, the NRE in the power sector grows at the annual rate of 10% (14% for RE only) for capacity and 12% (16% for RE only) for power generation, which has been mainly driven by solar PV, wind, and bioenergy.

According to the two latest energy plans mentioned above, the Korean government is targeting to deploy 36 GW of solar PV, in cumulative term, by 2030 and 113~118GW by 2040 and 17.7GW of wind by 2030 and 43GW by 2040. These deployment targets are about 20 folds increase for solar PV and 38 folds for wind in the next 23 years from the level in 2017.

NRE, in terms of primary energy supply, shows similar development patterns as in the electricity sector. As of the end of 2017, energy supplied by NRE sources totaled 16.45 Mtoe, accounting for 5.5% of the total primary energy supply, but the share shrinks to 2.2% if only renewable sources by the IEA standard is accounted. Waste was the dominant primary energy source over the past 15 years, and bioenergy, solar PV, and wind have been recently driving up the renewable primary energy.

The energy statistics show that the NRE in Korea began to grow since the early 2010s after long stagnation in previous decades as the NRE policy expanded in terms of breadth and depth. The recent growth is mostly driven by carbon-free renewable sources such as bioenergy, wind, and solar, with which the government is targeting to achieve its low-carbon energy transition.

7.3 Introduction of Korean NRE Policy

The Republic of Korea has implemented the NRE policy since the 1980s with its legal basis provided by the Alternative Energy Development Promotion Act of 1987, which was amended later to the Alternative Energy Development, Use and Dissemination Promotion Act in 1997, and to the New and Renewable Energy Development, Use, and Dissemination Promotion Act (the NRE Promotion Act, hereafter) in

[2] RE only includes solar PV, solar thermal, wind, hydro, marine, bioenergy, and geothermal in the following figures.

2004. The NRE Promotion Act legitimizes the NRE policy and attendant institutions and organizations, stipulating the process of designing, implementing, and executing the NRE policy.

7.3.1 Objectives and Targets of Korean NRE Policy

There are three primary objectives in the Korean NRE policy: economic development, energy security, and environmental sustainability. For these objectives, the NRE policy specifies two broad targets: (i) NRE technology development and (ii) NRE use and dissemination. Under each of the targets, various policy instruments are in place (Fig. 7.1).

The NRE policy aims to address the country's chronic energy security issues and global and domestic environmental change problems, while at the same time establishing the NRE industry as a national engine for economic growth.

When the policy was first introduced in 1984 under the Alternative Energy Development Promotion Act, the precursor of the NRE Promotion Act, the policy primarily concerned with the energy security issue as its single objective. With changes in domestic and global circumstances, the NRE policy later expanded its set of objectives to include economic

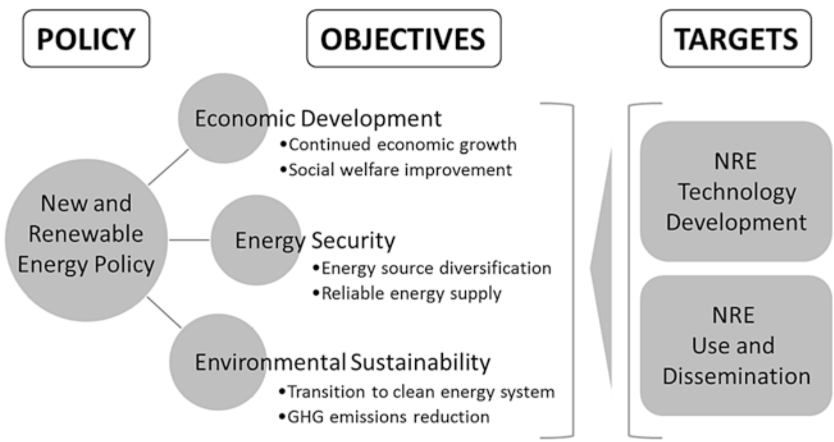

Fig. 7.1 Objectives and targets of the new and renewable energy policy in Korea. (Source: Author's description)

Table 7.1 Categorization of the NRE policy and its instruments

NRE research, development and demonstration (RD&D) programs			
Basic technology development	Source technology R&D program Strategic applied technology R&D program		Research & development
Technology commercialization	Commercializable technology R&D program Core technology R&D program		
Knowledge capability and infrastructures	Human resource development & international cooperation program Technology certification/ standardization/evaluation program		Research & development, information, and education
NRE use and dissemination programs			
Energy supply sector	Power producers policy (FIT/RPS)	Feed in tariff (FIT)[a] Renewable portfolio standards (RPS)	Economic incentives—Subsidy Regulatory standards with economic incentives—Marketable credits
	Transportation fuel policy (RFS)		Regulatory standards
Public and end use sector	Public buildings NRE adoption mandates		Regulatory requirements
	End user NRE dissemination policy (subsidy / rental program)		Economic incentives—Subsidy
	Municipal NRE dissemination policy (infrastructure development subsidy)		Economic incentives-subsidy

Source: Author's description

[a]Korean government replaced FIT to RPS in year 2012. There is no new FIT after 2012

development and environmental sustainability. The chronicle of the NRE policy is detailed in Section (4.1).

The NRE policy consists of many underlying programs and instruments prescribed for various sectors and stages, which can be broadly categorized into the research, development, and demonstration program (the RD&D Program) and the use and dissemination program. The overview of the NRE policy is given in Fig. 7.1 with its policy instruments described in Table 7.1.

7.3.2 *Instruments of Renewable Energy Policy*

Various policy instruments have been installed under the Korean NRE policy. The instruments can be divided into two broad groups, according to their target sectors and the stage along the process of NRE technology innovation—the NRE Research, Development & Demonstration Program, and the NRE Use & Dissemination Programs. Each program category hosts a number of policy instruments and programs, addressing various actors and institutions involved in the system of NRE innovation—industry research centers, academia, public-funded research institutes, electric power producers and other private corporations, residential consumers, and municipal governments (Table 7.1). The policy instruments include research & development programs, information and education programs, regulatory mandates and standards, and market-based incentives for NRE technology development and dissemination. The existence of a suite of policy instruments is one of the crucial characteristics of the Korean NRE policy.

7.3.3 Governance Mechanisms of NRE Policy

The NRE Promotion Act requires the Ministry of Trade, Industry, and Energy (MOTIE) to establish the New & Renewable Energy Development, Use, and Dissemination Master Plan (the NRE Master Plan, in short) under the consultation of the NRE Policy Council. The council consists of twenty national experts appointed by the Ministry of Strategy and Finance (MOSF), the Ministry of Science, ICT and Future Planning (MSIP), the Ministry of Land, Infrastructure and Transport (MOLIT), the Ministry of Oceans and Fisheries (MOF), the Ministry of Environment (ME), and the Ministry of Agriculture, and Food and Rural Affairs (MAFRA). The NRE Policy council drafts the NRE Master Plan for the next ten years and beyond, taking into account the country's other national master plans and development plans. Then the MOTIE outlines yearly NRE Implementation Plan with the support from the ministers of other governmental bodies, designating the plan's execution branches under the Presidential Decree and securing program budgets from the central government.

Overall, the NRE Promotion Acts not only designates the MOTIE as the main executing body for the implementation of the NRE policy and but also requires the installation of responsible monitoring bodies and coordinating entities to ensure that the policy remains consistent with other national plans and roadmaps (Fig. 7.2).

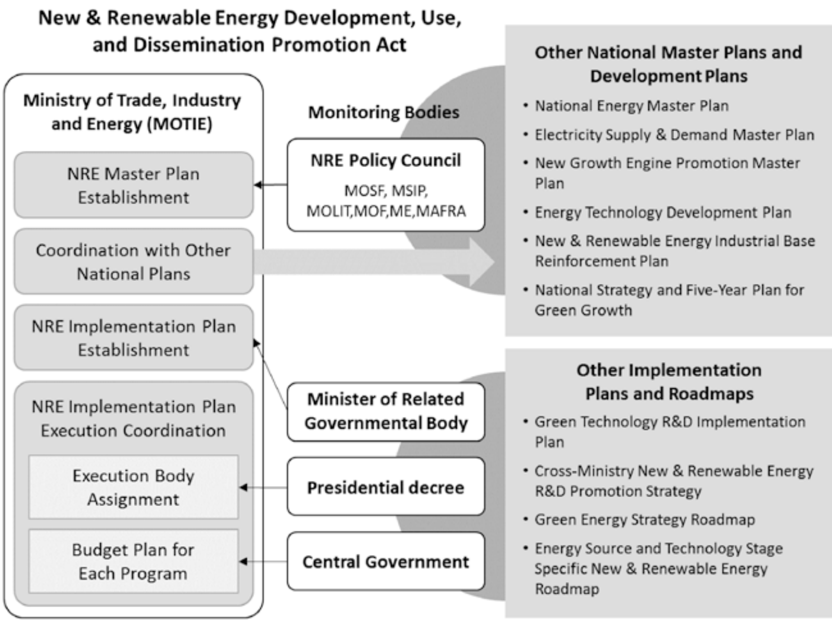

Fig. 7.2 Governance of the NRE policy. (Source: Author's description)

The New and Renewable Energy Center (NREC), an affiliate of KEMCO,[3] is held responsible for archiving NRE related data. The NREC conducts regular surveys, analyzing, managing, and disclosing national statistics and performances related to the NRE policy. There are two yearly statistical reports: the NRE Industry Statistics and the NRE Dissemination Statistics. The former contains the number of manufacturing companies in the NRE industry and their numbers of employment, sales, and exports. The latter provides detailed information on the demand for input resources and installed capacity for individual new and renewable energy technologies. In addition, the Korea Energy Agency publishes the NRE White Paper every other year, which contains descriptive information of NRE

[3] Korea Energy Management Corporation (KEMCO) is a government agency designated by the minister of MOTIE. The agency is responsible for implementing various energy conservation policies and energy efficiency improvement measures as well as climate change mitigation activities.

programs, performance statistics, and the specifications of individual NRE technologies.

7.3.4 NRE Policy and Finance

Among the NRE policy instruments, the NRE RD&D program has remained particularly intensive of financial resources with a varying degree of support to individual technology options. The NRE policy provides various financial supports for government R&D, private sector R&D, and use and dissemination projects. These program costs are sourced mainly from the Energy and Resources Industry Special Account and the Electric Power Industry Promotion Fund (installed in 1988).

Regarding the subsidy-based programs or public procurement programs under the NRE policy, those who receive subsidies or exclusive benefits are clear winners. In the case of RD&D programs, which often prescribe eligible institutions or consortiums in detail, the beneficiaries are very restricted. In other programs, the government often requires a particular minimum matching contribution from the potential beneficiaries. The level of contribution[4] varies by the type of NRE program and the characteristics of these beneficiaries. No apparent compensation mechanism for losers is currently in place under the NRE policy.

RD&D funding was allocated across various NRE technology options. The funding paid particular attention to the four flagship NRE technologies—integrated gasification combined cycle (IGCC), wind power, solar PV, and fuel cell—which were specified by the Green Energy Industry Development Strategy[5] pursuing the country's green transformation. The inclusion of IGCC and fuel cell, which are claimed as "new energy" but not regarded as renewable sources, is what distinguishes the Korean NRE policy from other countries' renewable energy policies. Wind power and solar PV technologies were chosen because, as compared to other options, these technologies were better positioned to be installed nationwide and also promoted for global business development. The funding for solar PV, wind, and bio has been gradually increasing since the mid-2000s, which

[4] The level of matching contribution ranges typically between 30–75%.

[5] On Aug. 15th, 2008, President Lee Myung-Bak announced a list of green energy technologies that the government plans to promote as an enabler of the country's green transformation.

coincides with the rapid deployment of these technologies since the early 2010s.

7.4 Evaluation of the Historical Development of the Korean NRE Policy

This section evaluates the historical development of the Korean NRE policy. It reviews the development of policy objectives and instruments while taking domestic and international environments into account. Then the section compares quantitative targets as specified in the NRE policy-related government plans with their actual performances. The section concludes with identifying possible enabling factors and barriers to the effective implementation of the policies.

7.4.1 Policy Objectives and Instruments

Over the last three decades, the Korean NRE policy has experienced several transitions in its legislation form, adapting and improving its objectives and policy instruments to accommodate the domestic and international needs. The current form of the Korean NRE policy objectives and targets highlight the country's ambition to solve pressing social issues while at the same time establishing a new growth engine based on the NRE sector. In other words, the NRE policy can be thought of as a reconciliation between the demand from the citizens and the international community for environmental and climate improvements and the country's ceaseless pursuit of global competitiveness, albeit the scarcity of its domestic natural resources.

7.4.1.1 Development of the Objectives of the Korean NRE Policy

The early stage of the NRE policy only took the passive path of addressing imminent concerns, such as energy security and air quality degradation. When the first form of the NRE policy was introduced in 1987 under the Alternative Energy Development Promotion Act, the attendant policy instruments focused mainly on the development of alternative energy sources as a means to diversify national energy supplies[6] thus to reduce the country's innate energy system vulnerability to external shocks,

[6] Alternative energy sources as stipulated by the legislation were solar energy, bioenergy, wind power, hydropower, fuel cell, energy from liquefied or gasified coal, energy from gas-

particularly to oil threats from geopolitically unstable nations. Not coincidentally, it was the time when the country barely survived after the two consecutive oil crisis in the 1970s[7] and went through a significant shift in the focus of national energy policy from its earlier petrolization strategy[8] (1960s to early 1970s) toward the promotion of energy security.

The NRE policy objectives and targets began to make their economic growth ambition clearer as of the late 1990s as the Alternative Energy Development & Promotion Act changed into the Alternative Energy Development, Use and Dissemination Promotion Act. The government was determined to promote the alternative energy industry as a significant strategic growth engine, establishing long-term policy objectives and enabling RD&D programs and instruments. Reflecting on the major shift in policy stance, the new Alternative Energy Development, Use and Dissemination Promotion Act started to pursue sustainable and sound economic growth by promoting the technology development, use, and diffusion of alternative energy sources. Unlike the energy security-oriented objectives under the old Alternative Energy Development & Promotion Act, the new act placed priorities on the promotion of the domestic NRE industry as a whole, seeking global business opportunities based on indigenous NRE technologies. It was also the time that environmental concerns, such as the abatement of air pollution and environmental protection, were gradually incorporated into its objectives.

ified heavy residual oil, marine energy, and energy from waste, not including oil, coal, nuclear power, and natural gas.

[7] On account of the state-driven industrialization policy, the country achieved a very rapid transition from primary industry-based economy to secondary industry-based economy—the share of manufacturing value-added in GNP increased from 11% in 1966 to 20% in 1973 with a 10.2% of an annual average rate of economic growth. Despite the 1973 oil crisis, the country was able to continue oil-based economic development, supporting the establishment of the heavy and chemical industry, which was energy-intensive. It was one of the reasons why the second oil crisis in 1979 resulted in minus growth, trade deficits, currency depreciation, and increased foreign debt. This dire situation continued until 1986, when the oil price war started to ameliorate the country's competitiveness. The Alternative Energy Development & Promotion Act was enacted then along with a series of policy instruments for energy security promotion.

[8] In 1966, the government introduced the petrolization strategy, based on the assessment that the coal-based energy development strategy was limited to support a major economic boost.

The country's strategic push for a particular sector like the NRE industry inherits its successful history of state-driven economic development.[9] The NRE industry was put forward as the government was compelled domestically to propose a new growth engine amid economic slowdown during the 2000s and globally to contribute to global environmental change, climate change in particular, as a responsible OECD nation. The country's growth model enabled by technological innovation capability and outstanding human resource base also made the emerging NRE industry an attractive strategic choice.

The Alternative Energy Development, Use and Dissemination Promotion Act has evolved into the New & Renewable Energy Development, Use, and Dissemination Promotion Act[10] in the mid-2000s. In fact, there was a considerable shift in the law's intent from the first alternative energy development and air pollution mitigation causes toward the purpose of "all-encompassing, environmentally friendly energy system transition." The shift suggests that the NRE policy started to assume a major responsible part in the establishment of the national energy policy, credibly and evidently demonstrating the government's determination to make the best use of the NRE industry as the country's new growth strategy. The NRE was no longer a mere response to energy security or domestic and international environmental concerns.

7.4.1.2 Development of the Instruments of the Korean NRE Policy

Along with the shift in the policy objectives, three significant changes were found in terms of the coverage of the policy's instruments and enabling schemes: (i) the consideration of the development and dissemination of fuller NRE technologies from its earlier single focus on the development of selected NRE technologies; (ii) fuller integration with other national

[9] The country strategically focused in the 1960s on export-oriented light industries and import-substituting industries (e.g., energy, fertilizer, cement), followed by the promotion of strategically focused industries (mechanical, steel manufacturing, chemical, shipbuilding, and electronics industries) in 1970s. In the 1990s, the country set the priorities of localizing 12 core industrial technologies, including aeronautical and semiconductor technologies, internationalizing research & development activities, and extending new technology investments overseas.

[10] The current NRE Development, Use & Dissemination Promotion Act stipulates that its purposes are (a1) energy source diversification, (a2) stable energy supplies (b1) environmentally-friendly transition of the national energy system (b2) reductions of greenhouse gas emissions (b3) environmental conservation, (c1) continued and strong economic development, and (c2) social welfare promotion.

energy policies and priorities; and (iii) the introduction of market elements. These changes in the policy instruments are embedded in the regularly drafted Alternative Energy Master Plan and the NRE Master Plan, which specify how the NRE policy would be implemented for the next ten years.

The 1st Alternative Energy Technology Development & Dissemination Master Plan (1997) was introduced along with the legislation of the Alternative Energy Development, Use and Dissemination Promotion Act. The master plan supported the use and dissemination of alternative energy and technology development. Several policy instruments, such as public procurement of alternative energy and subsidies for regional energy deployment, were implemented. The 1st Alternative Energy Master Plan and the following 2nd Master Plan (2003) both employed the select and concentration strategy and invested intensively on the three core technologies near commercialization, that is, solar PV, wind power, and fuel cell technologies, in an attempt to fast track the development of indigenous new and renewable technology systems (The Ministry of Trade, Industry, and Energy 2012).

By contrast, the 3rd NRE Technology Development & Dissemination Master Plan (2008) and the 4th NRE Master Plan (2014) as well extended the coverage to support a greater number of NRE technologies such as IGCC, addressing nearly full stages of the technology innovation process, ranging from R&D to demonstration, market formation, and diffusion (Grubler and Wilson 2014). The new NRE Master Plans provided various RD&D instruments, knowledge capability and infrastructure development programs, and dissemination programs, which would turn the NRE industry into the country's core growth engine. The R&D program under the new plans also set long-term, detailed implementation guidelines, such as strategic investments in technology commercialization, the establishment of local industrial infrastructures, and early achievement of economic feasibility by developing high efficiency and low-cost technologies. It was not until the new NRE Master Plan was introduced when the NRE policy began to be interconnected with the National Energy Master Plan.

The basic stance of the NRE policy, that of the dissemination program in particular, also experienced a major change as the NRE Master Plans substituted for the Alternative Energy Master Plans. First, the dissemination program for end-users has become increasingly responsive to market needs[11] and regional idiosyncrasies.[12] For example, One Million Green Home Program, which is a successor of the earlier Solar PV Home Subsidy Program that subsidized PV installations only, extended its support to various NRE installations deemed suitable to regional and household characteristics. The program for public procurement also changed from its adoption mandates with limited coverage into a more stringent mandate with broader coverage.[13] The second meaningful change is that the new NRE Master Plan intends to promote program efficiency by leveraging market competition. The instruments brought by the 3rd and 4th NRE Master Plan would incentivize private enterprises to take a prominent role in the NRE dissemination. Instruments for electric power producers shifted from a subsidy-based approach (e.g., feed-in-tariff) to an approach that introduces market competition among renewable suppliers (e.g., renewable portfolio standards)[14] (Fig. 7.3).

7.4.2 Evaluation of Policy Performance

Although the Korean NRE policy articulates its objectives and targets, the performance of the policy has not been systematically evaluated for the respective indicators in any of the earlier reports. There could be two reasons for this absence; (i) the targets are continuously adjusted in accordance with the policy and its instruments development, and (ii) the

[11] The solar rental program enabled consumers to avoid the risk associated with large upfront costs, allowing them to adjust contract terms, such as rental rate, rental period, and renewables certification. In addition, consumers who chose to use government-hired contractors for installation were provided with access to public procurement projects delivered by those contractors.

[12] Over time, the municipalities became more involved in decision-making processes. The examples include participatory community projects, such as cooperative unions and projects that promote the development of customized business models.

[13] The earlier public procurement program covered new public buildings only. However, it later extended the coverage for addition and improvement of existing buildings, increasing the required share of new and renewable energy investments (Public Buildings NRE Adoption Mandate Standard Expansion 1 & 2). Recently, the program added the provision specifying a mandatory share of new and renewable energy use.

[14] It is also true that the financial burden to the Korean government is one of the important reasons for the shift. The Korean FIT support scheme on the NRE industry, particularly on the solar PV industry, has well exceeded the breakeven point for the investors, making the policy expensive and ineffective (Davis and Allen 2014). The introduction of the RPS scheme was considered to be appropriate for the Korean government to recover its financial efficiency of the overall NRE dissemination program.

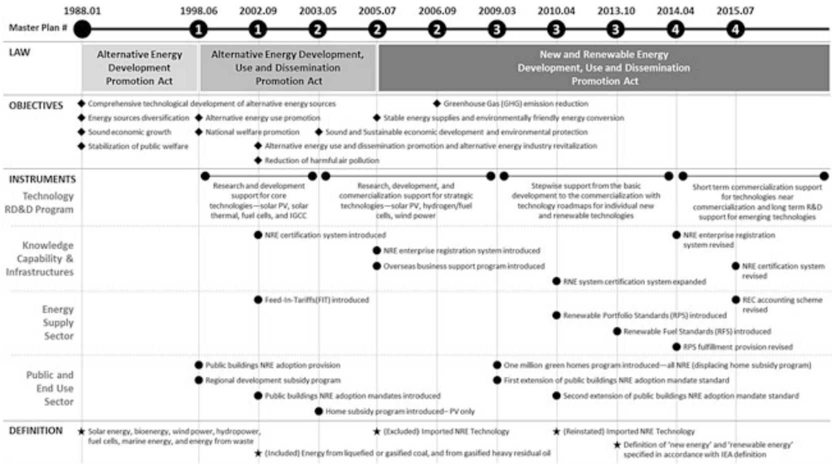

Fig. 7.3 Development of the Korean NRE policy legislation and instruments. (Source: Author's description)

statistics are reported in various formats and places depending upon the types of individual instruments and agencies held responsible.[15]

Perhaps as the most visible but controversial indicator of the policy effectiveness, the NRE primary energy supply targets in the series of NRE Master Plan are compared with their actual performances in Fig. 7.4. The targets set in the 2nd Master Plan were found to be overly ambitious so that the targets were adjusted downward in the 3rd and the 4th Master Plan considering the past deployment of NRE. It should be noted that the performance of NRE in terms of its share in the primary energy supply is reduced if only renewable sources are considered.

Figure 7.5 compares the installation targets for solar PV and wind power. As with primary supply targets, ambitious installation targets were adjusted downward in the following plans. The past installation performance is in line with the 3rd Master Plan, and, as of 2014, wind power deployment fell short of expectations, while solar PV deployment

[15] Although the rate of compliance with the RPS can be another indicator candidate for policy effectiveness, such statistics were not available. Quantification of the compliance rate also presents a major challenge because, due to confidentiality reasons, the fulfillment of the RPS is publicly reported only at the levels of aggregate REC [MWh] or generation capacity [MW] achieved, not at the level of individual power generation companies under the policy.

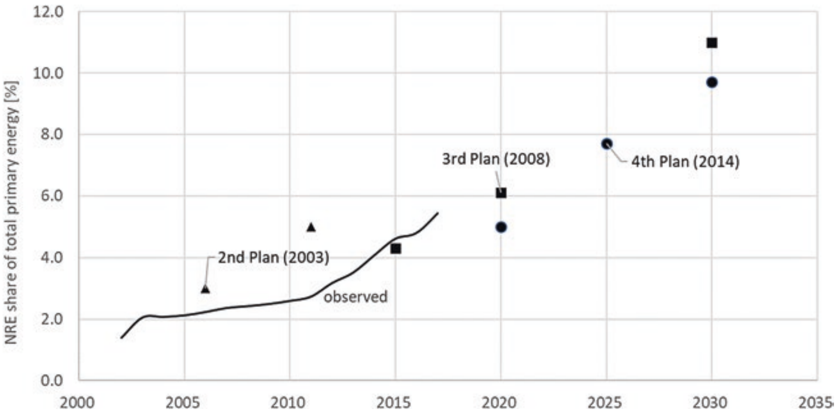

Fig. 7.4 NRE share target in the NRE master plans and real deployment. (Source: Author's analysis)

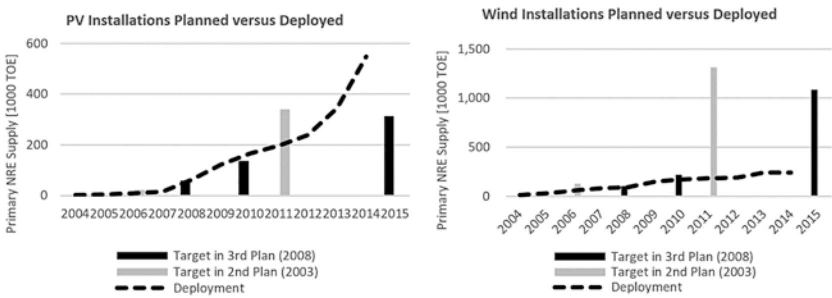

Fig. 7.5 Capacity installation target in the NRE master plans and real deployment. (Source: Author's analysis)

outperformed the target due to major cost reductions driven by fierce competition in the global PV market.

The economy-wide impact assessment of the NRE policy is not available, as the full benefit of the NRE policy will accrue over the next several decades. Nonetheless, it would be a good starting point to observe crude outcomes as expressed by some publicly available industry statistics, which would give a broad sense of how the policy has performed in response to various internal and external socio-economic and technological drivers and barriers. The NRE industry statistics such as the number of companies and employees, and revenue witnesses that the industry has been growing since the early 2000s in terms of its size, revenue, and export and ramped up quickly until the year of 2011 when the global over-capacitation of solar module supply triggered by European economic stagnation resulted in fierce price competition worldwide and has been recovering since then. Solar PV is the main driving technology of the NRE industry growth followed by wind and bioenergy.

7.4.3 Enabling Factors for Policy Effectiveness

The first enabling condition for effective implementation of the Korean NRE policy was its system-wide policy coverage. The policy, in fact, covered nearly all stages of the energy technology innovation process—R&D, demonstration, market formation, and diffusion (Grubler and Wilson 2014). This is because the Korean government identified the NRE industry not only as one of its major growth engines but also as a means to address climate change and energy security, seriously committing financial resources for implementing innovation and dissemination programs for NRE technologies (The Ministry of Knowledge Economy 2011).

The country's commitment to the full coverage NRE policy is well demonstrated by how the policy was developed and updated. The Korean government periodically evaluates the performance of its public and private sector R&D program, modifying some of the instruments or even revising the overall NRE promotion strategy. For instance, the government's implementation plans for NRE RD&D were incorporated into various national plans, including the Green Energy Strategy Roadmap (2011), the Energy Technology Vision Roadmap (2013), the New & Renewable Energy Vitalization Plan (2013), the 2nd Energy Master Plan (2014), the 3rd Energy Technology Development Plan (2014), the 4th NRE Development, Use, and Dissemination Master Plan (2014), and the Energy Technology Development & Implementation Plan (2015). These individual plans were drafted in such a way that their underlying policy instruments and measures would deliver synergistic coupling with the NRE policy.

The usefulness of the system-wide coverage of the NRE policy is, to some extent, supported by several studies. The studies indicate that the subsidies made via the NRE Use & Dissemination Program, in combination with income growth, resulted in an increased demand for NRE systems, in which private-sector R&D induced by the NRE RD&D Program played some modest part (Jeon 2007) . It was also indicated that the NRE RD&D Program, combined with industry-level experiences of NRE production, provided a positive influence on private-sector R&D activities (Lee and Noh 2009). The suggestion is that the system-wide approach taken by the NRE policy may have generated synergistic coupling between search processes in the upstream and downstream sectors.

The second related enabling condition for effectiveness would be the government's high-level RD&D guidance with detailed technology roadmaps, strengthened by the establishment of knowledge creation and management infrastructures. The government identified a set of NRE technologies to promote under its national technology innovation roadmaps, laying out associated NRE RD&D program with its enabling institutional arrangements specified.[16] It also delivered programs designed to help establish knowledge capability and infrastructures, with which the country's NRE innovation would be carried out effectively in accordance with other NRE policy instruments.[17]

The top-down, detailed RD&D guidance provided by the government would have the merit of (i) ensuring that the country's economic growth strategy is fully reflected in the RD&D program, (ii) facilitating the process of selecting beneficiaries of the program while reducing social costs associated with interest-group politics during its enactment and implementation, and (iii) allowing for parallel processing of multiple RD&D programs to serve technologies at different development stages (e.g., concurrent promotion of solar cells and balance-of-system development).

Nevertheless, caution has to be paid to the top-down approach, as it may present limited flexibility in adapting to rapidly changing market and technological environments. In this regard, the government required the related industry experts to participate in drafting NRE technology roadmap and attendant strategic plans, which in turn gave guidance to the industry stakeholders by keeping them from taking an irrelevant technology development path. Also, the government left room for possible revision of the roadmap by establishing multiple checkpoints and formal feedback loops to various stages of the NRE innovation process and also

[16] In Korea, basic technology development programs target industry-university-institution collaboration, whereas commercialization and core technology development programs are provided to firms or industry consortiums.

[17] For instance, standards for quality assurance and quality assessment in the NRE RD&D program, encourage firms to develop commercialization-stage technologies.

by monitoring global market and technology trends continually via expert consultation and international cooperation programs. Such a participatory process of developing the RD&D program and prompt, stage-wise evaluation, complemented with the country's relatively high innovation capability, suggests that the Korean NRE policy has what it takes to foster the effective implementation of the RD&D program.

The last enabler would be demand-pull from the public sector. The NRE policy's Use & Dissemination Program mandated government branches and related public institutions to purchase NRE technologies.[18] The state government also provided subsidies to municipal governments administering region-specific NRE dissemination programs. These public procurement programs helped create a foothold market, in which various NRE policy stakeholders, such as policy developers, technology providers, and end-users, could participate and learn from each other, resulting in the reinforcement of industry-wide knowledge capability.

With the public procurement, various NRE businesses engaging in technology development, sales, and installation and maintenance were able to enter and grow from the foothold market, not having to run the risk of failing to create a reliable consumer base. The government, as a purchaser, also benefitted from own experience of employing early-stage NRE systems, in terms of identifying potential room for improving various untested instruments of the NRE Use & Dissemination Program[19] and developing new instruments designed to build consumer trust, particularly in the early stage of technology development.[20] The state government and municipalities also learned from each other, sharing experiences gained from a variety of NRE projects implemented in various settings over the years, which in turn rapidly increased the government's capability of designing and administering the NRE program.

[18] The mandate also covered corporation established by the state, municipalities, public enterprises, government-funded institutes and businesses, subsidiaries of government-funded corporations, and special law corporations.

[19] The government, based on its program administration experience, used discretion in determining the share and delivery cost of NRE dissemination programs for private buildings and houses. Also, the government helped devise programs, such as solar PV rental program, which greatly reduced large up-front investment costs of NRE technology.

[20] Various trust-building programs, such as NRE quality certification, NRE technology standardization, NRE specialized company registration programs, were suggested and developed in this process.

7.4.4 Barriers to Policy Effectiveness

Not surprisingly, there have been several apparent barriers to the effective implementation of the Korean NRE policy. First, too much regulatory emphasis has been placed on the objective of economic development, not on energy security or environmental sustainability, even though all of the three objectives are stipulated in the NRE Promotion Act. Such an unbalanced pursuit of the three policy objectives is illustrated by indicators and measurements employed and reported by the government to monitor and evaluate the performance of the NRE policy. Presently, the performance indicators adopted and employed by the government for the NRE Use & Dissemination Program include NRE production, NRE installed capacity or use, NRE installation units per program expenditure,[21] and those for the NRE RD&D Program include the readiness level of NRE technology development, the number of NRE systems and products certified,[22] and the number of related corporations and institutions.[23] It is surprising that all of these performance indicators concern with the economic development objective, having little to do with the objectives of energy security and environmental sustainability. In particular, energy security and environment-related measurements, such as avoided air pollutants and greenhouse gas emissions,[24] energy self-sufficiency inducement, and changes in energy system stability and electric grid reliability, have rarely been used in monitoring or evaluation by the regulatory entities. Such unbalanced regulatory attention would make timely and proper revisions of the NRE policy increasingly difficult, imposing a serious barrier to the balanced achievement of the original set of objectives.

The lack of seriousness in pursuing the environmental objective in the Korean NRE policy is mainly because the Ministry of Trade, Industry, and

[21] For example, the NRE Use & Dissemination Program for buildings has so far produced the 43,142 toe of renewable energy between 1993 and 2014.

[22] The certification program has certified totals of 59 solar thermal models, 891 solar PV models, 161 geothermal models by 2013.

[23] The total number of 10,140 specialized NRE corporations have been registered under the NRE business certification program (as of September 2014).

[24] Among various end-user instruments under the NRE Use & Dissemination Program, only the housing NRE subsidy program reported the performance in terms of avoided CO_2 emissions. It reported that the total public investments of 671 billion KRW administered between 2004 and 2014 delivered a total of 171.8k solar-powered houses, 22.2k solar thermal houses, and 6.9k geothermal houses, generating 84,985 toe of NRE energy and abating 0.258 Mton of CO_2.

Energy is solely responsible for developing and administering the policy with no other government bodies, the Ministry of Environment, in particular, held primarily responsible. For example, the cross-ministry national GHG mitigation roadmap announced in 2014 did not report the estimated impact on GHG emissions of the policy's public buildings NRE adoption mandates, while the estimated impacts of other sectoral policies, such as Renewable Fuel Standards in the transportation sector, were provided. It suggests that cross-ministry communication and coordination in Korea with regard to the NRE policy remained mostly ineffective. Indeed, the absence of effective policy coordination between government bodies, aggravated by their different administrative jurisdiction, was found to be the main reason for the incompatibility of the Korean energy policy with other environmental or climate policy (Cho and Jean 2014).

The second barrier to effectiveness was the limited policy attention to turning developed NRE systems into real businesses, that is, bridging technology development with market formation. As described earlier, the NRE RD&D Program covers up to technology demonstration among various stages of technology innovation, while the NRE USE & Dissemination Program focuses on public-sector deployment. As a result, it was rare to see public-funded NRE systems near commercialization delivering profitable business cases (Lee and Noh 2009). This gap discouraged developers of basic- or commercialization-stage systems from staying their own boundaries, keeping them from engaging in business development or approaching to experienced business developers, especially when the market was highly uncertain (Lee 2013). It is thus suggested that the NRE policy should also focus on the missing but critically important part, business development, which provides social and environmental impacts, eventually serving the original objectives (Samsung Economic Research Institute 2008).

The third barrier would be the policy's uncoordinated pursuit of technology development versus technology dissemination. Most notably, the government rapidly expanded the size of the NRE Use and Dissemination Program even before indigenous technology systems were ready to be commercialized. This temporal mismatch allegedly made public and private sectors obliged to resort to imported core technology components, eventually impeding the development of a domestic industrial base (Samsung Economic Research Institute 2008). Previous studies point out that the NRE policy should adjust the targets and scope of the NRE Use and Dissemination Program, such that its original policy objectives (e.g., economic development) can be better served (Jeon 2007) while taking into account the characteristics and readiness of the technologies under consideration (Hyundai Economic Research Institute 2013). It was also suggested that the NRE policy should revise its RD&D program to reflect the realities and experiences of domestic dissemination (Lee 2013).

The last barrier to the effective implementation of the NRE policy relates to the country's limited resource endowment in terms of natural resource and consumer base. It can be argued that the policy's almost full coverage of NRE innovation stages, combined with formal feedback loops and multiple regulatory checkpoints, can create synergistic interactions between various developments made along the value chain, thereby making the innovation process better guided and more effective (Grubler and Wilson 2014). However, it should be noted that the country's small domestic market base *and* scarce resource base may not be able to keep up with the ambition of technology-based, export-driven economic growth. In other words, the country's innovation ecosystem presents a fairly week feedback loop from technology dissemination experiences to the public & private technology R&D. As such, some domestically developed NRE systems even fell short of their domestic economic feasibility criteria allegedly due to small domestic market demand and limited resource availability.

7.5 Summary and Lessons

The Korean new and renewable energy policy has been successful in establishing and institutionalizing NRE sectors as the nation's new economic growth engine and, albeit to a lesser degree, responding to the global pressure to combat climate change. The new and renewable energy policy is characterized by its all-encompassing coverage of the technology innovation process. Identifying global response to climate change as an economic growth opportunity, the Korean government has established, on the one hand, strategic roadmap and various supporting schemes for the research and development of new and renewable energy technologies. On the other hand, the nation pursued public procurement as the use and dissemination policy to create a scalable foothold market. The systematic policy approach to the development of new and renewable energy led to the pronounced expansion of the sector over the last decade, as indicated by authoritative national statistics.

Nevertheless, there are several hurdles to overcome. First, although the policy ostensibly has three grand objectives—economic development, energy security, and environmental improvement—only the first economic development objective has been adequately pursued. The assessment of policy effectiveness has not been seriously conducted from the environment/climate perspective or the energy security perspective. This lopsided regulatory attention to the economic development objective resulted in virtually no policy evaluation commissioned by the government on environmental and energy security impacts. Furthermore, two critical chasms were found along the technology innovation process, which deterred the materialization of its full potential. Although the RD&D Program supported the development of technologies from the basic up to near commercialization stage, these technologies often went astray without profitable business cases. Also, in many cases, the use and dissemination program ramped up too rapidly for the RD&D program's indigenous technologies to catch up. This temporal discordance resulted in windfall profits for foreign technology vendors and investors.

We, however, believe that the rapid upscaling of renewable energy in Korea that is required to meet the INDC does not seem feasible by the economic development objective alone, let alone the energy security rationale. The so-far subdued environmental and climate objectives need to be fully reinstituted with strong and consistent political will at all levels of government, as evidenced by across-the-board enabling instruments, sending credible long-term signals to the market. Another important suggestion in the pursuit of the multifaceted objectives is that the effectiveness and performance of the newly instituted policy need to be evaluated regularly and objectively so that the possible trade-off between the objectives can be better understood in the national and regional context and thereby reflected in the revisions of policy instruments to come. The Korean experience of the new and renewable energy policy accounted for in this case study demonstrates both possibilities and obstacles to the grand policy transition.

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CHAPTER 8

Renewable Energy Deployment to Stimulate Energy Transition in the Gulf Cooperation Council

Yagyavalk Bhatt

8.1 Introduction

Electricity consumption in GCC has increased rapidly over the past two decades by around 6% to 12% annually due to rising population and economic growth. With a positive economic outlook, this trend is expected to continue. As countries in the GCC are major oil and gas producers, their electricity production has typically relied on oil and gas. However, they are now slowly diversifying away from increased reliance on oil and gas to renewable energy and other sources (King Abdullah Petroleum Studies and Research Center, 2018).

As per the Table 8.1, In the GCC, Saudi Arabia has the highest capacity with about 83.70 GW, followed by UAE, and Kuwait. Further, fossil fuels are used as primary source of energy in generation of electricity in all the

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Table 8.1 Peak load, available capacity and share of fuel mix in GCC for 2016–2017

Country	*Available capacity*	*Peak load*	*Fuel mix*			
	Gigawatt	*Gigawatt*	*Natural gas*	*Crude oil*	*Heavy fuel oil*	*Diesel*
			% of fuel mix			
	Year 2016–17					
Saudi Arabia	83.7	60.828	45%	23%	24%	8%
United Arab Emirates	29.06	21	98%	0	2%	0
Kuwait	18.9	13.39	99.9%	0	0	0
Qatar	10.21	11	100%	0	0	0
Oman	7.8	5.92	97%	0	0	3%
Bahrain	4.82	3.418	78%	0	22%	0

Source: Kingdom of Bahrain Electricity & Water Authority, Kuwait Ministry of Electricity & Water, Oman Power and Water Procurement Company, Qatar Electricity & Water Corporation, Electricity & Cogeneration Regulatory Authority, Abu Dhabi Water and Electricity Company, Dubai Electricity and Water Authority, Sharjah Electricity and Water Authority, Federal Energy and Water Authority, KAPSARC data portal

GCC countries, primarily natural gas and crude oil and its products. Bahrain, Oman, Qatar, Kuwait and the UAE use gas for about 90% of their energy needs. Whereas in Saudi Arabia oil and oil products remain the predominant source. However, Saudi Arabia is transitioning from crude oil and its oil products towards domestic natural gas (International Renewable Energy Agency 2019).

Although, the GCC countries are the major contributor to the global energy markets because of its substantial hydrocarbon resources. Yet the GCC countries have an intent to be a global leaders in renewable energy. All the countries within the GCC have plans to include renewable energy power generation in their energy mix to address the issues of growing energy consumption with high demand for electricity due to development of industries and rise in energy consumption in residential sectors. Further, the energy prices are in GCC are lowest in the world putting them among the highest consumers of energy per capita. If alternative energy sources are not utilized to meet the energy demand, domestic consumption could absorb most of the region's hydrocarbon production. The energy diversification will free up hydrocarbon resources for export, foster economic diversification, accelerate strategically vital job creation, and reduce carbon-dioxide (CO2) emissions within GCC countries (World Economic Forum 2017).

The GCC countries are making efforts by reforming their markets to increase sector liberalization and private sector participation, further, by promoting renewable energy technologies and aligning domestic prices of electricity with the true cost of generation (KAPSARC 2017). As renewable energy, especially solar, is becoming a significant part of the global energy system. However, the GCC countries' have their vision and strategies in place, but to achieve them they need a more structured approach for supporting policy development. With abundant renewable energy resources and their leadership in the global energy sector, the current targets are entirely within reach for the GCC countries.

The GCC countries could be the world leaders in renewable energy deployment led by solar PV as the major technology provided current plans and visions are supported with enabling policy framework and renewable energy push driven by GCC's largest energy markets. This chapter explores the current policy intervention for the widespread adoption of renewable energy in GCC, the need for renewable energy and challenges & opportunities associated with the sector.

8.2 Promotion of Renewable Energy in GCC

Renewable energy plans and developments have come a long way in the GCC in recent years, with every country's ambitions differing from its market size and readiness. There has been a push through national vision documents with targets and strategies to promote renewable energy in the GCC. Renewable energy (RE) push alongside energy efficiency is an effort to safeguard natural resources and diversify the energy mix, which remains heavily dominated by fossil fuels.

The GCC countries have also integrated targets for renewable energy in their the United Nations Framework Convention on Climate Change (UNFCCC), Nationally Determined Contributions (NDCs). Some of the countries have also translated these state visions into concrete policy and projects, with short and long term dissemination plans. These policies and development plan particularly seem positive for more significant markets like Saudi Arabia and UAE.

8.2.1 Vision and Strategy for Renewable Energy Policies

GCC countries have come up with a dynamic policy framework (Fig. 8.1), which is necessary to accelerate renewable energy deployment, mainly through firm government commitment to renewable energy with time-bound targets and supportive investment mechanisms. Further, dissemination of renewable energy in the GCC has also been due to the creation of dedicated institutions with transparent bidding process for the projects. The GCC aspiration for energy diversification is a very realistic outlook. If current policy visions are backed up with the enabling frameworks for successful implementation of projects, then the future promises to have a significant growth in deployment of renewable energy in the GCC.

Renewable energy options such as wind and solar energy could also offer the region valuable alternative energy to fossil fuels in power generation and could also help in their UNFCCC commitments. The sections below delve deeper into the status of and policies for promoting renewable energy in individual GCC countries.

8.2.1.1 Saudi Arabia

The country's energy demand has been rising rapidly due to its economic and population growth, with total final energy consumption increased by about 74% from 2010 to 2016. The growth is expected to continue. Saudi Arabia accounts for about half of the GCC's total final energy consumption and is the region's largest energy market. It is estimated that its

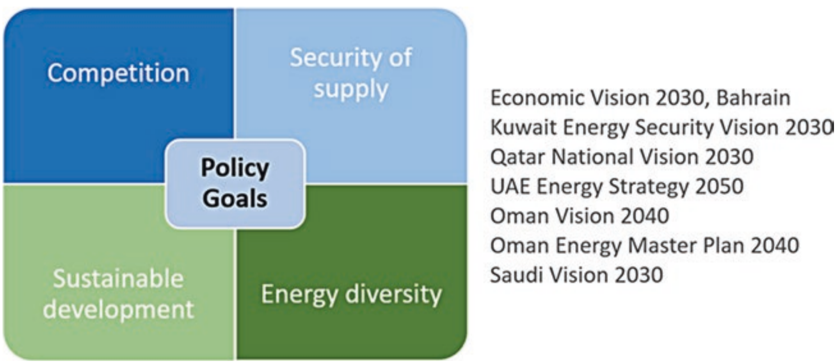

Fig. 8.1 Policy framework to accelerate RE in GCC countries. (Source: Author's description)

potential to harness renewable energy exceeds that of its neighboring countries.

Saudi Arabia's renewable energy plans and strategies can be traced back to the 2000s when several institutions were founded to support the development of renewables. The initial target was planned by King Abdullah City for Atomic and Renewable Energy (K.A.CARE) for competitive procurement of 54 GW of renewable energy by 2030, later delayed to 2040, was eventually abandoned (IRENA 2016b).

In the year 2016, Saudi Arabia came out with its long-term goals through a Saudi Vision 2030. In this vision document, Saudi Arabia plans to reduce its dependence on oil, diversify its economy, and develop public service sectors such as health, education, infrastructure, recreation, and tourism. In the vision document, Saudi Arabia set an initial target of 9.5 gigawatts of renewable energy. This target was to enable the renewable energy value chain in the Saudi electricity sector, including research and development, and manufacturing, among other stages (Kingdom of Saudi Arabia 2016).

However, Saudi Arabia revised its targets by establishing National Renewable Energy Program (NREP) under Renewable Energy Project Development Office (REPDO), Ministry of Energy. The NREP is a long term, a strategic initiative that directly supports the Kingdom's Vision 2030. The NREP will also enable jobs in the sector and accelerate economic development in Saudi Arabia. The NREP will also lead to the establishment of the renewable energy industry and create a conducive environment by coupling private sector investment and encouraging public-private partnerships (Renewable Energy Project Development Office 2016). In 2018, as per the first 5 year plan, Saudi Arabia's revised its renewable energy targets to 20 GW solar, with an overall increase of renewable targets to 27.3 GW. REPDO has also set a 40 GW target for solar and a 58.7 GW target for renewables overall by 2030 (Renewable Energy Project Development Office 2019b).

In its NDC, Saudi Arabia outlined a plan which seeks to avoid up to 130 million tons of CO2eq by 2030 annually. Further, Saudi Arabia would invest and implement programs for renewable energy (including waste to energy) systems, to diversify its energy mix. In addition, in its NDC, Saudi Arabia could invest in energy efficiency programs, carbon capture and utilization/storage, and use of natural gas for electricity generation. (Kingdom of Saudi Arabia 2015).

In the year 2017, Saudi Arabia's renewable capacity was only about 92 MW, mostly from solar PV projects and around 2 MW of onshore wind projects. However, in March 2018, Saudi Arabia and Softbank signed a memorandum of understanding to construct about 200 gigawatts of solar power facilities by 20,303 but during the end of the year, the project was put on hold, although the Softbank and Public Investment Fund (PIF) are continuing to collaborate on solar energy plans. Further, in the same year, Saudi Arabia came out with its Small-Scale Solar PV Systems Regulations to promote distribution system connected small-scale solar PV systems in the Kingdom of Saudi Arabia, a set of rules, which will be applied to projects not exceeding 1 MW (Electricity and Cogeneration Regulatory Authority 2017).

In October 2018, a new city powered entirely by renewable energy known as NEOM was announced by Saudi Crown Prince Mohammed bin Salman at the Future Investment Initiative conference in Riyadh. NEOM is set in North-Western Saudi Arabia and includes territory from Egypt and Jordan comprising a total area of 26,500 km^2.The zone is intended to be pollution-free and fully powered by renewable energy, forward-looking energy storage, and transport solutions as well as R&D and manufacturing. NEOM will be backed by more than $500 billion by the Public Investment Fund of Saudi Arabia, as well as private investors (Government of Saudi Arabia 2018).

One of the important changes which occurred in Saudi Arabia's ministerial structure was the combining ministries for oil and electricity under one umbrella of Ministry for Energy, Industry and Mineral Resources that formally administers the NREP (International Renewable Energy Agency 2019) . Under NREP, government with its intention to bring more solar power in its electricity mix carried out its 1st phase of auctions, which was launched in 2018, with issuance of tenders for two projects Sakaka 300 MW solar PV power plant in the northern region awarded to AWCA Power, which set a new world record with a bid of 2.34 cents/kWh backed by a 25-year Power Purchase Agreement (PPA) with the Saudi Power Procurement Company (SPPC) and the Dumat Al Jandal project of 400 MW, which will be Saudi Arabia's first utility-scale wind farm. Currently, Saudi Arabia invites bids for round two auction of 6 projects in two categories in line with NREP. REPDO's round two projects are 200 MW, 300 MW, 300 MW, and 600 MW as category "B" solar PV projects and 20 MW and 50 MW as category "A" small solar PV projects (Renewable Energy Project Development Office 2019a, b).

However, regulatory framework and policy instruments to achieve the country's renewable energy goals remain a challenge, since the private sector currently plays a minor role in the energy sector.

8.2.1.2 Kuwait

Kuwait relies almost exclusively on natural gas and oil products for electricity generation and its substantial desalination production. Each fuel currently accounts for about half of total energy consumption in the economy and per capita energy consumption in Kuwait is among the highest in the world. Electricity consumption grew, on average, by 5% per year from 2000 to 2015 and expected to grow even further (Kuwait Institute for Scientific Research 2019).

Although, renewable energy is in its early stages in Kuwait. However, there has been some major development in recent years mainly to diversify its energy mix and to mitigate rising environmental concerns. Kuwait Government has committed towards a highly ambitious plan to meet 15% of its energy requirements from renewable resources by 2030.

As part of their NDC, the Kuwait Government has committed to reducing its greenhouse gas emissions through energy production from renewable energy. Further, Kuwait also wants to improve petroleum products by producing clean fuel according to environmental specifications to supply power plants with it by 2020. The country also intends to construct a new refinery to replace the state's oldest refinery, which will meet international environmental standards. Kuwait also adopted a new Environment Protection Law to protect human health, control pollution, enhance natural resources, and promote energy efficiency and clean energy (The State of Kuwait 2015).

Kuwait's Vision 2035 and current Five-Year Development Plan (keeping aligned with its NDC) focuses on economic diversification and aims to position the country as a regional center for trade and finance. Kuwait's targets of renewable generation in their electric power system is to be 5% by 2020 and 15% by 2030 (IRENA 2016a, b: Table 8.2).

As of June 2019, there has been a handful of small renewable energy projects . One of the most important demonstration projects has been the Al Shagaya renewable energy park consisting of 10 MW of solar, 10 MW of wind and, 50 MW of concentrated solar power projects. (Ministry of Electricity & Water 2019).

With the full completion of Shagaya phase 1, Kuwait is planning the phase 2 of the program with 1.5 GW of solar PV Park known as Dabdaba

Table 8.2 Kuwait renewable energy targets

RE sector	*RE capacity by 2030*
Solar PV	4.6 GW
Solar CSP	5.7 GW
Wind	0.7 GW

Source: IRENA

project, whose construction is overseen by Kuwait National Petroleum Company (Renewables Now 2019). Kuwait is still in the early stages of renewable energy project dissemination in the region but with upcoming low bids for renewable projects in the region, it will look to ramp up their efforts to promote renewable energy.

8.2.1.3 United Arab Emirates

UAE is the GCC's 2nd largest energy market after Saudi Arabia but despite that UAE is the front runner when it comes to implementing renewable energy projects into its energy mix. Like other Middle Eastern countries, majority of generation of electricity is met from natural gas, and much of it is imported. UAE consists of seven emirates, like any other GCC countries, each emirate in UAE has emphasized on shift and reduce the reliance on oil and gas for its energy needs by adopting alternating sources of energy. UAE is also a leading solar market in the Middle East.

The United Arab Emirates pledged to pursue "a strategy of economic diversification that will yield mitigation and adaptation co-benefits" as part of their NDC. The UAE has set a target to increase its share of renewable energy in its energy mix from 0.2% in 2014 to 24% by 2024. The UAE also created the Ministry of Climate Change and Environment to make the climate one of the country's top priorities. Further, in other measure UAE seeks to reduce gas flaring, carbon capture and utilization/storage (United Arab Emirates 2015).

The UAE government in its UAE vision prioritized sustainable development both economically and socially through an increase in the share of clean energy. Further, in 2017, UAE launched "Energy Strategy 2050" as its first unified energy strategy. The strategy aims to increase clean energy contribution in UAE's energy mix by 50% and reduce the carbon footprint of power generation by 70% till 2050. The strategy targets an energy mix that combines renewable, nuclear and clean energy sources to meet the UAE's economic requirements and environmental goals. To achieve the above targets, UAE government is planning to invest approximately USD 163.35 billion by 2050 (UAE government 2017). UAE government has also developed the Green Growth Strategy in 2012, mainly focusing on becoming one of the world leaders in this area as well as a center for the export and re-export of green products and technologies. All these initiatives also emphasize on knowledge creation and technology innovation to support the job market in UAE.

Emirates in UAE are also playing their part in these initiatives through their individual efforts. Dubai revised its targets after a series of auctions, which revealed the declining price of solar. In 2015, Dubai increased its target of renewable energy by 15% by 2030. Later same year they further revised the target by 25% by 2030, mainly due to high solar potential (International Renewable Energy Agency 2019). In line with the vision and directives of UAE strategy, in 2012, Dubai announced its flagship project Mohammed bin Rashid Al Maktoum Solar Park owned by Dubai Electricity and Water Authority (DEWA) making it largest renewable-energy project in the world with a planned production capacity of 5000 MW upon completion in 2030. This initiative is also a part of the Dubai Clean Energy Strategy 2050 that aims to make Dubai a global hub for green economy. In addition, The Dubai Clean Energy Strategy aims to achieve 75% of Dubai's energy from clean energy sources by 2050 in a phased manner (Government of Dubai 2019b).

The Mohammed bin Rashid Al Maktoum Solar Park consists of 5 phases. The 1st phase started 13 MW in 2012 and the power plant became operational at the end of the year 2013. The 2nd phase started in 2017, a 200 MW project which was implemented by DEWA with a consortium led by ACWA Power from Saudi Arabia. In the 2nd phase, DEWA got the lowest bid of USD 5.6 cents per kWh, making it the lowest bid for the solar power project in the world. (International Renewable Energy Agency 2019). As a part of the 3rd phase, DEWA awarded the bid to Masdar-led consortium to develop the 800 MW of the solar park, in the process set a world record by obtaining the lowest price of USD 2.99 cents per kWh. As of now, the first 200 MW has been operational with the second and third phases being implemented in stages until 2020.

Further, in 2017, the 4th phase was launched for a largest single-site Concentrated Solar Power (CSP) project in the world. The project was awarded to a group of Saudi Arabia's ACWA Power, The Silk Road Fund, and China's Shanghai Electric. The 5th phase will include a development plan of 900 MW for Mohammed bin Rashid Al Maktoum Solar Park as per the IPP model with the commissioning of projects starting from 2021 (Government of Dubai 2019a, b). Further, Dubai had also launched its Shams Dubai program for rooftop and small scale solar systems. The program encourages the installation of rooftop solar through residential households and building owners.

Similar to Dubai, other emirates like Abu Dhabi are not that far behind Abu Dhabi's Shams 1 CSP project was the largest renewable energy project in operation in the Middle East when launched in 2013 with a capacity of 100 MW. Further, Abu Dhabi's Noor Abu Dhabi Solar Power Project a 1177 MW solar power plant became the world's biggest single-site solar power plant with the estimated development cost of USD 0.87 billion. The construction of the Noor Abu Dhabi Solar Power Project commenced in 2017 and began its commercial operations in 2019. It is expected that project could generate sufficient electricity to power approximately 195,000 homes and offset seven million tons a year of carbon emissions (NS Energy 2019a). Similar to Dubai, in late 2017, Abu Dhabi Distribution Company (ADDC), launched a program to allow residents and businesses to add solar panels on rooftops to reduce their electricity bills. Further, Emirate of Sharjah waste to energy facility will be the first of its kind in UAE. The facility will use around 37.5 tons (t) of unrecyclable solid waste an hour to generate 30 MW of electricity (NS energy 2019b).

8.2.1.4 Qatar

All the GCC countries are going through a population and economic growth phase, therefore, demand for utilities has also been increasing rapidly. Qatar is no exception to this growth. The Qatar Electricity and Water Company (QEWC) is one of the major companies in Qatar and among the first private sector companies in the region that operate in the field of electricity generation and water desalination. The company and its joint venture companies together have a capacity of over 10.590 GW of electricity and over 481.5 MIGD of desalinated water as of year 2018 (Qatar Electricity and Water Company 2018). To support the sustainable development in the country and replacement of natural gas as replacement for oil in the power sector, Qatar government in 2018, came up published with its Qatar Vision 2030. The vision document provides a framework for national development strategies and a balance among economic growth, social and human development, and environmental protection (Qatar General Secretariat For Development Planning 2008). In line with the vision Qatar came out with its National Development Strategy 2011–2016 (NDS-1), the first comprehensive development strategy aimed at achieving vision goals of sustainable and balanced growth including responsible use of oil and human resources through developing and modernizing government institutions. Along the same lines, Qatar came out with NDS – 2 plan for 2018 till 2022.

Further, in 2nd development strategy, Qatari Government emphasized the use of renewable energy to limit pollution and gas emissions and generates economic returns. Although need for renewable energy in Qatar's energy system is very minimal, nevertheless, the Ministry of Energy and Industry (MoEI) is developing and implementing a renewable energy strategy along with its policy with legal framework. Also, Qatar General Electricity & Water Corporation (Kahramaa) has developed a solar energy plan for 200 MW to be developed by 2020 and option to increase it to 500 MW after the completion of first phase (Ministry of Development Planning and Statistics 2018). The State of Qatar, in its NDC, kept focus on dealing with the potential impacts of climate change through promoting energy efficiency, clean and renewable energy, education, and research and development (Ministry of Environment, Qatar 2015). To date, Qatar foundation uses 3 MW of PV capacity to power its campus. Other renewable energy projects such as Biogas and municipal waste accounted for about 38 MW of power generation capacity in 2017. The Mesaieed plant is GCC's largest waste to energy facility with 30 MW capacity, which also generates 8 MW of biogas based power. Qatar is also working on small scale solar project, Qatar National Convention Center (NCC) installed a 667 KW capacity solar PV array. Similarly, Green Gulf also installed a 26 KW PV array at the national command center for Kahramaa (Alhaj 2017).

Although, regulatory framework and policy instruments are not satisfactory for private power producers, at the same time, need for renewable energy in the small country of Qatar is also very minimum. However Qatari government acknowledges climate change issues and need for sustainable development and environmental protection for its future generation, therefore, Qatari government is putting every possible positive step to address sustainability through renewable energy dissemination not only in energy sector but other sectors as well.

8.2.1.5 Bahrain

Bahrain one of the smallest oil produces in GCC. Same as other GCC countries, the energy sector is almost completely dependent on fossil fuel, mainly natural gas and heavy fuel oil. Due to this, Kingdom of Bahrain looks to diversify its fuel supply to the power sector (EIA 2016). As of 2016, Bahrain had an installed generating capacity of about 4 GW, of which just 6 MW was from renewable energy. Bahrain also gets a supply of electricity from GCC and ALBA interconnection links which is about 900 MW in capacity (Electricity and Water Authority of Bahrain 2018). Just like any other GCC, Bahrain is going through a transformation with rapid growth in population and industrial development, demand for power is ever-growing in Bahrain. In October 2008, Kingdom of Bahrain launched its Economic vision 2030 which focused on protecting natural environment with direct investments to technologies that reduce carbon emissions, minimize pollution and promote the sourcing of more sustainable energy (Government of Bahrain 2008).

Bahrain, to diversify its energy mix, came out with its National Renewable Energy Action Plan (NREAP) in 2017. The Plan represents the implementation efforts of Bahrain's NDC commitments under the Paris Agreement, the United Nations Sustainable Development Goals, and the League of Arab States Renewable Energy Framework. NREAP sets a renewable energy (including waste to energy) target of 5% by 2025 and 10% by 2035 in its energy mix. (Sustainable Energy Authority 2017) (Table 8.3)

Further, Bahrain's NDC also aims to reduce Bahrain's dependence on oil & gas. The country thus emphasizes demonstrating PV solar technology under local conditions to support upscaling of renewable energy through BAPCO's 5 MW PV grid-connected plant. The project consists of the installation of 21,000 smart solar panels to generate a substantial number of electric units annually. Other mitigation efforts focus on energy efficiency in building, industry, transport and the energy sector (Kingdom

Table 8.3 Bahrain's renewable energy target

Renewable energy targets	*2025*		*2035*	
	MW	*GWh*	*MW*	*GWh*
Wind	50	125	300	750
Solar	200	340	400	680
Biogas	5	13	10	26
Total	255	478	710	1456

Source: Sustainable Energy Unit of Bahrain of Bahrain 2015). As a step to fulfil its vision and policies, in March 2017, Bahrain's Electricity and Water Authority launched a tender for a solar park at Askar landfill, which was won by Saudi energy company ACWA Power with winning bid $0.039/kWh. Similarly, the Solar Energy Unit of Bahrain in collaboration with the United Nations Development Program launched a 3 MW tender for solar arrays at eight locations containing 66 government buildings (PV magazine 2019).

Kingdom of Bahrainis small island nation in GCC with very limited resources. Diversification to renewable energy will not only provide the country energy diversification but also enable the country to become self-sustainable.

8.2.1.6 Oman

In Oman, natural gas is the primary fuel for power generation and water desalination, whereas diesel is used in rural areas. Nearly a quarter of the domestic natural gas consumption comes from electricity generation and desalination plants with remaining by industrial and petrochemical sectors and rest is exported as Liquefied natural gas (LNG). With the rise in Oman's domestic requirements, the government is planning to diversify its energy mix. Oman has witnessed a robust compounded annual growth of 9.09% in peak electricity demand from 2010 to 2016 with available capacity rising from 4.05 GW to 7.8 GW. The government of Oman came out with its National Energy Strategy 2040, which seeks to ensure the country's long-term energy sustainability. In its strategy, the government has set a target of at least 10% of electricity generation from renewables by 2025 and up to 3000 megawatts (MW) of coal-fired power plants by 2030. In addition, to previous target, the National Program for Enhancing Economic Diversification (Tanfeedh) has modified the target to 11% of electricity generation from renewable energy by 2023. Similar goals were also integrated in Oman's Vision 2020 and the 5-Year Development Plan (2016–2020)(Hasan et al. 2019).

In their NDC, the Omani government aims to increase the share of renewable energy. Further, Oman will also seek funds, capacity building and transfer of technology from the UNFCCC for further efforts in development of renewable energy. Further, Oman mitigation contributions also include measures such as reducing gas flaring from oil industries and boosting energy efficiency (Ministry of Environment and Climate Affairs, Oman 2015). Table 8.4 shows the renewable energy development plan for

Table 8.4 Renewable Energy Development Plan – MIS (MW)

	2019	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*
Ibri II solar IPP	–	–	–	500	500	500	500
Solar IPP 2022	–	–	–	–	500	500	500
Solar IPP 2023	–	–	–	–	–	500	500
Solar IPP 2024	–	–	–	–	–	–	500
Wind IPP 2023	–	–	–	–	–	100	100
Barka WTE IPP	–	–	–	–	100	100	100
Total capacity	–	–	–	500	1100	1700	2200
Capacity contribution	–	–	–	100	295	430	530

Source: OmanPWP

Oman's Main Interconnected Transmission System (MIS) Network, which supplies majority capacity for the country.

In view of the diversification of its energy resources and manage the rising growth of the energy sector, Oman is moving rapidly towards renewable energy projects. Oman announced its 500 MW Ibri Solar Project in December 2017, which was awarded to Saudi-based ACWA Power, Kuwait-based Gulf Investment Corporation and Kuwait-based Alternative Energy Projects Company in 2019 through competitive bidding process (Times of Oman 2019). Similarly, 105 MW Amin Solar PV Project was awarded to a consortium led by Marubini in 2018. Oman has an extensive coastline and vast unpopulated areas; therefore, wind power project can contribute significantly to the future electricity supply of the country. Masdar owned Dhofar Wind Power Project will have an installed capacity of 50 megawatts, making it the first large-scale wind farm in GCC (Masdar Clean Energy 2019). To promote the wind energy in Oman, the Oman Power and Water Procurement Company (OPWP) has created a wind atlas for Oman and will conduct a wind resource assessment to collect wind data for future wind energy projects (business live me 2019).

The Rural Areas Electricity Company (RAECO) (Tanweer) identified 11 sites for a technical and economic feasibility study to implement solar-diesel hybrid projects with a total of 42 MW capacity. RAECO also started purchasing electricity for 20 years from the 307 kilowatt-capacity project operated by Bahwan Astonfield Solar Energy Company, Oman's first commercial solar power project in 2015 inaugurated in Al Mazyona. Further, RAECO, under the "SAHIM" initiative introduced by Authority for Electricity Regulation (AER), has also formulated a plan to implement the regulatory framework by establishing a team to activate the solar energy implementation of small and medium-scale grid-connected solar systems to all customers (Tanweer 2018).

The SAHIM initiative was launched in May 2017 by the Oman Authority for Electricity Regulation (AER) and had two phases. The SAHIM I allows large households and businesses to install small-scale grid-connected PV systems at their own cost. Whereas, SAHIM II is aimed at promoting small-scale grid-connected PV systems for around 10% to 30% of residential sector as competitive bidding for private developers as per the build, own and operate machinery. If this plan is realized, it would reduce the government's annual subsidy bill. Oman government is also been promoting in the rural and mountain regions of Oman (Oman Authority of Electricity Regulation 2017)**.** If SAHIM is realized the prospective benefits for Oman are as follows, gas savings over 25 years of between 2 billion Sm^3. Further Co_2 emission reduction over 25 years of about 3.2 million tons with average reduction in customer bills of around 42% (Ghaithi 2017)**.**

Oman had also developed 1.021 GW of a solar thermal facility located in south of Oman. The steam generated from the thermal power plant is utilized for thermal enhanced oil recovery (EOR) to extract heavy and viscous oil at the Amal oilfield. With the successful implementation of the solar EOR project, Petroleum Development Oman plans to add another four blocks beginning from 2019 (Power technology 2016).

Oman among GCC countries is an example when it comes to the liberalization of the electricity sector. With this liberalization and vision to diversify its energy sources. Oman is poised to become one of the leading markets in renewable energy in GCC.

8.3 Challenges to Promoting Renewable Energy in GCC Countries

Rising electricity demand, economic and environmental constraints have encouraged governments in the Gulf Cooperation Council (GCC) region to consider integration of renewable energy in their electricity mix. However, delivering renewable energy targets requires robust policies, finance, and technological framework. A homegrown creative solution is needed for the GCC countries to tackle rising energy consumption and population. Utilities/independent power producers (IPPs) are provided with subsidized fuel for power generation. Removing price distortion in the supply side in GCC region, and price reform measures are crucial for addressing the concern. At the same time electricity to residential sector in most of the GCC countries is highly subsidized, which makes dissemination of distributed renewable (solar) energy very difficult.

Most of the national electricity markets in the GCC region are vertically integrated, that is owned, operated and built by state or have a single buyer model. Liberalization of national electricity markets is desirable but not a prerequisite. Several countries in the region, including Saudi Arabia, Oman, Abu Dhabi, and Dubai have established electricity regulators who face the daunting challenge of balancing the interests of consumers, companies, and governments. But, for renewable energy, GCC countries are adopting a policy framework to encourage independent power producers and private entities (King Abdullah Petroleum Studies and Research Center 2018a, b).

Currently, renewable energy projects are entirely government-led projects but strong policies and regulatory frameworks are needed to attract private sector investments. At present policy instruments are either weak or absent, therefore, they are unable to attract market players. Some of the initiatives are needed for grid-connected renewable energy that should cover incentives, facilitation, and clearances for private power producers. There should be enabling regulatory provisions in place such as tariff determination for different technologies, provisions of trading and evacuation of power. There should be a creation of supplementary market for meeting the grid-related challenges from solar and wind (Hasan 2019).

The GCC countries should also focus on capacity building in terms of manufacturing or services in the sector for renewable energy projects. All the GCC countries acknowledge the fact that the benefits of renewable energy into their energy mix but in the GCC countries the biggest challenge will be to create energy consciousness and awareness to use the energy in smarter ways among general public. The GCC countries have the resources and capability to address these challenges, especially, the recent development in renewable energy sector has commendable. But they need to act on these challenges rather sooner than later.

8.4 Harnessing the Renewable Energy Opportunity in GCC Countries

The GCC is a hydrocarbon driven market and most of its energy needs come from fossil fuel. The Gulf Cooperation Council (GCC) nations, such as Saudi Arabia, Bahrain, Kuwait, Oman, Qatar, and United Arab Emirates, have come up with vision and strategy to set different renewable energy dissemination plans for next decade or so. However, According to The World Bank data, GCC countries are among the top 25 countries contributing to carbon dioxide emissions per capita, with high carbon footprint and rapid urbanization & socio-economic growth. The GCC countries are more determined to increase the share of renewable energy in their total energy mix (The World Bank 2014).

The GCC region has considerable renewable energy potential, particularly for solar photovoltaic (PV) generation, making it a favorable market for solar generation (Table 8.5). Tapping into the renewable energy market will not only provides a medium for low carbon footprint but also can address rapid urbanization and socio-economic growth.

Renewable energy, especially, solar and wind can bring socio-economic benefits to all the GCC countries. The GCC countries are expected to gain, if they achieve their targets by 2030, can save about 354 million barrels of oil equivalent in power sector. Further, the region can reduce about 136 million tons of CO2. The GCC region can not only on its fossil fuel resources and reduce its CO2 emissions but can also create more than 0.22 million direct jobs (International Renewable Energy Agency 2019).

The water and energy sectors are interlinked in the GCC countries and one of the most important commodities. The GCC is among the most water-stressed regions in the world with very limited water resources. This makes renewable energy technology even more important, especially in power sector, since water is very important in fuel extraction and processing as well as for power generation. The GCC countries can save about 11.5 trillion liters of water through renewable energy from power production and fuel extraction for power extraction (International Renewable Energy Agency 2019).

Apart from socio-economic gains from renewable energy, the GCC countries can also pioneer in the renewable energy sector by creating awareness and become example in front of the whole world through high capacity power projects. The GCC countries have the opportunity to be a

Table 8.5 Renewable Energy Projects in GCC

Country	*Project/site*	*Technology*	*Size (MW)*	*Status*	*Expected start of operation*
United Arab Emirates (Dubai)	Mohammed bin Rashid Al Maktoum Solar Park, phase IV	CSP	700	Contracts awarded	To come online in stages starting in 2020
		Solar PV	250		Assumed 2020 onwards
	Mohammed bin Rashid Al Maktoum Solar Park, phase III	Solar PV	600 (of 800)	Construction has begun in 2017	2020
			200 (of 800)	The first stage of 200 MW completed in May 2018	
	Mohammed bin Rashid Al Maktoum Solar Park, phase II	Solar PV	200	Completed in March 2017	2017
	Mohammed bin Rashid Al Maktoum Solar Park, phase I	Solar PV	13	Completed	2013
United Arab Emirates (Abu Dhabi)	Noor Abu Dhabi, Sweihan	Solar PV	1177	Under construction	2019
	Shams 1	CSP	100	Completed	2013
Oman	Dhofar, phase I	Wind	50	EPC contract awarded	2020
	Dhofar, phase II wind 150	Wind	150	Planned	2023
	Miraah solar thermal	Solar thermal	1000 (GWth)	Under construction	100 MW complete, delivering 660 tons of steam/day as of February 2018
	Ibri PV plant	Solar PV	500	Companies shortlisted	Early 2021
	PDO Amin PV plant	Solar PV	100	Contract awarded	

(*continued*)

Table 8.5 (continued)

Country	*Project/site*	*Technology*	*Size (MW)*	*Status*	*Expected start of operation*
Saudi Arabia	Sakaka	Solar PV	300	Under construction	To begin commercial operation in 2019
	Dumat Al Jandal	Wind	400	Bids received; expected to be awarded start of 2019	
	Waad Al-Shamal	CSP	50	Completed	
Qatar	Al-Kharsaag	Solar PV	700	Bids received	2020 (first 350 MW)
	Mesaieed waste to energy	Waste to energy	38	Completed	
Kuwait	Shagaya	CSP	50	Completed	
		Solar PV	10	Completed	
		Wind	10	Completed	
	Al Dibdibah/ Shagaya phase II	Solar PV	1200–1500	Bids invited	2022
Bahrain	Askar landfill	Solar PV	100	Request for concept	December 2019
	Al Dur	Solar-wind hybrid	5		

Source: IRENA

state of the art renewable energy hub through research and development, creating universities and academia programs.

Further, renewable energy or alternative sources of energy can also provide a diversification option to transportation fuel in the region. The electrification of vehicle fleet using alternate sources of clean energy can offer opportunity to tap renewable sources even further.

The GCC countries have limitless opportunities to be a global leader in the renewable energy landscape from state of the art project developers to the manufacturers of renewable energy equipment. With current trends in the GCC energy landscape, it is foreseeable that they can be the biggest players in the renewable energy markets globally.

8.5 Conclusion

Renewable energy has taken long strides in the GCC countries over the past 5 years, but still has a long way to go in the GCC. There is a patterned shift in energy mix of the GCC countries. The GCC countries are now more focused than before for tapping renewable energy in their energy mix. But GCC countries still require a regulatory framework and financing structure for promoting renewable energy. The institutions, especially, think tanks in the region should work in close coordination with relevant national-level entities and, more importantly, with electricity regulators, transmission companies and system operators.

In GCC countries most of the projects are grid-connected utility-scale projects but GCC countries should try to go beyond that by promoting distributed renewable energy projects, which often provides a sustainable way of electricity generation options for the rural and farfetched areas.

Renewable energy, primarily solar energy will likely play an important part in its future energy mix, although there is a drastic difference between the deployments of renewable energy in different countries in the GCC region. The GCC countries, in the long run, can easily link the cost-effectiveness of solar power to oil. The potential additional benefits that renewables energy brings for the region, most importantly environmental mitigation of the high per capita fossil fuel use and CO_2 emissions, and through new industrial diversification, are immense.

Policymakers and stakeholders in the GCC have an excellent opportunity to capitalize on global trends in renewable energy for rapid deployment. Specifically, the region is well suited for renewable energy, especially, solar and wind deployment. If GCC countries are able to successfully and sustainably deploy renewable energy projects, the overall sector may see increased participation and diversification in the future.

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PART IV

Governance and Legal Aspects

CHAPTER 9

Power Purchase Agreements as Instruments of Risk Allocation and Alleviation for Renewable Energy in Asia

Anjali Viswamohanan

9.1 Introduction

The power sector in Asia has been the target of significant overhaul in the past decade. Countries have recognised the need to implement and oversee an energy transition to ensure energy security driven by a blend of technological innovation, change in supply and demand dynamics and policy shifts (WEF 2018). While the pace of transition may not be at the same level throughout the continent, the movement towards renewable sources of energy is definitely here to stay, with countries like China and India spearheading the revolution. International organisations such as the International Solar Alliance (ISA) and the International Renewable Energy Agency (IRENA), with their headquarters at New Delhi, India and Abu Dhabi, United Arab Emirates, respectively, have played pivotal roles in shifting the narrative of the renewable energy transition from Europe to the Global South. Moreover, several countries in Asia have taken the initiative to implement ambitious national renewable energy policies and targets.

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Apart from facilitating the technical incorporation of renewable power into the energy systems through policy and regulation, a major push has been to bring in investment into these emerging energy sectors. There has been significant national and international focus on aiding the flow of finance to fund the energy transition movement in Asia. However, an early realisation for the sector was the high cost of finance for these projects in a number of these countries, including India (Chawla and Aggarwal 2016). There was an initial struggle in achieving competitive tariff rates for renewable power in these countries, rendering offtaker issues in the sector, due to the availability of cheaper sources of conventional power. There arose the need for these governments to structure policies and incentives to lure foreign investments into renewable power projects. Some of these measures have created an unsustainable ecosystem for the broader power sector. One evident manifestation of such measures is that the state-owned power distribution companies in India, which are already in poor financial conditions, are unable to take on excessive long-term capacity contracts (Bhushan et al. 2019).

The real renewable energy boom is yet to arrive in other Asian economies as compared to countries like India which are investing more in solar PV than in all other fossil fuel sources on electricity generation put together (in 2018) (IEA 2020). The need to re-examine measures that are being implemented to facilitate the flow of investment in renewable energy projects in these countries is urgent. Needless to say, the transparency and predictability of the regulatory framework along with the financial viability of an infrastructure project are prerequisites for investment. Furthermore, through regulations and policies, governments have placed priority on according returns to renewable energy investors, at least at par with what is attained in other infrastructure sectors (Chaudhary et al. 2015).

While there are several ways to address the present issues in the renewable energy sector, one systemic correction that has been relatively overlooked so far is the re-examination and optimisation of the terms of the standard power purchase agreements (PPAs) being implemented in renewable energy projects. Several other infrastructure sectors, such as the roads and ports sectors, have over time developed a robust contractual agreement that addresses several concerns of private parties through elaborate provisions, covering most scenarios that play out during the lifetime of the project (DEA 2011). However, the renewable energy sector is relatively nascent on this front. There is a growing need to re-examine the PPA as an instrument, to lower the risk on receivables faced by renewable energy project developers and financiers. This will bring down the cost of finance, as well as reduce some of the burden on the offtaker due to the regulatory nature of the agreement.

This chapter will be drawing on the evolution of the PPA structure, related regulation and its judicial interpretation in India. However, several developing countries suffer from similar risks and employ similar contractual structures. This chapter identifies risks from various markets in Asia, and draws parallels between manifestation of these risks in India and other Asian countries, wherever applicable. However, Sect. 9.4, which focuses on identifying PPA remedies is exclusively focussed on the Indian market.

9.2 Risks, Uncertainties and the Power Purchase Agreement

This section is intended to provide a basic introduction to the structure of the PPA, the relevant actors directly and indirectly included in the PPA and then delves into how risks and uncertainties could be addressed by the terms of the PPA.

9.2.1 PPA, Its Signatories and Secondary Actors

PPAs are long-term contracts that define in its entirety, the terms for the sale of electricity between the seller (herein referred to as the project developer) and the buyer (herein referred to as the offtaker). The secondary actors that are indirectly involved in the negotiation of the PPA include:

(i) The Government Authority
(ii) The Regulator
(iii) Transmission Companies
(iv) Distribution Companies
(v) Lenders/Project financiers

The terms of a PPA are generally fixed by the Government Authority overseeing the bidding process for the allocation of power projects at the bidding stage, taking into consideration the type and requirements of the project. The regulator is required to sign off on the final terms of the PPA before execution and is also responsible for approving the tariff rate. The draft of the terms of the PPA are attached to the bidding document and there is little to no room for negotiation of the terms of the PPA once the project has been awarded. In the case of India, the terms of the PPA are identical for categories of renewable energy projects. For example, projects allocated under Phase I of the Jawaharlal Nehru National Solar Mission (JNNSM) are expected to employ the JNNSM Phase I Model PPA. Similarly, the contracting authority in each state has a model PPA that is followed for projects being awarded in that state. The model PPAs are updated time and again to reflect market trends. This rigidity in model contract structures is prevalent in most markets. For example, the terms of the Kazakhstan standard form PPA does not contain standard provisions required by international investors (step-in rights, international arbitration, compensation in case of early termination, insurance, etc.). On the other hand, some progressive policies in markets like Serbia have taken to adopting PPA models where the provisions are a mix of obligatory and optional. They also provide a further possibility to modify some of the model's provisions and to introduce changes to the PPA from the outset 'so that its application is adjusted to the needs of a particular case' (Popovic 2016).

The long-term nature of the PPA is beneficial to both parties and serves as a risk alleviation instrument in itself. The terms guarantee the sale of part or the entire of its production at a pre-established price for the next 10 or 20 years, and therefore, an insured, predictable income and with a much lower risk than direct market retribution (AleaSoft 2019).

9.2.2 Addressing Risks and Uncertainties

Infrastructure projects require long-term contracts that last for the entire life of project operation. Such long-term contracts must provide for both risks and uncertainties that may arise during the life of the project. Risks pertain to foreseeable occurrences while uncertainties are associated with unforeseen circumstances (Triantis 1992). Standard long-term contract provisions such as the force majeure provision and the change in law provision, cater to both risks and uncertainties (Primack and Weinberger 2009).

Several project risks are foreseeable ones, with lapses in accounting for these in contract structuring due to the absence of forward-looking risk management (Beckers and Stegemann 2013). Clear identification and allocation of risks among the various stakeholders in the sector at the outset provides long-term stability for the project. The risk should be allocated to the party that is most capable (in their technical and financial capacity) of absorbing and dealing with the risk (ALSF and CLDP 2014). Project developers and financiers stand most to lose from inefficient identification and allocation of risks in renewable energy projects. Clear demarcation of these risks at the outset will also better prepare the sector for long-term risk mitigation (NRC 2005). For instance, currently in India, the offtaker is forced to bear the entire demand risk, resulting in disproportionate curtailment of renewable power since there is a penalty in the form of fixed cost payment for curtailment of thermal power. Emerging risks such as these cannot be effectively allocated through simple contractual structures that are being employed in renewable power projects currently. In many of these cases, there arises a need to balance the risk among the parties to the PPA to avoid situations of bankruptcy and project termination.

9.3 Overview of Renewable Energy Project Risks

The following table (Table 9.1) lists and describes the key risks that arise in the context of renewable energy projects. Some risks are present throughout the lifecycle of the project, while others are restricted either to the construction or operations phase. Risks such as force majeure, change in law, etc. may affect the project at any stage of its life. The project risks have been broadly classified into construction phase risks, operations phase risks and general risks, in accordance with the World Bank Manual on Power Purchase Agreements. In several jurisdictions, the construction-related provisions are laid out in a separate agreement termed the implementation agreement and does not form a part of the PPA (The World Bank Group PPPLRC 2016). The table below does not delve into detail on the construction phase risks as it is beyond the scope of this chapter. The table aims to identify existing risks in Asian markets and how they are being addressed (if at all) in the PPA. It also provides a link to the next section of this chapter by listing out PPA provisions that could be added or modified to address these risks better.

Sections 9.4.1 and 9.4.2 may be applied across all risks listed in the table above.

Escalation of risk beyond the scope of remedy provided in the PPA may result in default of either party's obligation under the PPA. The concerned party is then entitled to turn to the dispute resolution process or

Table 9.1 Existing risks in Asian markets

Key features and examples of manifestation of risk	*Existing PPA provision to deal with the risk*	*Suggested provisions to remedy risk*
Operations phase risk		
1. **Offtake risk**—This is typically a private party risk pertaining to payments for power generated by the project, which is in turn linked to the demand risk. The GCC economies have reliable off-takers. Once a project developer enters into a PPA, timely payments are guaranteed by public off-takers, and therefore the risk and cost of financing go down (IRENA 2019). On the other hand, outstanding dues of solar-power companies supplying power to Telangana, India, have shot up to INR 24 billion, plunging them in a financial crisis (ORF 2019).	The minimum offtake guarantee provision is designed to address this risk partially by guaranteeing the offtake of a fixed quantity of power monthly/annually (as applicable). The payment security mechanism whereby the offtaker provides a form of security for the payment due in relation to the minimum offtake obligation also aids in alleviation of this risk.	Lender's substitution provision (discussed in Sect. 9.4.6 below)
2. **Technology risk—**Lack of adequate data to estimate the longevity of the equipment used in the project because the technology is new, evolving rapidly, and often owned by companies with moderate-to-weak credit quality (CRISIL 2019). Unproven technologies with moderate reputation and limited track record face more risks such as steep degradation and dramatic equipment failure. There are also risks associated with implementation of enhanced technology that may be required for existing projects in the future to ensure better integration of renewable power.	This risk is currently addressed under the Change in Law provision. In the case of retrofitting of existing thermal plants to comply with stricter emission restrictions imposed by the Ministry of Environment, the Central Electricity Regulatory Commission opined that it would be considered as a Change in Law (NTPC v, MPPMCL 2016).	Change in scope of the project associated with technology enhancement (discussed in Sect. 9.4.4 below)

(*continued*)

Table 9.1 (continued)

Key features and examples of manifestation of risk	*Existing PPA provision to deal with the risk*	*Suggested provisions to remedy risk*
3. **Infrastructure risk—**This is a contracting authority/offtaker risk concerning the grid infrastructure keeping pace with the requirements of expanding renewable energy supply in the market.	Ensuring coordination between the development of transmission infrastructure and the date of scheduled commercial operation of the project lies with the offtaker. This risk is managed through the obligations of the offtaker and the deemed offtake provision which kicks in post the commercial operation date of the project.	–
General risks		
4. **Demand risk—**Risk associated with the financial health of the offtaker. Regulatory pursuits to encourage renewable energy such as renewable energy purchase obligations imposed on the state-owned distribution companies without considering their financial health and energy supply mix, further aggravates this issue in the current market.	This risk is ultimately borne by the authority under whose jurisdiction the PPA lies. In India, the State Commission has the power under Section 86(1)(b) of the Electricity Act, 2003 to verify the reasonableness of the quantum, price and mode of supply of power under a PPA entered into under its jurisdiction. This risk is quantified in the form of a minimum offtake obligation in the PPA.	Restructuring the minimum offtake obligation (discussed in Sect. 9.4.5 below)

(*continued*)

Table 9.1 (continued)

Key features and examples of manifestation of risk	*Existing PPA provision to deal with the risk*	*Suggested provisions to remedy risk*
5. **Political risk and regulatory risk—**Risk associated with political and policy uncertainties and the potential occurrence of incidents related to corruption, terrorism, etc. that pose a risk to the investment in power projects. This includes incidents such as change in applicable taxes, risks associated with cancellation of or change in applicable tariffs, regulatory environment concerning the sector, etc.	This risk is dealt with under the change in law and force majeure provisions.	Enhanced change in law and force majeure provisions (discussed in Sects. 9.4.7 and 9.4.8 below)
6. **Currency risk—**This is a business risk concerning the fluctuating rates of exchange affecting investors' return from projects, in case of foreign investment in these projects, where recovery is typically in the local currency.	Foreign exchange rate is a known risk factor in projects that have a significant import component, and has to be accounted for by the businesses at the time of bidding for the projects. There is no explicit provision in the PPA to deal with this risk. In a 2017 case before the Central electricity Regulatory Commission, it was concluded that fluctuation in exchange rate is not a Force Majeure event (GGEL v. NVVNCL 2017).	Linking of PPA tariffs to foreign exchange rates and inflation (discussed in Sect. 9.4.3 below)

Source: Author's summary

termination provision of the PPA. A summary of the dispute resolution process is provided in the table below (Table 9.2).

There is a need to expand the scope of the current PPA structure to afford parties more flexibility in terms of available options to deal with these risks, such that the default provision is not triggered easily. For

Table 9.2 Governing law and dispute resolution process in the PPA

Contracting parties have a right to choose the governing law of a contract, which shall be inferred from the terms of the contract (NTPC v. Singer 1993). However, most model PPA formats prescribe that the laws of the country where the project is being implemented shall apply.

The dispute resolution process varies across different models of the PPA, based on the will of the contracting authority. For example, the 2018 solar and wind bidding guidelines released by the Ministry of Power, Government of India prescribes that any dispute between the contracting parties to a PPA with regard to tariff related matters, will be decided by the appropriate regulator (which is either the Central Electricity Regulatory Commission or the State Electricity Regulatory Commission). Any other matter of dispute is to be resolved by arbitration as per the Indian Arbitration and Conciliation Act, 1996.

It is worthwhile to note that most newer forms of PPAs mandate arbitration as the preferred means of dispute resolution. Most jurisdictions prescribe a time frame for completion of the arbitration process. For example, in India (under Section 29A of the Arbitration Act), arbitral tribunals are required to make its award within a period of 1 year, which can be extended by 6 months. However, several other Asian jurisdictions such as the United Arab Emirates and Indonesia prescribe a shorter time period of 6 months.

The arbitral award can be enforced as if it were a court decree and is final and binding on the parties to the arbitration. However, parties are permitted to challenge the award within a prescribed period (which varies from 30 days to 3 months across jurisdictions). The grounds for challenging the award are largely procedural and include the following:

- lack of capacity of the parties to conclude an arbitration agreement;
- lack of a valid arbitration agreement;
- lack of proper notice of appointment of an arbitrator or of the arbitration proceedings, or inability of a party to present its case;
- lack of impartiality or independence of the arbitrator;
- composition of the tribunal or conduct of the proceedings contrary to the effective agreement of the parties;
- non-arbitrability of the subject matter of the dispute; or
- conflict with the public policy of the country

Countries in Central Asia such as Kazakhstan follow a similar format of dispute resolution process where arbitration at the Astana International Financial Centre is prescribed (Nurbekov and Zharasbayev 2019), while jurisdictions in south-east Asia such as Vietnam allow for negotiation of provisions for international arbitration under the aegis of a neutral tribunal such as the Singapore International Arbitration Centre, as agreed to between the parties.

The inclusion of a workable dispute resolution clause is a key element in assessing the bankability of the project. However, it is also important to understand that there may be local limitations on forum selection on the contracting authority.

Source: Author's summary

example, the model concession agreement for construction, maintenance and operation of roadways in India, provides for an extension of the term of operation of the project in case the project does not recoup the invested money (in the form of toll collected from the users of the constructed road) in the anticipated time period. Such flexibilities in the terms of the contract that provide comfort to the project stakeholders are absent in the current structure of the PPA. There is a dire need to examine how the risks and uncertainties in the sector can be better managed by introducing such flexibilities, to avoid delays and an eventual breakdown of contractual relations between the parties to the PPA.

9.4 Identifying Lacunae and Remedies in (and for) Existing and Future PPAs for Renewable Energy in Asia: A Case of India

The renewable energy sector in India has received significant government support in terms of policy pushes such as waiver of inter-state transmission charges, capital subsidies, government guarantees, renewable energy purchase obligations and so on. However, the sector recently suffered from a significant setback when the state government of Andhra Pradesh ordered a review of already executed solar and wind PPAs owing to the high tariffs recorded in these PPAs (Bajaj 2019). Utilisation of the state's power to upset the sanctity of the contract leads to a direct drop of investor confidence. The terms of the PPA must be based on a comprehensive mutual understanding between the parties and should not be used as a dictatorial instrument. Renegotiation of the terms of the PPA should occur only in case of mutual agreement for renegotiation, since revised contractual terms are bound to affect all project stakeholders.

At this stage in the development of the sector, the process for risk allocation needs to be nimble and receptive to the needs of the investors and other parties responsible for the construction, operation and maintenance of renewable energy projects. Rigidity in the contractual risk allocation mechanism provides very limited room for manoeuvring the concerns of the project financiers and the project developer. There are many lessons to be learned from developed markets and other sectors in terms of risk-alleviation provision that could render the PPA more investor-friendly and bankable.

The risks discussed in Sect. 9.3 above stretch across the nearly the entire lifetime of the project and, therefore, identifying explicit remedies for these risks in contractual terms is quite challenging. These are also important factors that affect the bankability of the PPA. The renewable energy sector could benefit significantly from the mechanisms utilised in other long-term infrastructure projects to deal with some of these risks that are common across all infrastructure projects. For example, limiting the extent of some of these risks by introducing thresholds or expanding the scope of some of the existing provisions to provide clarity on how the manifestation of these risks would be dealt with will reduce the extent of risk exposure for project stakeholders to some extent.

This section draws on lessons learnt from other infrastructure sectors and renewable energy sectors in developed markets to identify measures to deal with each of the operational phase risks and general risks effectively.

9.4.1 Setting Thresholds for Anticipated Risks

For certain anticipated risks such as that of change in law, technology enhancement, curtailment, etc., which are likely to arise during the course of project construction and operation (as applicable), the project financiers are better equipped to handle these risks when they occur, if they are able to build in a cost associated with these risks in their business models. One way to enable this is to set thresholds for each of these risks in the PPA.

For instance, the minimum offtake guarantee is one mechanism to build in a threshold for the risk of curtailment where the offtaker is contractually bound to offtake a minimum quantity of power generated by the project. This in turn guarantees a minimum monthly/annual revenue for the project, better equipping the project financiers to deal with losses associated with curtailment of power generated over and above the minimum offtake quantity. This provision cushions the risk of curtailment for the project financiers (Viswamohanan and Aggarwal 2018).

Similarly, prescribing a threshold for costs associated with a change in law or a technology enhancement risk in the PPA that the project developer must bear, provides comfort for both the project developer and the contracting authority. It will also ensure that only substantial change in law claims are raised (Gopal 2019). Certain Indian renewable energy project PPAs, such as those issued by Gujarat Urja Vikas Nigam Limited since 2017, have taken to specifying a threshold linked to a percentage of the project's estimated revenue.

The project developer is assured that costs associated with these risks that are beyond the prescribed threshold will either be passed on to the consumers or be absorbed by the offtaker or the contracting authority. On the other hand, this provision provides the contracting authority with guidance on the extent of these risks that can be borne by the project developer, without disrupting the functioning of the project and the project company (in terms of debt repayment). To ensure that this threshold provision is not misused by either party, the role of an independent consultant is predominant. The independent consultant verifies the reasonableness of the costs incurred in accordance with current market rates and measures.

The setting of these thresholds must be followed by specific provisions on the project developer's recourse in the event that the threshold is exceeded.

9.4.2 Upfront Determination of the Formula for Calculation of Termination Payment Due

Termination under the PPA may occur under the following circumstances:

(i) Due to a material breach by either party;
(ii) Due to the occurrence of an event that renders the performance of the contract impossible;
(iii) Due to the occurrence of an event, the risk of which is borne by either of the parties to the agreement.

Typically, the quantum of the termination amount payable will depend on the cause for termination. For example, if the termination is on account of breach by the project developer, the termination payment should at least amount to outstanding bank debt, with perhaps the return on equity being held back as a penalty for the breach. On the other hand, if the termination is on account of default by the offtaker or the contracting authority, the termination payment should include the agreed rate of return on equity, together with the outstanding bank debt for the project and any other costs associated with the termination process. Clear specification of the applicable termination payment formula for each event that could lead to termination is a key feature of a bankable PPA (IBRD and TWB 2016).

9.4.3 Linking of PPA Tariffs to Foreign Exchange Rates and Inflation

Currency fluctuation is largely an emerging market risk that lies with the project financiers. Most conventional power project PPAs link the PPA tariff to inflation and foreign exchange rates, in accordance with the needs of the investors. These benefits must be afforded to financiers of renewable energy projects as well. This is a necessity to ensure continued foreign investment into the renewable energy sector in Asia, considering the fact that many of the Asian emerging markets do not provide for adequate foreign exchange risk mitigation mechanisms at present.

9.4.4 Change in Scope of the Project Associated with Technology Enhancement

To ensure safety or efficiency in performance of infrastructure projects during the long lifetime of these projects, change in scope of these projects is a foreseeable risk, specifically for emerging technology projects. For instance, thermal power plants are required to comply with the addition of retrofitting control systems to reduce harmful emissions that emanate from these plants. However, this regulation is facing a significant backlash from the developers of these projects owing to the high costs associated with such retrofitting requirement.

Technology-related risk is best dealt with by specialised operators that are equipped to provide suitable low-cost remedies. One way to deal with the enhancement of the scope of the project (beyond a certain threshold) for inclusion of new technology that may improve performance of the project, is through a provision for submission of fresh bids for that specific purpose. In case of a change of scope of an infrastructure project, the contracting authority is typically provided with the right to award the contract for the expanded scope to the bidder that is able to provide the service at the cheapest cost. In these cases, the existing project developer is provided with the right to participate in such a bid. However, if the existing developer is unable to provide the service at the lowest cost available in the market, the contracting authority can award the bid to an alternate bidder. In such cases, the developer must be assured an adequate termination payment, covering the cost of capital of the project. This ensures that the change is scope requirement is carried out in the most cost-efficient manner and also that the existing project developer is not coerced into taking on more risk than he is prepared to.

To provide more stability in the market and to the PPA, some portion of this risk may be retained by the public sector by guaranteeing a subsidy for these changes in scope of the project.

9.4.5 Restructuring the Minimum Offtake Obligation

The purpose of the minimum offtake guarantee provision is to provide the project developer and financiers with an assured revenue stream that commiserates with the required monthly or annual returns, which covers the debt service, operating costs and agreed equity return for the project. This provision states that the offtaker shall be obligated to offtake the agreed quantity of power from the project on a monthly/annual basis.

The quantum of minimum offtake is an important value that is considered by lenders in providing debt facility to the project company. This provision deals with the dual risks of demand and curtailment by forcing the offtaker to be responsible for the payment associated with the minimum offtake obligation, regardless of whether there is adequate market demand for the power generated or if there are grid issues associated with influx of variable renewable power. While the regulation associated with power offtake from renewable sources in India, prescribes that all power generated from these sources must be accepted by the distribution companies that enter into a PPA with the project company (termed as the 'must-run' status), this regulation is subject to an exception that concerns the safety and security of the grid. It is interesting to note that the Madhya Pradesh Commission, did away with the must-run status for renewable power plants and made procurement of power from renewable sources subject to scheduling and merit order dispatch principles. As a consequence, offtakers were legitimately in a position to refuse power under existing PPAs, as the merit order dispatch principles prioritise procurement of power from cheaper sources (ELP 2018).

Increased penetration of RE based sources have increased the balancing requirement for the grid. At present system operators at various level are empowered to finalise schedule and issue real time curtailment and ramp-up instruction to manage the grid. The risk of curtailment has been growing because there is no data or mechanism to determine whether there was an actual threat to the grid safety when the renewable power is being curtailed.

The minimum offtake obligation should be structured to guard against this risk, ensuring that the obligation is over and above any chance of curtailment due to concerns regarding the safety of the grid. Newer PPA structures provide for minimum offtake that is computed on an annual basis to guard against the risk of curtailment, which is often beyond the control of the offtaker. Curtailment is a function of both location and time period, and therefore it may be higher in some months and not others (CEEW 2018). By spreading the offtake obligation over the course of the year, the offtaker is able to balance the curtailment risk better by compensating for low offtake during certain months through higher offtake in other months.

It is also important to ensure that the force majeure provision does not impinge on the minimum offtake obligation to replicate the fault with implementation of the must run status regulation. The force majeure provision's applicability to the offtake obligation should be restricted to instances of complete breakdown of the physical transmission infrastructure due to incidents that are beyond the scope of control of the offtaker, or the grid planners and operators. In case of such events, typically an extension of the term of the PPA is sought.

The risk of curtailment due to grid failure is applicable in most Asian markets currently. The model PPA for wind projects in Vietnam expands the scope of the offtaker's obligations to provide the project developer with prior notice regarding any interruption to the offtake of power from the project. The PPAs also restate the existing legal obligation of the offtaker and the grid manager to ensure that any interruption in the operation of the grid is in conformity with regulations (Baker McKenzie 2019).

9.4.6 Lenders' Substitution

In case of default in debt payment under the project financing documents, the lenders mandate that the control of the project be handed over to them in accordance with the terms of the financing documents. The project developer is required to replicate this provision in the project documents, including the PPA.

The PPA must explicitly recognise that the project developer has availed external financing for the construction, operation and maintenance of the project and must afford the project developer with the right to assign and substitute the rights and benefits of the project to the lenders. The project developer must also be entitled to create security over their rights in the project in favour of the lenders. Most infrastructure project agreements provide for a form of a substitution agreement that is entered into with the offtaker as a guarantee to the lenders regarding their right of substitution. This increases the bankability of the project and should be incorporated into the structure of the project documents.

9.4.7 Change in Law

The project developer is obligated to comply with all applicable laws and regulations in the jurisdiction of the country where the project company has been incorporated and where the project has been constructed. The applicable laws and regulations are bound to change during the term of the PPA (which in most cases is around 25 years). Such changes could be in the form of either addition of new laws and regulations or modification of existing laws and regulations applicable to the project and the project company. Project companies are bound to take into account all costs associated with such compliance in determining the overall project cost. Some level of change in law risk is also anticipated over the course of the project lifetime. However, beyond a certain threshold, the project company may not be financially capable of absorbing the added costs associated with a change in law event. As identified in Sect. 9.4.1 above, setting a threshold for a change in law risk which is deemed to be reasonable by both parties to the PPA, would be beneficial for all project stakeholders.

The Tariff Guidelines as issued under the provisions of Section 63 of the Indian Electricity Act, 2003, clearly recognise that the project companies are required to be placed in the same financial position as it would have been had the Change in Law not occurred, which is essentially the principle of restitution (MoP Solar Power Projects Bidding Guidelines 2017). Accordingly, as long as the event qualifies as a ‘change in law’ under the terms of the PPA, resulting in an increase in the recurring or non-recurring expenditure incurred by the project developer, the project developer is entitled to seek approval for appropriate relief in the form of compensation for the additional expenditure.

However, it is interesting to note that the Central Electricity Regulatory Commission of India, in a recent order (CERC Petition 2018) has decided that if the PPA does not have a provision dealing with restitution, costs associated may not be granted (GMR Warora v. CERC 2017). This brings a new perspective to the drafting of the change in law provision in PPAs to provide this added cushion of the principle of restoration.

In several recent occasions, uncertainty regarding what events would qualify as a 'change in law' under the terms of the PPA has led to significant project delays. In 2018, the Directorate General of Safeguards in India (which has been recently renamed as the Directorate General of Anti-Profiteering), had recommended the imposition of a safeguards duty on the import of solar cells and modules to protect the domestic manufacturing industry, creating uncertainty in the sector with regard to projects that were in the bidding and construction stages. Filing a petition before the Regulatory Commission to ascertain revised tariff (in case of significant change in capital cost of the project due to the imposition of the safeguard duties) is a long-drawn process. Due to this risk, banks were reluctant to fund new projects. It was clarified later that the such safeguard duty imposition would be covered as an event of 'change in law' under the granted compensation (CERC Petition 2018). Clarity regarding coverage of policy changes by the PPA provisions at the time of issuance, would facilitate smoother implementation of the PPA terms. There is also a need to ensure that the definition of what constitutes a change in law is comprehensive and unambiguous to avoid confusion on applicability.

9.4.8 Force Majeure

Force majeure relates to an event that is outside the control of the parties to the PPA, that renders impossible the performance of the parties' obligations under the PPA. The term force majeure would not include any event or circumstances which are within the reasonable control of the parties and would not normally be construed to apply where the contract provides for an alternative mode of performance (Cowell and Wetherill 2019). Abundant case laws on the matter have settled the position that a more onerous method of performance by itself would not amount to a force majeure event (APML v. MERC 2019). For example, parties generally cannot hope to invoke force majeure to escape the burden of a contract that remains physically and legally possible to perform, albeit unprofitable or less profitable.

On invocation of the force majeure clause, the concerned party is required to prove that the relevant circumstances lay outside of their reasonable control and that appropriate steps were taken to mitigate these circumstances to the best possible extent (Cowell and Wetherill 2019). Further, during the affected time, both parties are required to ensure that all efforts were made to keep costs associated with dealing with the event, at a minimum. Occurrence of a force majeure event during the operations stage will affect the project revenue stream. These risks are typically shared between the parties, as per conditions prescribed in the PPA. For example, in the UK Project Finance Initiative guidance (HM Treasury 2007), there is a distinction between Compensation Events (where authority takes responsibility and contractor is compensated), Relief Events (which relieve the contractor from termination for failure to perform but not of the financial effects of delays) and Force Majeure Events (which relieve the affected party from liability for breach and where the parties share the financial effects of delays).

Availing insurance products to protect against the occurrence of force majeure events is in the interest of all project stakeholders. To the extent that the project developer is compensated through insurance, the risk is typically not shared between the parties. For most infrastructure projects, the project companies are required to take out insurance policies to guard against force majeure events that can be insured. In these cases, the costs associated with the occurrence of those events will lie with the project developer. Further, political force majeure events lie within the ambit of the contracting authority and therefore, the contracting authority may agree to bear risks associated with these events. For uninsurable events, costs are typically split evenly between the parties.

Parties are entitled to resort to termination of the agreement only in case of occurrence of a force majeure event for an extended period.

9.5 Conclusion

There are many moving pieces that need to align to ensure the success of a sector. While there has been significant policy push and government support to attract investment into the growing renewable energy sector across the world, the evolution of the structure of the PPA to meet the needs of investors in terms of risk allocation in emerging economies has been lacking. This chapter sets out some of the more established mechanisms that have been utilised in long-term contracts to alleviate investor concerns, in response to some emerging issues in developing country markets. There is also room to experiment with mechanisms that are more attuned to address sector-specific issues.

Several countries in Asia are either considering or have already implemented the transition from feed-in tariff policy to the bidding policy for awarding renewable energy projects. This transition brings the PPA into the limelight owing to the increased autonomy over risks and tariff price under the bidding policy. Further, with several initiatives to strengthen continental co-operation over renewable energy finance, generation, transmission and purchase, Asian countries will benefit from standardised PPA models.

The models of the PPA that have been used in the sector over the past several years in many Asian countries have been largely stagnant, apart from a few exceptions. The balancing of risks in these model PPAs has been stacked against the interests and concerns of investors, on a number of key issues. When there is a clear intent to promote investment into the sector, incorporating simple measures and mechanisms that have been tested though implementation, will make the PPA more bankable. Benefits of bankable projects include facilitation of loans with long loan tenors, high debt-to-equity ratios (ranging between 70% and 86%), and low interest rates. The intended takeaway from this chapter is that the process of arriving at a standardised model for a PPA is an evolving one, taking into account the concerns of all project stakeholders, and this evolution needs to be constant.

It is crucial to have a balanced understanding of the risks in the market, the provisions contained in the PPA to address these risks, and an insight into the practical reality of how these provisions may be interpreted in a court of law. The key to a successful PPA is to adopt a strategy of cooperation and coordination amongst the parties that will be bound by the terms of the PPA. It is only through this balanced approach that the risks can be mitigated and the rewards of a long-term PPA be realised for all parties involved.

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CHAPTER 10

A Tale of Two Cities: Governing Renewable and Low-Carbon Transitions in Tokyo and Nagano, Japan

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10.1 Introduction

Throughout much of the world, cities are playing an expanding role in climate change policy. From land use planning to public transport financing, cities make a wide range of decisions affecting greenhouse gas (GHG) emissions. Increasingly these decisions directly and indirectly influence low-carbon transitions. These decisions and the subsequent transitions do

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not occur in a vacuum, however. Efforts to steer cities down low-carbon paths are made with the broader goal in mind of boosting economic competitiveness, attracting industries, generating jobs and building sustainable communities (Bulkeley and Betsill 2003; Yi 2013; Cheng and Yi 2017). They are also often occurring against the backdrop of a mounting international pressure to respond to a climate crisis. Finally, they are unfolding with a recognition that subnational governments are well-positioned and uniquely qualified to govern transitions that generate and spread low-carbon innovations.

To a significant degree, the above characterization applies to Japanese cities. As the home of the Kyoto Protocol, Japanese cities have been adopting subnational responses to climate change since the 1990s. Following the accident at Tokyo Electric Power Corporation's (TEPCO) Fukushima Daiichi Nuclear Power Plant in Fukushima prefecture in 2011, both the depth and breadth of those responses has increased considerably. The accident exposed vulnerabilities in Japan's then highly centralized energy system. The recognition of these weaknesses resulted in both national and policy reforms that have advanced energy savings and renewable energy policies at the subnational level. Among the highest profile reforms was the post-2012 deregulation of the retail electricity market. For almost a decade, Japanese cities have been encouraged to offer grants to households and small-medium enterprises that lower the costs and facilitate the spread of energy efficient and renewable technologies as part of deregulatory reforms. This particular example is emblematic of a more general shift in urban energy policy in Japan. It is also broadly consistent with literature on multi-level sustainable transitions and multi-level governance. That literature emphasizes responses to climate change often take root locally and can grow from interactions when the interests of a number of stakeholders are aligned at different levels (Corfee-Morlot et al. 2009).

While there is both a growing number of empirical and theoretical reasons to examine how cities in Japan have governed clean energy transitions, there have been few studies to outline the similarities and differences in how cities responded to this challenge. This paper aims to fill this gap in understanding. Its primary purpose is to review some of the key institutional and policy changes that subnational governments have taken to shape their energy futures in Japan. The focus of this review is on the well-known mega-city of Tokyo and mid-sized city of Nagano. These cities are selected not only because they diverge in their approach to energy savings but exhibit parallels despite notably different contexts.

Overall the chapter finds that local governments can indeed be policy innovators for renewable energy. The support for innovation is especially likely if an exogenous shock such as the Fukushima nuclear crisis creates broader changes to the policy environment. However, the willingness to lead and the degree to which innovations grow may be contingent on underlying conditions in the city. Having sufficient capacity within the government and industry appear to be particularly important set of underlying factors. In instances where those capacities are lacking, the amount and type of support from national governments may be increasingly important. Another potentially critical factor is how effectively cities can work with industries to create this virtuous cycle of learning can drive a transition. While much of the analysis focuses on the interactions between national and local policy, developments at the international level (such as reforms that led to the pledge and review of nationally determined contributions (NDCs) appear to be a potentially useful enabler of change.

The remainder of the paper is divided into three sections. The next section reviews literature on sustainable transitions and multilevel governance. Section 10.3 presents the case studies of Tokyo and Nagano. A concluding section provides recommendations on how other large and mid-sized cities could govern similar transitions in and beyond Japan.

10.2 Policy and Institutional Drivers of Renewable and Low-Carbon Transitions

Over the past two decades, cities have played increasingly important roles in formulating and implementing clean energy and low-carbon policies. One of the chief explanations for the rise in locally driven climate actions comes from work on multi-level governance. These studies noted that cities were often moving more quickly than national governments on climate policy. Importantly, these locally driven responses spread when there is effective coordination across government agencies with different portfolios and between lower and higher levels of government (Corfee-Morlot et al. 2009) .

However, large-scale change could also encounter difficulties. One potential obstacle is politically powerful vested interests. Companies that could lose from clean energy reforms could stand in the way of major changes to energy, transport and urban systems at one level and halt reforms at others (Jaglin 2014). Building coalitions around green industrial policies and gradually rewarding industries in those coalitions can help push through barriers (Meckling et al. 2015). Transnational city networks such as ICLEI or C40 can help capitalize on their flexibility to work across and between different levels and bring low-carbon solutions to cities (Bulkeley and Betsill 2003).

A related set of explanations for the emergence and spread of innovative climate responses comes from research on multi-level transitions. These studies emphasize wide-ranging collections of forces (policies, institutions, markets, ideas) that give rise to and spread environmentally sustainable innovations changes at multiple levels.(Smith et al. 2005; Frantzeskaki and Loorbach 2010). Among the different approaches to transition, the one that has arguably generated the greatest interest is the multi-level perspective. The multi-level perspective maintains that a transition involves creating a "niche" or space where innovations emerge (Rotmans et al. 2001; Kemp et al. 1998, 2007; Smith et al. 2005; Loorbach 2007; Frantzeskaki and Loorbach 2010). These innovations achieve changes at greater scales when shifts in regime level institutions and infrastructures as well as breakthroughs in wider landscapes of cultural values and economic markets (Geels and Schot 2007; Lachman 2013).

A similar insight from work on transitions is large changes are not easy. Established interests and outdated sociotechnical systems may lock in resource-intensive patterns and prevent far-reaching changes (Sandén and Azar 2005; Frantzeskaki and Loorbach 2010). Fortunately, these barriers are surmountable. For example, networks that promote "experimentation and pilot projects, the exchange of experiences, [and] training and competence building" can help build partnerships that drive change (Kemp et al. 2007; Nevens et al. 2013). Further "reflexive forms of governance" can help overcome resistance by aligning the shared interests of ecological and social movements, local communities and energy sector workers.

To some extent, the multi-level transitions and multi-level governance work share similar views on the drivers and challenges to innovative clean energy innovations and initiatives. Both suggest that big changes often begin at lower level and gain ground with supportive higher-level changes. They also recognize that existing interests and institutions can block progress but that these can be overcome due to well-designed policies, carefully crafted governance strategies, and coalitions of diverse stakeholders (both within and beyond the city). The two approaches also differ in some respect: most notably, the multi-level governance focuses more concretely on policies and institutions, whereas transitions theories emphasizing a wider range of factors that includes but goes beyond policies and institutions such as shifts in markets or changes to the surrounding ideational environment.

The next section will draw upon the shared insights from these theories to identify some of the key clean energy institutional and policy changes that helped advance clean energy policy in two subnational governments in Japan: Tokyo and Nagano.

10.3 Case Studies

This section offers a comparison between the two cities of Tokyo and Nagano and the striking similarities in the approach taken to develop their unique system for promoting clean energy innovations.

10.3.1 Setting the Context

In 1994, Japan's central governments began officially working on climate change. That year Japan's government adopted a national climate change law; a climate change headquarters as well as renewables law followed three years later. Around the same period, local governments were required to submit climate change action plans, opening opportunities for cities to influence an energy policy that the national government theretofore dominated. To some extent, reforms following the national response to the Kyoto Protocol created space or a niche at the subnational level for clean energy innovations.

That niche would expand considerably in the wake of the 2011 Great East Japan Earthquake. The earthquake and subsequent Fukushima crisis left the country paralyzed by energy shortfalls. The sense of insecurity from these shortfalls provided the impetus for the reorganization of Japan's vertically integrated energy system. Those reforms have moved forward since 2011 with more authority delegated from the central to regional and local governments. Some local governments have since been moving quickly to promote and scale the use of renewables in the region. Table 10.1 provides a summary of some of the key enablers of change in Tokyo and Nagano's policies.

Table 10.1 Key elements of the local enabling environment for innovative reforms

<table>
<tr><th>Tokyo</th><th>Nagano</th></tr>
<tr><td colspan="2">Reporting system</td></tr>
<tr><td colspan="2">Easy to use tools</td></tr>
<tr><td colspan="2">Coalition building</td></tr>
<tr><td colspan="2">Consultation and feedback</td></tr>
<tr><td>Third party verification</td><td>Awards</td></tr>
<tr><td>Peer pressure</td><td>Means for job creation to gather support from local industries</td></tr>
<tr><td>Institutional governance requirement</td><td></td></tr>
</table>

Source: Derived from Tokyo Metropolitan Government and Nagano Prefectural Government websites and compiled by the authors

10.3.2 The Case of Tokyo

This section explores how Tokyo's skilled technocrats were able to bring in other stakeholders to create a collective push that reduced energy consumption in buildings.

10.3.2.1 Background

For much of Japan's modern history, Tokyo has gained the well-deserved reputation for creating growth opportunities through innovation. Its status as an innovation hub continues today; the more than 63,000 offices and factories (or 10 percent of the national total) located in the greater Tokyo region regularly churn out new ideas and products. This concentration of building and people explains why over 70 percent of energy demand originates from buildings. It also accounts for why Tokyo places a premium on saving energy in the building sector. The fact that innovation does not only apply to product development but also policy formulation helps to understand why Tokyo has been at the cutting edge of saving energy from buildings and is increasingly pushing the envelope on renewable energy.

10.3.2.2 Promoting Energy Savings in Buildings

One of the clearest indications of Tokyo's innovative approach to saving energy in buildings is the three programs supporting sustainable building policy (Tokyo Metropolitan Government 2019). The programs are so-named because one regulation apply to new buildings and two apply to existing buildings. The two programs targeting *existing* buildings—and that will be featured here—were the "Carbon Reduction Planning for Energy Efficiency" and the "Cap and Trade Program." Building owners and tenants participated in these programs and reported efforts to cut energy and CO_2 emissions using government provided guidelines on institutional organization; reporting methods results; and technical suggestions per building type. Easy-to-use tools to calculate energy consumption and GHG emissions from electricity, gas and water bills were also available. Tokyo government officials in the Environmental Bureau, Energy and Climate Section were instrumental in making these programs work; they possessed technical skills and data to make recommendations and offer feedback on the energy efficiency efforts to building owners.

Tokyo has not only been able to leverage the expertise of its own staff to drive change. It has also been successful in bringing other stakeholders into the collective push for energy savings. This was evident in a subtle but important shift. In 2002, the Tokyo government asked buildings to voluntarily report on their targets and actions for cutting energy and CO_2. Three years later the Tokyo Metropolitan Government introduced a scheme that harnessed peer pressure by making the results open for evaluation and publicly available. A group of external technocrats were involved in the making of the scheme through the employment of *Coolnet*, Tokyo's external arm for technical outreach to citizens, businesses and other entities.

The "Tokyo Carbon Reduction Reporting Programme" was initially started in 2002 as a learning process for building owners to understand what was in their power in terms of climate change measures, their level of GHG emissions, and to develop the skills to develop targets and plans to achieve those targets. In 2005, the energy efficiency measures that had been conducted voluntarily was officially consolidated into a set menu of 213 measures for which buildings would be evaluated every year. Emissions levels were calculated either from past records of energy consumption, or using emission intensity standards (kg-CO_2/m^2/year) that would differ by building type (e.g. Data centers are allowed larger emission intensity than parking lots).

In 2008, it would then draw upon market forces and a broader collection of stakeholders to build upon past successes by introducing a "Cap and Trade Program" which is now covered by over 1300 selected buildings. Modelled along the lines of California's emissions trading program, Tokyo's "Cap and Trade Program" was gradually developed through two phases (phase 1: 2010–2014, phase 2: 2015–2019) during which the compliance levels for emission reductions were enhanced, allowing for building owners, tenants to get used to the system. To induce building owners and tenants to reduce energy consumption, Tokyo has enacted local laws that have promoted the use of new reporting methods to engage both building owners and tenants in an effort to improve energy efficiency using an energy benchmarking system. Furthermore, as the system was being developed it became clear that the top management's commitment was critical and therefore it now requires the involvement of the chief executive officer, the facility manager, and the equipment manufacturer in the making of the energy reports. The involvement of the equipment manager is hoped to trigger development of new low- or zero-carbon-related business opportunities. A third party verified carbon reductions for each building and registered those reductions in a carbon registry to facilitate trading. It also continued to employ information and public pressure as a tool to drive change. Participating buildings would be ranked on a fifteen-point scale that would show if the buildings are above average or not on energy consumption by showing their compliance levels for the 213 energy efficiency measures. Buildings with high compliance levels were encouraged to apply for either "top level" or "near top level" status by Tokyo to enjoy the privilege of being publicly known for their efforts that would enhance their asset value. Labels with the rank are presented at the building entrance. In violation of their compliance to their designated compliance factors, penalties and monetary fines have also been introduced but have never been administered.

10.3.2.3 Promoting Renewables

In terms of clean energy, many of Tokyo's reforms have moved from the bottom-up to place pressure on the central government to catalyze change. Tokyo depended on Tokyo Electric Power Company (TEPCO) for a significant share of its electricity prior to the 2011 Great Earthquake. In its wake, Tokyo's Governor Inomata submitted a letter to the national government requesting deregulatory reforms to the energy sector. The deregulatory reforms would allow new utilities that relied on renewables into the energy market; and it would enable Tokyo to meet 30 percent of its energy demand with new utilities and outside Tokyo's jurisdiction. In the years that followed, Tokyo continued to submit policy requests to the national government calling for deregulation of the energy market. It has also expressed enthusiasm for a feed-in-tariff (FIT) in the hopes wind power generated in the Hokkaido and Tohoku region could be used in Tokyo. Tokyo aims to turn 30 percent of its energy mix into renewables (Tokyo 2018).

Tokyo has also been active in engaging local businesses and other stakeholders locally to advance its clean energy plans. In this connection, it has concentrated in developing renewables in hospitals; water and wastewater facilities; railroads; evacuation centers. In parallel, Tokyo's public apartments have become a source for decentralized energy. New real estate developments such as those planned for the Tokyo Bay area (2020 Olympic Games) became a location that could develop an energy supply and demand network (electricity and heat) operate independently from the grid during disasters (Funazaki 2012).

In recent years, Tokyo has reached out to an expanding pool of potentially interested parties to spread renewables. It is currently working with *Coolnet* toward these ends; *Coolnet* is an information portal that provides advice on the installation and operation of renewables, and information for return in investments for both businesses and households. It has also combined the support for renewables with other programs. For example, renewables became one of the criteria when Tokyo evaluated buildings under the Cap and Trade Program. Meanwhile, green minded households are able to purchase green energy certificates based on the electricity generated by solar power and heat on Tokyo's facilities that entitled them to cuts in inheritance tax. Tokyo has declared it will realize a Zero Emission Tokyo that will contribute to efforts towards achieving net zero CO_2 emissions by around 2050 (Tokyo Metropolitan Government 2019).

10.3.3 The Case of Nagano

This section introduces Nagano's approach of using peer pressure with the private sector for promoting energy savings in buildings, and villages for renewables.

10.3.3.1 Background

Nagano prefecture adopted its first set of climate change measures in 2001—four years before the national government required local governments to register local climate change action plans. Preceding Tokyo and many other cities, Nagano saw an opportunity to lead on climate change. The chief reason for moving early was nonetheless slightly different than Tokyo; it was mainly to develop low-carbon industries in the face of poor economic prospects. This motivation grew from continued lags in economic development in 2001 ten years after the economic bubble burst in Japan. These problems worsened because much public infrastructure related investment in the rural prefectures fell due to lower national fiscal transfers and local revenue streams. A depressed economy then created the opportunity for a proactive response to climate. That proactive response consists of two policy pillars: climate change and sustainable energy. To work on these two pillars, Nagano has been promoting (1) an energy saving and (2) renewables policy package(UNFCCC 2018).

10.3.3.2 Promoting Energy Savings

For the energy savings package, many of Nagano's targeted reductions took a page from reporting scheme that existed for environmental actions for businesses. The program in question mandated businesses with significant energy demand of over 1500 kl/year or with vehicle ownership of over 200 cars to submit annual reports on their energy use targets and plans for energy efficiency and savings to the prefectural government (i.e. the countermeasure planning for global warming). The prefectural government possessed sufficient capacity and expertise to evaluate, grade, offer technical advice, and award businesses with significant reductions in energy demand for their efforts.

These programs also leveraged information (and implicit peer pressure) to encourage energy savings. The use of simple and universal benchmarks allowed businesses to identify how they measured up relative to other businesses, which led to a healthy competitive environment that would promote and increase the number of reports submitted to the prefectural government. Energy intensity and CO_2 intensity gauged progress because they were easy to calculate and compare. A set of examples on the return of investments for major emission reduction countermeasures allowed new entrants to choose effective and efficient measures and curbed unforeseeable risks.

Spreading the movement: Other programs sought to bring businesses more directly into the energy savings efforts. Toward these ends, Nagano prefecture sought the contribution of large enterprises to serve as role models. Hence, a mechanism was created to enhance information sharing between businesses through seminars and distribution of case studies. Further, what was learnt from the initial phase was transformed into guidelines for small to medium businesses. This strategy proved effective as many small and medium sized offices and factories became enthusiastic to submit the same reports as the large enterprises counterparts while using the same evaluation and award schemes even without legislative mandates to participate. The benefits for such small entities was their exposure to new information on energy efficiency from the prefectural government with the submission of their reports. To sustain the interest among large enterprises to continue exceeding their efforts, Nagano chose to conclude an agreement with innovative companies on advanced targets and plans. The agreement is renewed every three years to keep up the momentum.

The historical background: Nagano's approach to energy savings in building employs similar design features as more general approach to energy savings. A reporting scheme for green buildings requires owners of new constructions of substantial floor size (over 2000 m^2) to report to Nagano prefecture on three areas: (1) the energy efficiency level; (2) installation of renewable technology; and (3) use of excessive heat (i.e. heat pumps, district heating). After building construction is complete, the reports are made publicly available on a voluntary basis. Building owners are also equipped with a set of tools to help them to calculate their energy efficiency levels, several energy efficiency indicators (i.e. Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Energy Pass) were designated for the performance review requiring building designers to acquire skills to use at least one of them. National regulations were employed for setting energy efficiency levels; guidelines were made available for planning installation of energy efficiency equipment, renewables and heat.

There were also institutional changes undertaken to support these and likeminded reforms. A Council to Facilitate Housing Structures in Nagano was created with representatives from Nagano prefecture and major local business associations to provide advice on energy demand reduction using government funded audits. This was further supported by building certification systems that were shared through training sessions with local contractors over several stages. This multistage effort gradually prepared the building industry for stronger regulations in the use of new insulation and energy savings equipment in both new construction and renovations.

Information and implied peer pressure were also used to reinforce the above efforts and even appeal to households to conserve energy. Energy peak shifts were promoted through informational campaigns during the summer and winter seasons when energy demand peaked. The Shinshu energy conservation campaign combined energy saving seminars, a distribution of case studies, and outreach through business council channels during these peak seasons. Industrial energy demand as well as those from the green building reports, and mandatory reports for energy suppliers (utilities and retailers) on their global warming measures and the level of renewables within the energy mix allowed for a systematic way for utilities to collaborate with households and businesses to shift peaks.

10.3.3.3 Promoting Renewable Energy

The Nagano energy strategy was developed with the input from consultations with 35 different groups, town meetings, and public comments. Renewable potential was calculated; targets for energy self-sufficiency rates within the prefecture were developed; job creation, decoupling economic growth from emissions were placed at the center of the strategy (The Asian Cobenefits Partnership 2017).

When the potential for different renewables was surveyed and calculated based on nationally available guidelines, it showed Nagano had abundant renewable resources: solar, biomass and hydro. Due to this diversity, Nagano prefecture asked each district to register and promote one renewable project based on the renewable that was most available; the "One Village One Renewable Project" encouraged the development and expansion of projects unique to that village. Villages with successful case studies were then introduced to the novice "learning" villages, and experts were sent to assess and fill needs. The local government decided to use these models as a basis for streamlining project implementation processes and tailoring them to different renewables. To illustrate, support for local-led social businesses for solar roof installations; incubation of a new business model for the local timber industry to use biomass power generation; support from the river bureau for residential consent on micro and pico-hydroelectric plant development.

Coalitions for renewable energy: Similar to the *Coolnet*, Nagano also created a *Shinshunet* which served as the information platform with working groups for each renewable source. Experts were made readily available. The municipality offered their support in terms of policies using finance and regulations. The use of the national model zones subject for deregulation was also available for incubation of new models. A model for each renewable was also shared with the public.

10.4 Conclusions and Way Forward

Both cases shed revealing light on the application of multi-level governance and transition theories (see Fig. 10.1 for a simplified illustration of some of the drivers of the transition highlighted in the article). They clearly demonstrate that local governments can take the lead on climate change. Arguably more so than central governments, local governments possess the knowledge and flexibility to pursue innovative strategies that open new niche opportunities to save energy or spread clean energy. Further, they can also work across multiple agencies and different actors—particularly business—to inject momentum into these efforts. The more visible reforms described herein were shaped by the collective inputs of multiple agencies and actors. They also show evidence of working not only horizontally across but vertically with national governments—albeit on a more limited basis than suggested in the multi-level governance theories. Finally, they also underline that broader changes to national markets and norms in the landscape levels that were evident in the aftermath of Fukushima as well as the post-bubble economy open opportunities for niche innovations to spread and place pressure for changes in existing policies and programs in the regime levels. Finally, frontrunner cities such as the ones featured in this chapter are often held up as trendsetters by the national government; in some cases, local experiences are incorporated

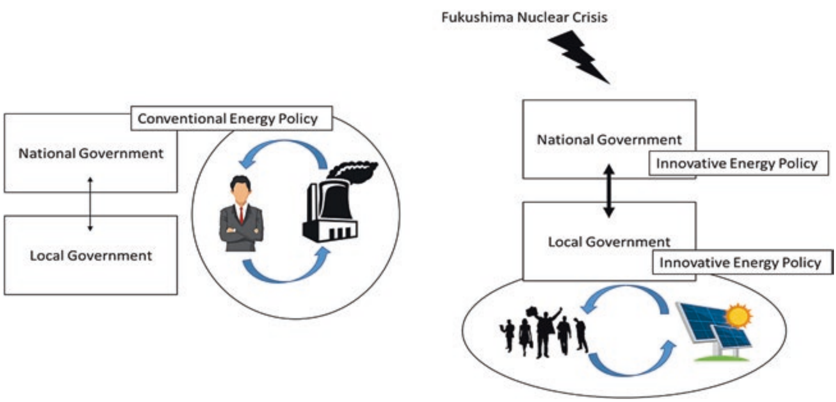

Fig. 10.1 The factors contributing to a transition in Japan. (Source: Created by the authors)

into national policies, action plans and programs that can be disseminated from the national level.

The cases of Tokyo and Nagano also suggest some differences with the theoretical expectations. One of the main differences is an approach that draws upon a combination of peer pressure and information dissemination to drive change. In both Tokyo and Nagano, well-staffed and technically skilled agencies began the reform efforts but made deliberate attempts to encourage broader changes by learning and sharing information from and with businesses. As noted above, the central government helped guide this process—for instance, through setting energy efficiency standards—but much of the dynamism pushing these reforms forward came from within: the local government working with leading local businesses and residents helped generate healthy completion that took on a life of its own. To some extent, this pattern matches a strand of transitions literature that highlights the potential for combining and packaging different policy instruments to build support for more transformative changes.

The cases of Tokyo and Nagano also differ with regard to each other. Arguably due to the differences in their energy structure and resource endowments, Tokyo decided to set up a "Cap and Trade Program" focusing on buildings, whereas Nagano opted to harness large concentrations of renewables with "One Village One Renewable Project." Further, perhaps reflecting its status as a national capital and strong sentiments of post-Fukushima energy insecurity, Tokyo pushed from the bottom-up on the national government to change the entire countries energy policy. Nagano engagement with the national government was a more limited use of guidance from the top-down. Perhaps most strikingly is that these two very different localities employed a similar approach to climate and energy policy that involved the skilled use of government resources, private sector knowledge, and peer pressure to animate reform efforts. Despite large differences in contexts, the approaches were very similar. These approaches alone might have worked in Japan, but financial incentives in the form of installation grants and/or penalties for non-compliance might also serve as a trigger to cities in other cultures and social norms.

From this review, a few conclusions can be distilled and questions asked about the drivers and enablers of low-carbon transitions. First, local governments are indeed well-positioned to initiate these reforms. In locations where there are already sufficient staffing and resources local governments can spearhead reforms. However, not all governments may possess the initial capacities to take the lead. In these cases, additional support from national governments may be needed. More research is hence needed on a broader collection of locales in and beyond Japan. Second, the combination of working with, learning from, and then sharing business experience has considerable potential in many contexts. From a theoretical perspective, there is a greater need for how this virtuous cycle of learning can drive a transition. From a policy perspective, there is a greater need to recognize how this combination of policies, platforms, and learning can be embedded in low-carbon policies and plans. This includes the Nationally Determined Contributions that countries have pledged to the United Nations Framework Convention on Climate Change. In many ways, the NDCs were supposed to create this learning dynamic at the national and international levels; integrating it into the NDCs would hence be in line with the spirit of the pledge and review architecture that is part of the climate regime.

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PART V

Energy Access

CHAPTER 11

Achieving "Energy for All": Solar Mini-Grids for Rural Electrification in Asia

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11.1 Introduction

Electricity plays a vital role in socio-economic development (Pereira et al. 2011). Sustainable, affordable, and reliable electricity is a major driving force for the economic as well as for human development of a nation (Davidson and Johansson 2005; IEA 2018; Kaundinya et al. 2009). Countries with the highest levels of poverty tend to have lower access to modern energy access (World Bank 2017). Countries with a higher Human Development Index (HDI) have better energy access and higher per capita income as compared to low HDI countries (Bhattacharyya 2012). Energy access means physically accessible and available modern energy services. Energy should be of acceptable quality, reliable, adequate

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and affordable in terms of low capital and operating cost (Balachandra 2011). The stable, efficient, affordable and safe energy access will have a positive impact on income and health. Access to energy can reduce poverty, support education, increase access to other services and improves the overall quality of life (Pachauri et al. 2012). In September 2015, member states of the United Nations had agreed to implement 17 Sustainable Development Goals (SDGs) to end poverty and secure peace and prosperity by the year 2030. The UN has included sustainable energy as the seventh goal of the 17 SDGs, to "ensure universal energy access to affordable, reliable, sustainable and modern energy for all" (UN ESCAP 2019a).

The SDG-7 has set five targets to be achieved by 2030: (i) ensure universal access to affordable, reliable and modern energy services; (ii) increase the share of renewable energy in the global energy mix; (iii) double the global rate of improvement in energy efficiency; (iv) enhance international cooperation to facilitate access to clean energy research and technology; and (v) expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in the developing countries. It also supports programs including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promotes investment in energy infrastructure and clean energy technology. United Nation – Economic and Social Commission for Asia and the Pacific (UN ESCAP) monitors the progress of SDG-7 targets and publishes periodical reports. As per the progress report of 2019, the Global electrification rate had risen from 83 per cent in 2010 to 89 per cent in 2017. Since the initiative of SDG 7, every year 153 million or more people have accessed electricity. During this period, electricity deployment has seen tremendous growth; the Global population without electricity access has dropped from 1.2 billion in the year 2010 to 840 million in the year 2017 (UN ESCAP 2019a). The report further mentioned that the average annual gain in the electrification rate for the period 2010–17 was 0.8 percentage points per year, and with this growth rate it would be difficult to reach the said goal of universal access to electricity by 2030. At this rate, only 92% of the global population will have access to electricity, and approximately 650 million people will be left without access to electricity. To achieve universal electricity access goal, the rate of electrification growth should be 0.86 percentage points annually between 2018 and 2030 (UN ESCAP 2019a).

As per UN ESCAP (2019b), approximately 325 million people (7% of the total population) in Asia-Pacific region lack basic electricity. Basic electricity means "having initial access to sufficient electricity to power a basic bundle of energy services – at a minimum, several lightbulbs, task lighting (such as a flashlight), phone charging and a radio – with the level of service capable of growing over time”(IEA 2018). Within Asian region, about 255 million people in South, South-West Asia and 48 million people in South-East Asia lack access to basic electricity. The other regions of Asia have achieved universal electricity access. Although, Asian region is progressing in providing access to electricity, with the current policies, this region can attain 98.4 percent electricity access by 2030 (UN ESCAP 2019b). Even after achieving this gigantic target, approximately 66 million people will be left without electricity (ibid.). Access to electricity has a positive impact on the socio-economic condition of the people. A study by Jiménez (2017) examined 50 impact evaluation studies, focused on the impact of electrification on education, labour, income and other social indicators. The study observed an increase of 7% in school enrolment, 25% in employment, and 30% in incomes with electrification. UN-ESCAP examined electrification programs in the Asian countries Bangladesh, Cambodia, India and Vietnam and observed increased income, improved primary and secondary education and reduced poverty (UN ESCAP 2019b; Table 11.1).

Electricity in most of the Asian countries is primarily provided through central grids (Bernard et al. 2018). However, there is a wide disparity in access to electricity in rural and urban areas. Electrification rate is lower in remotely located regions, and often grid connectivity is not available due to geographical and economic constraints (UN ESCAP 2019b). In the last two decades, cost of renewable energy technologies has declined and service quality improved. In addition, international climate change negotiations have pushed for wider adoption of renewable energy technologies. Due to these factors, several policy actors have promoted the use of solar mini-grids in Asia (Knuckles 2019, UN). According to World Bank, out of 26,000 mini-grids in 134 countries, around 9300 are located primarily in South Asia and several thousand other mini-grids are located in East and Central Asia (ESMAP 2019). The current electricity scenario in Asia will not be complete without analysing the role of mini-grids in the emerging electricity mix.

In this background, we argue that mini-grids could become an important element in the electricity policy of Asian countries. We first discuss the state of rural electrification in Asian countries. We then take a deep dive in the case study of two villages in the state of Bihar in India where solar mini-grids were established to connect un-electrified villages in remote areas of South Bihar. We conducted socio-economic survey in these villages, and examine the impact of electrification on the socio-economic

Table 11.1 Electricity Access Impact Evaluations in Selected Countries

Country	*Impacts*			
	Income	*Education*	*Inequality*	*Poverty*
Bangladesh	21 per cent increase in household income	Girls: Extra 12 minutes study per day and 2 extra months of schooling Boys: Extra 22 minutes study per day and 3 extra months of schooling	Richer households benefit more from electrification than poorer households	Poverty decreased by 1.5 percentage points per year
Cambodia	16.6 per cent increase in daily per capita consumption	8.5 month increase in total schooling and 7 per cent increase in ever having been enrolled	Richer households benefit more from electrification than poorer households	–
India	38.6 per cent increase in household income	Girls: 7.4 per cent more likely to have enrolled and 6 extra months of schooling. Boys: 6 per cent more likely to have enrolled and 3.6 extra months of schooling	Richer households benefit more from electrification than poorer households	Poverty decreased by 13 percentage points in total
Vietnam	28 per cent increase in household income	Girls: 9 per centage points more likely to have enrolled and no change in total schooling Boys: 6.3 per centage points more likely to have enrolled and 1.4 extra months of schooling	Richer households benefit more from electrification than poorer households	–

Source: UN ESCAP. (2019b). Universal access to energy in Asia and the Pacific: Evidence-based strategies to achieve empowerment, inclusiveness and equality through Sustainable Development Goal 7 (Note by the Secretariat ESCAP/75/13; Review of the Implementation of the 2030 Agenda for Sustainable Development in Asia and the Pacific: Energy) development of the households in two stages. Phase-I (pre-grid connectivity): moving from no-electricity to mini-grid and Phase-II (post grid connectivity) shifting from mini-grid to grid power. In addition, the chapter also explores the following questions: a) What happens to mini-grid when a village gets connected with the main grid?, b) Does a mini-grid act as a substitute for the main grid or complement it or goes in oblivion?, and c) What lessons can be drawn to provide affordable, reliable and sustainable “energy for all”? Finally, we conclude with some generic lessons related to mini-grids that can be derived for countries in Asia, based on our in-depth case study of the two Indian villages.

11.2 Rural Electrification in Asian Countries

Asian countries have shown significant progress in deployment of the electricity, 91% of this region is having access to electricity, China, Brunei, Malaysia, Maldives, Thailand Singapore and Vietnam have achieved 100% electrification, whereas Afghanistan, Bhutan, Indonesia, Nepal, and Sri Lanka have more than 95% electrification rate (Table 11.2). Other developing Asian countries such as Bangladesh, Pakistan and India also have shown significant progress in the last decade (IEA 2018; World Bank 2020). Yet, approximately 500 million population in Sub-Sharan Countries (33% of electrification rate), and 340 million population in Developing Asia remain without electricity (UN ESCAP 2019a).

There is a lot of disparity in urban and rural electrification rate, in 2017 global rural access rate was 79% (an access deficit of 728 million population), which is much lower as compared to the urban access rate of 97%. The disparity in Sub Saharan Africa is wider compared to that of Asian countries (as indicted in Table 11.2). During the same time, almost all Asian countries have achieved 90 per cent or more access in urban areas, and 80 per cent or more rural access rate (except in Mongolia, Myanmar and Pakistan) (UN ESCAP 2019a; World Bank 2020). The literature on rural electrification indicates that polices of Asian countries often supports connection with the central grid as a major mode for expansion of electricity services, which is cited as a significant reason for low rural electrification rate in these countries (Heynen et al. 2019; Palit and Bandyopadhyay 2016; Rahman and Ahmad 2013). As an alternative, several governments have promoted off-grid connection in remote rural areas. As per IRENA (2018), the number of mini-grid projects and solar home systems (SHS) has increased worldwide, as of 2016, the estimated off-grid renewable

Table 11.2 Electricity access in Sub Saharan African and Asia

Region/ Country	*Population without electricity as of 2017 (000 s)*	*Electrification rate (%)*					
		2017			*2010*		
		Rural	*Urban*	*Total*	*Rural*	*Urban*	*Total*
Sub Saharan Africa	572,637	22	79	44	14	69	33
China	0	100	100	100	99	100	100
Mongolia	435	56	100	86	42	96	79
Afghanistan	817	97	100	98	30	83	43
Bangladesh	19,760	81	100	88	40	90	55
Bhutan	19	97	99	98	59	99	73
India	98,849	89	99	93	68	94	76
Maldives	0	100	100	100	99	100	99
Nepal	1317	95	99	96	59	94	65
Pakistan	57,548	54	100	71	56	97	70
Sri Lanka	526	97	100	98	83	96	85
Brunei D.	0	100	100	100	100	100	100
Cambodia	1749	86	99	89	16	91	31
Indonesia	4910	96	100	98	90	99	94
Lao PDR	439	91	100	94	59	97	71
Malaysia	0	100	100	100	98	100	99
Myanmar	16,110	60	93	70	32	89	49
Philippines	7344	90	96	93	78	94	85
Singapore	0	100	100	100	100	100	100
Thailand	0	100	100	100	99	100	100
Vietnam	0	100	100	100	98	100	98

Source: (World Bank 2020)

capacity was about 6.5 GW, out of which Solar PV accounts for 2.2 GW. According to ESMAP research and analysis, approximately 47 million people in 134 countries and territories currently have access to electricity through 19,000 mini-grids. Asian countries account for 85% of the total installed mini-grids (approx. 16,000), Afghanistan has most of the mini-grids (5000) followed by Myanmar (4000), India (3000), and Nepal (1500) (Knuckles 2019).

According to IRENA (2018), nearly 133 million people are connected to off-grid, and capacity had increased from 2 GW in 2008 to 6.5 GW in 2017. The growing demand for off-grid technologies is due to a decline in the cost of the technology; advancement in the technological and financial innovation; and supportive public policies and measures. The Global average levelised cost of electricity (LCOE) for solar PV was USD 0.085/kWh in 2018, and it has become competitive compared to fossil fuels, the LCOE is expected to fall between USD 0.02 to 0.08/kWh by 2030 and USD 0.014 to 0.05/kWh by 2050 (IRENA 2019). As per ESMAP database, 210,000 mini-grids will provide electricity to more than 500 million people by 2030 (Knuckles 2019). Figure 11.1 provides an off-grid installation capacity since 2007. During the period 2011–2016, there is a steady growth in the production of hydropower, and also, solar-related renewable energy power has shown remarkable growth. Asian countries have the highest share of Hydro, Solar lights solar home systems (SHS) and other off-grid Solar PV technologies, whereas African countries have the highest share in the deployment of solar mini-grids.

Although access to electricity through mini-grids are increasing worldwide, the functioning of existing installed mini-grids itself faces several challenges (Raman et al. 2012; Sharma 2020). Most of the existing mini-grids provide electricity only for 4–6 hours/day and supports low power consuming devices such as small lighting units, mobile phones, fans, radios etc. Further, the demand for grid connectivity increases in villages installed with mini-grid whenever the neighbouring village gets electrified through grid expansion (Sharma 2020). In India, the rural electrification scheme "Saubhagya" of Government of India, reports that around 820 villages (out of 3059 off-grid villages) were got re-connected to the main grids. In

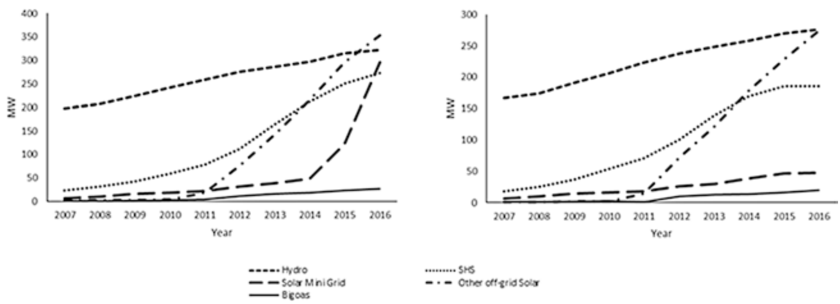

Fig. 11.1 Off-grid installation: Global total (panel a) and Asian Countries (panel b). (Source: IRENA 2018)

the next section, we provide an account of electrification through off-grids in selected countries of Asia, with a focus on solar mini-grids.

11.2.1 The Emerging Alternatives: Off-Grid Electrification and Solar Mini-Grids

Between 2010 and 2019, Asian countries have implemented several rural electrification programs and achieved incredible growth. Except for Pakistan, Mongolia and Myanmar, all other countries have provided electricity to more than 80% of the rural population. In these countries, wherever the main grid was not available, electricity was supplied through off-grid such as solar mini-grid, solar lighting and solar home systems (SHS), hydropower and biogas. SHS had played a significant role in providing access to electricity in Afghanistan (700 thousand people), Bangladesh (14 million), India (49 million) and Nepal (1 million). Solar mini grid (SMG) is more prevalent in Indonesia, followed by India, as of 2016, approximately 540 thousand people in Indonesia and 260 million people in India have access to electricity through SMG (Table 11.3).

The scenarios of the mini-grid connections and their importance in rural electrification in the selected Asian countries are presented below:

11.2.1.1 Lao PDR

Lao PDR's rural electrification rate has seen incredible growth from 59 per cent in 2010 to 91 per cent in 2017 (Table 11.2). Lao PDR contains one-third of the Mekong river basin and receives relatively high rainfall, because of these advantages, the country's energy need is primarily supported by the hydropower. The annual production of the power from hydropower in 2015 is estimated as 14,335 GWh (86% of total power generation), coal-fired power plants contributed another 2225 GWh (14% of total electricity generation), and solar power accounted for a small share with the production of 0.001 GWh (OECD 2019). The country exports hydropower to Thailand and Vietnam. Due to economic growth in recent years, domestic demand for electricity has been growing rapidly; between 2010–18, the annual electricity consumption increased at an average rate of 14.5% per annum (World Bank 2019). At the same time, the generation capacity from hydro reduces during the summer/dry season in summer due to low water inflows. Considering these facts, the country is now focusing more on off-grid electrification. The Government of Lao PDR has aimed to increase the share of non-hydropower to 30% of total consumption by

Table 11.3 Off-grid electricity access in selected Asian Countries

Country	*Rural electrification rate*		*Off-grid energy access in 2016 (thousand people)*						*Funding agency*
	2010	*2017*	*SMG Tier1*	*SMG Tier 2*	*SHS >50 W*	*SHS 11-50 W*	*SHS <11 W*	*Total*	
Afghanistan	30	97		20	15	27	664	726	ADB, USAID, IFC etc.
Bangladesh	40	81		39		13,929	358	14,326	IDCOL, World Bank
Cambodia	16	86				172	148	320	GoC, Private Owners
India	68	88	25	241		2882	46,973	50,121	GoI, NGOs
Indonesia	90	96	85	463	13		414	975	GoIndonesia, UNDP, Private Owners
Myanmar	32	60	10	2			207	219	Myanmar Govt.
Mongolia	42	56			249			249	Global Env. Facility Trust Fund, Govt. of Netherlands
Nepal	59	95				1660	207	1867	World Bank and NGOs
Pakistan	56	54					434	434	Pakistan Govt.
Sri Lanka	83	97			134		154	288	GoS and World Bank

Source: (IRENA 2018)

Note: Solar Mini Grid (SMG) – Tier 1: Basic lighting (>50 W), Tier 2: lighting and other electric appliances (TV, Fridge, Computer etc. 50 W–500 W)

2025 (OECD 2019). The government has identified solar power as an alternative source, as the country receives good sunlight during the dry seasons. With the help of international organisations, foreign aid, and private companies, about 18,657 households across 430 villages (equivalent to 1.64% of total households nationwide) are connected through solar power systems, the number of households connected to solar off-grid is expected to increase in the coming years (OECD 2019).

11.2.1.2 Myanmar

With only 60% of rural electrification, Myanmar is one of the least electrified countries in Asia. As per Pascale et al. (2016) study, only 9.5% of the total villages in Myanmar are covered with grid electrification. Around 70% of the rural households depend on kerosene lamps, diesel generation units, batteries or candles for meeting their lighting requirement. About 1200 hilly communities in Myanmar are electrified through hydropower mini-grids called “waterwheels” (Tharakan and Acharya 2014). In the delta region of the country, biomass gasification mini-grids are common; with the growing demand for the electricity, along with hydropower, the government is promoting SHS in the rural parts of the country. As of 2016, about 200 thousand people have gained access through SHS. But compared to the demand, deployment rate of SMG and SHS are low; this is due to lack of regulatory framework, small budgets and lack of attractive financing (Pode et al. 2016).

11.2.1.3 Cambodia

Cambodia has seen a remarkable rural electrification growth in the last ten years. Access to electricity in rural areas has jumped from 16% in 2010 to 86% in 2017 (see Table 11.1). In the 90s, to promote electricity supply, Cambodia has given license to private owners/village entrepreneurs, because of this initiative, many of the isolated diesel-based mini-grids were started. In 2001, the Electricity Authority of Cambodia was established and allowed the isolated mini-grids to connect to small power distributors which later got connected to the main grid. As of now, more than 250 isolated private mini-grids have been connected to the national grid and is providing electricity to more than one million people. No country in the world has ever connected so many mini-grids to the national grid (Bernard et al. 2018). Cambodia has achieved this success by implementing the following policies: (a) it has issued the licenses to the private mini-grid operators and allowed them to connect to the national grid (b) it allowed the higher tariff and zero loans to the private parties/entrepreneurs (c) it allowed the private owners to operate efficiently and expand to other neighbouring villages. In addition, currently, SHSs are serving more than 300 thousand people in the country.

11.2.1.4 Indonesia

Indonesia has one of the highest rural electrification rates in Asia. Government supportive policies helped the construction of micro and mini-grid projects in the mountainous, remote and island terrain of the country. As per the Bernard et al. (2018) report, around 1300 mini-hydro and mini-grid solar projects were constructed since 1990 and providing electricity to 10,300 villages. These projects vary from 5 kW to 500 kW, most of the projects were in the range of 5–40 kW (Suryani 2013). After villages were connected to the main grid, due to Indonesian law and operational issues, a large number of villages abandoned the mini-grid projects, only 6 per cent of the mini-grid projects were connected to the main grid and exported the electricity to the national grid.

11.3 Solar Mini-Grids for Rural Electrification in Asia: A Case of Two Villages in India

In recent years, India has enacted several policies to ensure universal access to electricity (Bhattacharyya 2006; Narayan et al. 2020). Yet, in the rural areas of the country, a large number of people are still living without electricity (Comello et al. 2017; Hartvigsson et al. 2015). In India, grid extension remained one of the prominent ways of rural electrification (Robert and Gopalan 2018). However, over the last decade, solar mini-grid technology and solar home systems (SHS) have been promoted as an alternative mode of rural electrification (Kar et al. 2016). The government has pushed solar mini-grids to connect people who live in remote areas where electrification through the grid is beyond the reach.

In line with UN SDG, especially to achieve universal electrification for both rural and urban households by December 2018 (12 years ahead of SDG-7 target by 2030), in 2017, Government of India launched a program Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya). The program's objective was to electrify about 25 million households who were not covered under another broader rural electrification program started in 2005, Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) or Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY). Under Saubhagya program, Government of India identified the beneficiaries (Below Poverty Line households) using the 2011 socio-economic and caste census (SECC) data and offered free connections to un-electrified deprived families. Other non-eligible households of SECC were provided electric connection after payment of INR 500; the initial amount can be recovered in instalments from the beneficiaries. With DDUGJY and Saubhagya programs/schemes, approximately 99% of people gained access to electricity through grid extension and decentralised distributed generation such as solar mini-grid and stand-alone solar home systems (places that cannot be reached via grid expansion) (Palit 2018).

On 28th April 2018, Prime Minister of India had announced that every single village of India is electrified. But as per NITI Aayog report on National Energy Policy, about 304 million people are still without access to electricity, and a large chunk does not have access to reliable supply (Aayog NITI 2017; Heynen et al. 2019). This discrepancy is due to the definitions of "village" and "electrification" in the government records. As per the Government of India, a village can be categorised as "electrified" if it has a population of 100 or more households and at least 10% of the households have access to electricity. In other words, if a village has 100 homes, and if ten among them are electrified then it can be considered as an electrified village (Malakar 2018). The official web-portal of the Saubhagya scheme reports that 93 per cent of the un-electrified villages are electrified, remaining 7 per cent of villages (1270 villages) are reported as uninhabited. Even if all the villages are electrified, hamlets which have population less than 100 households, and localities at sub-village levels may not be connected to the grid and will remain without power, and based on estimates the number of people without access to electricity would be around 200–300 million (Singh 2016). Although GoI is aiming to achieve 24X7 access to electricity for all by 31st March 2019 (PIB – GOI 2018), due to inadequate services of the grid connection, high transmission and distribution losses (approx. 23% of electricity), grid-connected households may not get adequate electricity (Heynen et al. 2019). Within India, there are wide differences among different states/region in terms of access to electricity in rural areas. Bihar is one of the laggards. The following subsection will provide the scenarios of recent developments in rural electrification in Bihar.

11.3.1 Rural Electrification in Bihar

The state of Bihar is located in the eastern part of India and area-wise it is the 13th largest state. It is the 3rd populous and 6th densely populated state with a population density of 1106 people per sq. km (Census 2011[1]). Bihar's per capita income is estimated as USD 630 which is lowest among all the Indian states (MoSPI 2019) and per capita consumption of electricity is 280 kWh which is also the lowest among all the Indian states and way below the national average, 1122 kWh/person (Ministry of Power 2018). Low per capita power consumption indicates that a large portion of the population does not have access to modern, stable and clean energy. More than 85% of the population lives in rural areas and mostly rely on conventional sources of energy for meeting their daily energy requirements. In 2016, to achieve universal household electrification in Bihar, the Government of Bihar has started a program Har Ghar Bijli (supply of power to all households). On 31 October 2018, the State has announced that electricity connections to all the households who were willing to get connections were provided (Government of Bihar 2019).

Further, the State has claimed that the availability of power in rural areas has increased from 6–8 hrs to 18–20 hrs. Even if rural areas get 18 hrs power supply, a large section of the rural population still remains dependent on kerosene as an alternative source of lighting (Jain et al. 2018). Bihar has a peak demand of 5139 MW whereas the availability is only 4535 MW (Government of Bihar 2019), due to this gap, often villages face load shedding. A study by CEEW reviewed power situation in nine districts of Bihar and revealed that 93% of the respondents are dissatisfied with grid connection because of the unreliable power supply, voltage fluctuations and inadequate supply. The study also observed that grid-connected villages receive less than eight hours of electricity supply in a day (Jain et al. 2018). A study led by Rockefeller Foundation (2019) observed that one in every two grid-connected households faces power cuts of at least 8 hours daily in the states of Bihar, Uttar Pradesh, Odisha and Rajasthan. It is interesting to explore how the recent rural electrification drive is faring in Bihar. In the next section, we describe the impact of electrification on socio-economic indicators in our study area and along

[1] http://censusindia.gov.in/2011-prov-results/data_files/bihar/Provisional%20Population%20Totals%202011-Bihar.pdf and https://www.census2011.co.in/census/state/bihar.html

with that we explore the challenges and limitations of providing "energy to all" in remote villages of one of the least developed states of India.

11.3.2 Impact of Solar Mini-Grids on Socio-Economic Conditions

In literature, several studies have examined the impact of rural electrification on socio-economic development, income, education, health, and environmental issues (Barman et al. 2017; Chakrabarti and Chakrabarti 2002; Imai and Palit 2013; Kanase-Patil et al. 2010; Mondal and Klein 2011; Palit and Chaurey 2011; Thomas and Urpelainen 2018; Urpelainen 2014). Imai and Palit (2013) study have observed a significant increase in farmers' income with Solar-mini-grid installation in the region of Sundarbans, State of West Bengal, India. The study also observed that Solar-mini-grid installation has a positive impact on reading hours for children and business hours for women. Barman et al. (2017) study has examined the implementation of Solar Home Lighting System (SHLS) in four districts of Assam. The study has observed a significant reduction of kerosene consumption and improvement of lighting, mobile recharging and income generation through small business during evening hours. Due to the extended working hours, women in those regions, have engaged in homemade food businesses like pickle making, weaving etc., which helped them to earn an extra income. The study also identified an increase in the children's evening study hours. The Solar Home Lighting System (SHLS) has improved the daily needs of the household like mobile charging for which they had to travel far distances and pay an amount of INR 10 for one-time charging. These solar systems have also contributed to connecting the households' latest information through television and radio.

Urpelainen (2014) study has examined the implementation of off-grid electrification projects in the villages of three states of India, West Bengal, Rajasthan and Uttar Pradesh. The study observed a substantial improvement in children's education, income generation activities through small businesses and public health with the off-grid electrification. Due to the regional scarcity of kerosene and diesel, solar power has become the most affordable option for the villagers. With a decrease in kerosene consumption for lighting, indoor air pollution has reduced. Aklin et al. (2017) study did not find any consistent effect on savings, household expenditure or in the generation of new business as solar microgrid provides only basic lighting, mobile charging, etc. Earlier studies mostly discussed the success or failure of the mini-grid project and its impact on socio-economic development. In this chapter, we examine electricity access in selected villages in more comprehensive terms. We analysed the electricity access in two phases. Phase-I – pre-grid connectivity: moving from no-electricity to mini-grid and Phase-II – post grid connectivity: shifting from mini-grid to grid power.

11.3.2.1 A Background of Study Villages

Four villages were considered in this study to assess the potential impact of two types of rural electrification systems (Table 11.4). Two villages (Bahsa Pipra and Badil Bigha of Tankuppa block of Gaya district in Bihar) were connected with solar mini-grid and other two villages (Mahadevpur and Pilkhi of Rajgir block of Nalanda district in Bihar) were connected with the central grid. Bahsa Pipra village is situated about 8 kms from the block headquarter Tankuppa and around 20 kms away from the district headquarter Gaya. The geographical area of the village is 288 ha with a total population of 2501 people and about 401 households. Whereas, the other village Badil Bigha has a population of 597 with total no. of 106 households. The Badil Bigha village is about 5 kms from the block headquarter Tankuppa and around 17 kms away from the district headquarters Gaya. Both these villages are predominantly inhabited by marginalised communities. The villages are located in a region, which was affected by left-wing extremism. Most of the working population was either involved in farming or wage labour. Till today, these two villages do not have proper

Table 11.4 Villages considered for the Study

Village	*Number of households*	*Grid connection*	*Mini-grid*		*Dist. from nearest town*
		Year	*Year*	*Capacity*	
Badil Bigha (Dist. Gaya)	106	2018	2016	12 KW	17 km
Basha Pipra (Dist. Gaya)	401	2018	2016	30 KW	20 km
Mahadevpur (Dist. Nalanda)	165	1972	–	–	1 km
Pilkhi (Dist. Nalanda)	710	1972	–	–	2 km

Source: Author's assessment based on various sources road connectivity. They got connected with the central grid just a few years back. To provide a comparison, two other grid electrified villages of Nalanda district were selected, both Mahadevpur and Pilkhi villages are situated near Rajgir block of Nalanda district. According to 2011 census data, Mahadevpur has a total of 165 households and a population of 1065 people with about 564 males and 501 females. Whereas, Pilkhi has about 710 households and a population of 4770 with 2494 males and 2276 females.

With the help of Corporate Social Responsibility (CSR) project, Container Corporation ltd. (CONCOR) has initiated the solar mini-grid pilot project in 2015 with the budget of INR 10 lakh in Badil Bigha and Bahsa Pipra villages. The Central Electronics Ltd. (CEL) has provided technical assistance to install 12 KW in Badil Bigha (106 households) and a 30 KW installed capacity of solar mini-grid in Bahsa Pipra (401 households). For an efficient and easy power distribution to all the beneficiaries, centralised power stations, battery backups and individual meters were installed at each village. Along with solar mini-grid, Badil Bigha village has received a 3KW DC pump to facilitate drip irrigation to the farmers. The beneficiaries of the solar mini-grid project are charged an initial amount of INR 500 and provided with two 5 W LED bulbs, one 20 W DC fan, and one 5 W Solar lantern along with a mobile charging point and individual pre-paid meter system. For smooth operation and maintenance, the pilot project was handed over in May 2016 to the Bihar Rural Livelihoods Promotion Society's JEEVIKA, run by the village women community.

To assess the potential impacts of solar mini-grid in rural electrification and to understand the energy access both through the grid and solar mini-grid electrification system, the study was undertaken in two phases at the two selected villages of Gaya district. In phase – I (24th Dec 2017 to 26th March 2018), field visits were conducted in all four villages and we gathered information related to socio-economic development which accompanied with solar mini-grid installation and grid connection. In phase – II we re-visited the mini-grid connected villages after they were connected through the grid and examined costs and benefits of the grid connection (Badil Bigha on 14th November 2018 and Basha Pipra on 14th April 2019). During the phase –I, a questionnaire-based survey was carried among the beneficiary households. Besides, we have done two Focus Group Discussions (FDG) with the members and officials of JEEVIKA. We also interviewed the technicians and program coordinator of the mini-grid system. A semi-structured questionnaire-based survey was done in all the four villages. We interviewed a total of 165 households, 50 from each of the two mini-grid villages and 65 households from two grid-connected villages. During the survey, we have enquired about the reliability, quality, and affordability of the electricity through solar mini-grid and grid. Both male and female respondents were selected; we employed a simple random sampling technique. In the second phase, we mostly carried qualitative interviews with selected respondents from Badil Bigha and Basha Pipra. In total, we carried out 40 interviews in this phase.

Initially, the study examined the changes in socio-economic conditions with access to electricity in our study area. Badil Bigha and Basha Pipra were not connected to the main grid (the nearest grid-connected village is approximately 10 km far) and considered for the mini-grid installation. Whereas Mahadevpur and Pilkhi are located very close to Rajgir Town and connected to the main grid.

The mean monthly income of the grid-connected villages is 50 percent higher than that of villages connected with mini-grid (Table 11.5). During our visit to grid-connected villages, we have observed several home-based business activities; approximately 25% of the respondents have mentioned that they have a home-based business, and nearly 60% of the respondents earn their income through daily labour. These villages receive approximately 22 hours/day of electricity supply during winter and 18 hours/day in summer. Similar observations are made in other grid-connected villages in Bihar (Jain et al. 2018; Rockefeller Foundation 2019). Although the villages have access to electricity through the grid, there is dissatisfaction among the respondents regarding the peak hour supply and the unit charge of the electricity. Currently, distribution companies in Bihar have a minimum tariff of six rupees per unit (1kWh), which is higher than other states of India[2].

In villages connected through mini-grid, we found that approximately seven hours of electricity supply is provided in summer (6 PM to 1 AM) and 10 hours in winter (6 PM to 4 AM). The increase in electricity duration for the households in the winter was due to less consumption of electricity. Approximately 65% of respondents surveyed expressed that the electricity supply through mini-grid supports their basic needs (provide lighting during the evening hours) whereas others felt that capacity of the solar mini-grid is low and hence it is not able to meet all their

[2] https://www.bijlibachao.com/news/domestic-electricity-lt-tariff-slabs-and-rates-for-all-states-in-india-in.html#bihar

Table 11.5 Electricity Supply and Usages in the Study Area

	Badil Bigha	*Basha Pipra*	*Mahadevpur*	*Pilkhi*
Number of respondents	50	50	15	50
Mean Household size	8	11	7	9
Mean monthly Income	INR 3900	3310	5500	5200
Hours of Electricity Supply[a] Winter Summer	Solar Mini-grid (12KW) 10 hrs 7 hrs	Solar Mini-grid (30KW) 10 hrs 5 hrs	Grid 22 hrs 18 hrs	Grid 22 hrs 18 hrs
Peak Hour Electricity (6 PM to 11 PM) in Summer	Yes	Yes	No	No
Electric Appliances	5 W LED bulbs one 20 W DC fan one 5 W Solar lantern with mobile charging point	5 W LED bulbs one 20 W DC fan one 5 W Solar lantern with mobile charging point	No restriction: Bulbs, Fans, TV, refrigerator, iron box etc.	No restriction: Bulbs, Fans, TV, refrigerator, iron box etc.
Monthly Electricity Consumption[b]	10–15kWh	7.5–15kWh	40–100kWh	40–100kWh
Monthly Expenditure[c]	INR 50	No expenditure	INR 240–700	INR 240–700

Source: Authors assessment

Note:[a] In mini-grid villages, electricity supply in winter: 6 PM to 4 AM and summer: 6 PM to 11 PM
[b]Maximum monthly electricity consumption was calculated in the following way: (two 5 W LED+ 20 W Fan + 5 W Lantern)*10 hrs *30 days; for Grid-connected villages, monthly bills were considered
[c]Beneficiaries in Badil Bigha charged a monthly maintenance charge of INR 50, whereas in Basha Pipra, there were no monthly charges

requirements. Even with these limitations, we found certain changes in the socio-economic conditions of these villages. Our study found similar benefits with mini-grid installation (Palit and Chaurey 2011; Thomas and Urpelainen 2018) such as an increase in the income and savings, extended study hours for children, and safety during the night hours.

11.3.2.2 Impact on Household Income, Education and Access to Other Services

The primary occupation of the households surveyed in the two villages is largely agriculture (53%) followed by small businesses (29%) such as grocery shops, herbal shops, rice mills, husking units, tailoring shops, tea stalls, small eateries etc. Opening hours of their shops got extended till 9 PM. Earlier it used to be closed by 5:30 or 6 PM. In other words, due to mini-grid, their business hours have increased. One of the respondent from Bahsa Pipra mentioned that,

> "After the solar electrification I open my shop till 8:30 PM which earlier used to close at 5:30 PM due to darkness and it was difficult to run the shop on a kerosene lamp, I feel empowered after coming of electricity". (Usha Devi runs a grocery shop at Bahsa Pipra village)

Similarly, another respondent from Badil Bigha stated that,

> "The earnings have increased from earlier, as I can work for more hours on tailoring than before, as it was difficult to do stitching in insufficient light". (Manoj Kumar, Badil Bigha Village')

Although the villagers could benefit from extended business hours, our study could not capture the increase in income as they were unable to provide information about extra income. So, to quantify the benefits, we calculated the extra income/savings gained by foregone cost on kerosene, dry-cell batteries, mobile charging etc. Before these two villages were electrified through solar, the villagers largely depended on kerosene for the source of lighting. The average monthly kerosene consumption of the household was about five to seven litres. They used to receive two litres from the public distribution system (PDS) on a subsidised rate of INR 12/litre and remaining from the private market for INR 60 to 70/litre. The study has observed that with the solar mini-grid, the kerosene consumption has reduced to one to two litres. On average the monthly saving from kerosene is approximately INR 278 to 325.

Earlier villagers use to travel 8–10 km (nearest market) and spend around five to ten rupees for charging mobile. Usually, every person used to get it charged three to four times per week. Along with LED bulbs and fans, the beneficiaries also received a solar lantern with a mobile charging point. With the solar lantern, the usage of batteries and cost for mobile charging was eliminated. The estimated household monthly saving on mobile charging through solar lantern is about INR 171 to 339 in Badil Bigha and INR 214 to 427 in Bahsa Pipra, the evidence from the literature also reflects that the Solar Home Lighting System (SHLS) has improved the daily needs of the household like mobile charging for which they had to travel earlier to far distances and to pay an amount of INR 10 for one-time charging (Barman et al. 2017). Similarly, the study also observed that villagers save an average of INR 114 to 199 per month from buying batteries and candles. It shows that access to electricity is one of the substitutes for all these expenses. The average monthly households savings in Badil Bigha were in the range of INR 645 and INR 986. In Bahsa Pipra savings were estimated in the range of INR 705 to 1111. Given a mean monthly income of the households of the two villages (see Table 11.5), the savings due to mini-grid can add to their monthly income by 20 percent to 30 percent. Interestingly, these savings are not directly observed by the respondents.

Villagers have expressed that with reliable electricity supply from solar mini-grid, their children's study hours have extended by 2–3 hours. Better quality of light does not stress the eyes of children studying in the evening hours anymore. A large number of respondents revealed that access to electricity had enhanced access to media. As electricity has the potential to boost the level of information in a community that resides in remote areas. Electricity becomes the utmost importance as modern information is circulated through an electronic medium. After the installation of solar mini-grids, streetlights were provided in both the villages. It enhanced the mobility of the inhabitants in the night. During the focused group discussion, some of the beneficiaries shared their experience as: "Our village is scattered in three settlements, earlier it was quite unsafe to go out in the evening, it used to be pitch dark, but after the installation of street lights, we are not in tension even if our children are playing outside. The incidence of snakebite has reduced in the community due to sufficient light".

11.3.2.3 Energy for All: Mini-Grid to Main Grid

In the Phase-I, the study identified the socio-economic changes brought through the solar mini-grid project. However, we also found that the beneficiaries of the project were not completely satisfied with solar mini-grid. The primary concern was that of the inadequate amount of electricity supply. Once they got electricity connection, the villagers wished to use more electric appliances; however, electricity provided through mini-grid was only enough to fulfil their basic power requirements. Under the Bihar Governments program Har Ghar Bijli scheme, these two villages were connected to the main grid in August 2018. We revisited both the villages after grid connection i.e. in November 2018 and April 2019.

During the visit in November 2018, we found that solar mini-grid systems in both the villages became almost dysfunctional. The major disruption that changed the energy access pattern was the introduction of the grid connection. The main grid connection provided adequate access to energy and villagers were able to use electric appliances like TV, refrigerator, fans etc. The complaint regarding the inadequacy of electricity supply from solar mini-grid was resolved after the connection with the main grid. Connectivity with central grid has been cited as a major barrier for the spread of solar mini-grids in India (Bernard et al. 2018; Comello et al. 2017; Sharma 2020).

In Basha Pirpa and Badil Bigha, the solar mini-grid failed to emerge as a successful electricity generation and distribution model. In Badil Bigha, village's entire 12 KW solar mini-grid with 40 solar panels were installed on the rooftop of government buildings. The operation and maintenance of the solar mini-grid were with the village women community (JEEVIKA group). In Basha Pipra, 30KW with 100 panels was installed on three different private buildings. The project implementers invited the women community to manage the operation of the mini-grid. However, owners of the private buildings where the solar panels were installed did not let the women group involved in operation. Although the project was funded as part of CSR activity, due to lack of involvement of all the stakeholders, private building owners had emerged as mediators regulating the distribution and use of electricity. They patronised the other beneficiaries. It has eroded the trust of other members on this project. Rather than emerging as a public system taking care of the electricity needs of the whole community, it remained a semi-private enterprise for the selected households in Basha Pipra. The selection of sites for installing solar panels in mini-grids thus have strategic value and if wider community interests are not considered than it can put the future of the project at peril.

To monitor the electricity consumption among the beneficiaries through mini- grid system, a metering system was installed at the household level. A maximum user charge of INR 105 and certain fixed units were allocated to each beneficiary. A delay in installing individual meters during the initial phase of the project (between August 2018 and November 2018) also shaped their response towards the mini-grid. Many of the beneficiaries felt that it is a government-funded project and does not require any financial contribution from the beneficiaries. Even, overall, the maintenance of the meters was not properly carried out and it mostly remained dysfunctional. Another group of villagers considered the user charges beyond their reach. In the Badil Bigha, the beneficiaries were paying a monthly maintenance charge of INR 50 (an amount of INR 50,000 was collected when the solar mini-grid was operational), whereas in Basha Pipra, beneficiaries did not pay any amount for maintenance or user charges. There was another group, which availed the mini-grid connection but never contributed for maintenance or paid the user charges. After the connection with the main grid, the villagers started using energy-consuming incandescent bulbs over CFL or LED (due to price difference and availability) and many other electric and electronic appliances. This was the phase when they completely neglected the mini-grid.

We again visited these villages in April 2019 and interacted with households who were interviewed in November 2018. This time, we have witnessed that villagers were un-happy with the central grid connection. The prime concern was the user charges. The beneficiaries were asked to pay electricity bills from the day they got connected with the main grid. The bill amount of the household ranged from INR 300–700, which accounts for 10–30 percent of their income. Although they benefited in terms of electricity access and savings on kerosene and other benefits. Nevertheless, many of the villagers found it difficult to cope with the new practice of paying the electricity bills. Some of the villagers were reluctant to pay the bills and wanted to go back to the old system (solar mini-grid). However, by this time, none of the mini-grid remained functional. In the case of Badil Bigha, villagers were willing to fix the battery system with the maintenance money (about INR 50,000) that was collected earlier when the mini-grid was functional. Whereas in Bahsa Pipra, as no monthly charges were collected there was no corpus amount available to get the mini-grid fixed. Moreover, as all the panels were installed on private buildings in Bahsa Pipra, the community mobilisation remained absent. Private owners continued to use the solar panels for their own purpose.

11.4 Conclusion and Recommendations

Mini-grids are being discussed as a potential alternative for providing electricity access to millions of people, especially in the developing world. The issue holds relevance for many Asian countries. Our research intends to highlight some important learning for Asian economies through a case study of two Indian villages. The gap in policies and regulations along with weak institutional support, lack of operation and maintenance after deployment, community ownership, adaptability for new technology, and uncertainty due to future grid extensions, are some of the significant challenges faced by developers of mini-grids in Asia. Hence, to address these challenges and for sustainable deployment of mini-grids, an appropriate institutional arrangement and overall capacity building is required. Overall, the study offers the following recommendations:

As private developers are involved in the deployment of mini-grids, governments should make predictable grid expansion plans to protect the investment in mini-grids and its full utilisation. Tariffs should be fixed for end users in such a way that the revenue from mini-grids projects could be viable. The paying capacity of rural communities especially from the marginalised communities is quite low in many parts of developing Asia. PAYG (Pay-as-you-go) financing payment model could be employed for enabling easy adoption of mini-grids without burdening the consumers with the up-front cost. Even then, the initial investment needs to be supported by governments, multilateral agencies, or corporates. Currently, the mini-grids are designed for meeting the basic requirements, increasing the capacity to support the additional demand would allow users to continue relying on mini-grids. In our case, in one of the villages, the solar mini-grid was completely abandoned, whereas, in the other, after the connection with central grid it was partially abandoned. In the second village, people were interested in fixing the mini-grid and using it as complementary to the central grid during the peak hours.

Reliable, adequate and continuous access to energy is still a big challenge in many parts of rural India (Aklin et al. 2017; Barman et al. 2017; Jain et al. 2018; Rockefeller Foundation 2019), as well as rural Asia. In such situation, solar mini-grids can play a significant role in providing universal access to reliable energy. In other words, mini-grids and the main grid can complement each other in providing access to electricity. Once the physical interconnection takes place, different buy and sell transactions between the two delivery technologies can lead to more reliable and less expensive electricity for consumers (Bernard et al. 2018). Community engagement is the key to the success of any off-grid energy project. It has been seen in the past that in the absence of community involvement, such projects do not sustain in the long run (Sharma 2020). Our study, further corroborates this weak link. Local capacity building with an appropriate ownership model and management would enhance the economic benefits and utilisation of mini-grids.

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PART VI

Water-Energy Nexus

CHAPTER 12

Water-Energy Nexus: Shaping Narratives Across Diverse Issues

Vaibhav Chaturvedi

12.1 Introduction

Energy and water are critical resources impacting the development pathway of a country. While energy has been powering the lives of millions through supporting the industrial production process as well as providing comfort and services at the consumer end, water has been mainly connected with drinking water and sanitation, along with production of food and non-food crops. Traditionally, these resources have been viewed, analysed and managed in their own silos. Experts, stakeholders and policy makers dealing with the energy sector have rarely had to include water in their debates and narratives, while those dealing with water have rarely had to engage with energy related aspects.

Increasingly, however, water-energy nexus is being viewed within the same framework (FAO 2014; IRENA, 2015; Endo et al. 2017; Rao et al. 2017; Aboelnga et al. 2018; Albrecht et al. 2018; Stercke et al. 2018; Terrapon-Pfaff et al. 2018a; Chen et al. 2019). It has been highlighted by numerous researchers, that water is required in the energy production,

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transformation and use process, and that energy is used for collecting, treating and distributing water. This is a welcome development, as the nexus view could have a significant and positive influence on how these inter-linked resources are managed and governed, ultimately impacting the progress of the world towards the sustainable development goals.

The nexus perspective has the potential for shaping narratives across countries in Asia (UNESCAP 2013; Rasul and Sharma 2014; Keskinen et al. 2016; Karthe et al. 2017; Perera and Zhong 2017; Taniguchi et al. 2017; Srinivasan et al. 2018; Terrapon-Pfaff et al. 2018b; Zhang et al. 2018; Wicaksono and Kang 2019; Chaturvedi et al. 2020). Asian countries have a varied economic and demographic structures, resource endowments, and energy and water use profiles. Apart from the high-income counties of the Middle-East and Japan, economies of most other countries in Asia are growing at a significant pace. It is often said that the global economic growth is powered mainly by the Asian economies. A high rate of economic growth implies increasing pressure on both energy and water resources. While the Middle-East region can be classified as the most water stressed region in Asia, most parts of Bangladesh, India, and Pakistan are under significant water stress. The Central Asian region also faces water related challenges, as is the case with some parts of China. Countries in the south-East Asian region (Cambodia, Indonesia, Vietnam etc.) can be considered as water abundant, and so is the case with Korea and Japan. Energy used for water is subsequently high in countries where provision of water is a challenge, be it for desalinisation in Middle-East countries, or for withdrawal and transportation of water as in India.

As is the case of water, Asian countries also vastly differ in terms of their energy production and use profiles. Energy use profiles correspond closely with the level of economic development of a country. In Asia, Japan, Singapore and high-income countries of the Middle-East have high per capita energy use at one end, and low per capita energy use on the other end in south Asian countries like Bangladesh and India. As energy production grows, the water footprint associated with it is also expected to grow significantly in these economies.

The role and importance of renewable energy (RE) in Asia cannot be emphasised enough. Asia is where significant economic growth is expected to happen in the next two decades. Actions for mitigating climate change also need to be enhanced significantly in the next two decades. Renewable energy is going to play a critical part in the fight against climate change in Asia. All the major regions and countries in the Asian region have plans and policies for rapid uptake of renewable sources in their energy portfolios. While their location in the tropics implies that solar energy will be a mainstay of renewable energy in most of the Asian economies, wind energy is also going to play a critical role. Along with these, bio-energy has been highlighted as a critical resource for the world and Asian countries for meeting the targets of low-carbon world.

Along with the increased impetus on renewable energy because of climate change concerns, RE is also receiving a fillip because of energy access related concerns, especially in developing Asia where grid has not been able to provide access to millions living in energy poverty. This is especially true for the south Asian economies that have traditionally been energy poor. Decentralised energy access, either through RE mini-grids or stand along systems (like solar roof-top systems), are also gaining more ground in the debates related to energy systems. Energy access is not only related to household energy use, it is also related to agriculture energy use. For instance, Indian farmers are significantly dependent on ground water for meeting their irrigation requirements. Groundwater withdrawals require significant energy. Energy provision for withdrawing groundwater, hence, is an important priority for Indian policy makers. This is true for other Asian countries as well which have a significant number of people dependent on agriculture for their livelihoods,

The future penetration of renewable energy in Asia is going to be impacted by the water scenario, and the water scenario is going to be impacted by the increasing use of renewable energy. Within the larger context of water-energy nexus and RE in Asia, we focus on three emerging narratives that are increasingly becoming important in the energy and water debate, and examine how the inter-dependencies of water and energy will shape these narratives. The first narrative relates to renewable energy integration and the impact of water-energy nexus on it, the second nexus narrative relates to bio-energy, particularly in combination with carbon capture and storage (CCS) for negative emissions, and the third narrative relates to solar pumps for irrigation. The first two narratives are driven by the climate change debate, while the third one is driven in part by climate change and in part by energy access for irrigation and food. In this chapter, we first explain all the three narratives as they stand now, and then explore how the nexus perspective can shape these narratives. We then highlight the key takeaways for the stakeholders dealing with these narratives in Asia.

12.2 Renewable Energy Integration and Water-Energy Nexus

Renewable energy is gaining ground in Asia. The penetration of RE has increased significantly across countries in Asia. The country leading in terms of the largest installation of solar and wind energy is China, due to the significantly large size of its energy systems compared to other countries in Asia. Other countries in Asia also have a significant penetration of renewable energy, increasing at a fast pace year on year. The fillip in renewable energy is due to significant support by respective governments, with support ranging from financial subsidies, to provision of dedicated supporting infrastructure, to investment in research and development. It is amply clear by now, that renewable energy is going to grow by leaps and bounds.

Though there is hardly any doubt that renewable energy will play a significant role in the energy systems of the future, some challenges are emerging. One such challenge that is increasingly being realised across the world is that of integrating variable renewable energy (VRE) in the electricity grid systems (Hirth et al. 2015; Chaturvedi et al. 2018). Variable renewable energy implies that the electricity generation profile is variable. In the current context, this primarily applies to wind and solar energy, though other forms like tidal energy are also variable. Variability of resource in itself is not an issue, if it is a predictable variability. It is the unpredictable variability of the resource that leads to significant challenges in the operational planning of the grid. Solar and wind energy are both unpredictable and variable. These require either storage systems or back-up generators to manage fluctuations in their power output to maintain stability of the grid. At lower level of VRE penetration in the grid, managing integration is not a big issue. However, as the share of VRE grows in the grid, integrating it becomes a significant challenge.

The distribution profile of a technology across time and space is also critical for integration. For any given point of time, the more uncorrelated a resource is across a geographical space and time, the better it is from the integration perspective. For example, in any country, if the wind distribution profile is uncorrelated across east and west regions, then it becomes easier to integrate it into the grid. This is because at any point of time, either more wind electricity will be generated in the west or in east region and it is easier to be absorbed into the grid. If these are highly correlated, most of the wind electricity will be generated in the same time slice, and it would be difficult to absorb it into the grid if this is higher than the demand at that time, while at other time only little wind energy will be generated.

In the RE portfolio, some technologies are better suited from the integration perspective, as compared to others. One such technology is the concentrated solar power (CSP) technology. The rate of growth of solar power across the world has been mainly on the back of the photovoltaic (PV) technology. CSP technology is another critical technology that harnesses the power of solar energy. It is also known as solar thermal technology because of the way it harnesses solar energy. When the solar revolution started, CSP was touted as the more promising technology as compared to PV technology. In fact, all the initial solar power plants that were accepted after bids in India were CSP power plants. However, the price of PV technology declined at an unprecedented pace, and market dynamics ensured that the PV technology took centre stage in all discussions.

As the share of solar (and wind) grows across Asian countries, so will be the challenge of integrating it into the grid. From an integration perspective, CSP is argued as a better technology because of the mechanics involved in its process of producing electricity from solar energy (UCS 2015; Awan et al. 2019). PV, as compared to CSP, is expected to need much more support for balancing and integrating it into the grid. Hence, as the share of solar grows in the grid, the value that CSP technology brings to the table because of its technical superiority as far as grid integration is concerned will only increase.

There, however, is another side to the debate- that of water. The water required per unit power generation is much higher for CSP power plants as compared to PV power plants. The median water requirement in Indian conditions, for example, is 2.68 m^3/KWh for CSP, as compared to 0.1 m^3/KWh for PV (Chaturvedi et al. 2020). This is because in PV power plants, the main use of water is for cleaning solar panels. On the other hand, CSP is a thermal technology, which implies that water is required for thermal cooling of the system, as in the case of any other technology that uses thermal power, for example coal or nuclear power plants. On average, water consumption of CSP power plants is lower than that of coal in India. However, a coal power plant can be located close to a water body, be it a river or sea. This is not the case with a CSP power plant, as a CSP power plant would be located in areas with the best solar resource. The CSP technology performs best in areas with diffused radiation, like desert areas, which in all probability would also be a water stressed area.

In the first of its kind evaluation of India's National Solar Mission in 2012, a report by CEEW and NRDC (2012) presented that all the CSP power plants that were sanctioned in the desert state of Rajasthan in India were all clustered around the only surface water channel in that area. The implication of this was that once these planned CSP power plants would start operating, water meant for domestic and agricultural uses would be diverted to meet the thermal cooling needs of these CSP power plants. As almost all of these planned power plants were not constructed due to sharp fall in PV power prices, a major water-energy nexus conflict was averted. This however, might not be the case in the future.

The trade-off between integration of solar energy and water requirements for the same is going to be critical for the future of renewable energy not just in India, but also other Asian countries. How this trade-off will shape the narrative aligned with the future of power systems will impact the future of solar technology, particularly CSP, in Asia.

12.3 Bio-energy and Water-Energy Nexus

Biomass is another renewable energy resource which is expected to contribute to mitigating climate change. Bio-energy is expected to contribute to the mitigation of power sector emissions through biomass pellet (or co-generation) based electricity, as well as mitigation of transportation and industrial emissions through higher use of liquid bio-fuels. Bio-energy is considered as carbon neutral, as it sequesters carbon while growing, and emits equal amount of carbon while energy is derived from it.

The role of bio-energy is especially being highlighted for deep decarbonisation scenarios. Bio-energy with carbon capture and storage (CCS) technology has been highlighted as a critical technology for limiting the global temperature increase to 2 °C and 1.5 °C (IPCC 2018). This technology, often also called as a negative emissions technology, will be instrumental in scenarios in which overshoot of emissions happens relative to the optimal mitigation pathway, in which global emissions peak in 2020 itself. Emissions higher than that in the optimal pathway will be compensated by negative emissions in the second half of the century. The bio-CCS technology will help in achieving the target even if emissions in the near term can-not be abated at the required pace. Emissions from the power sector are expected to be a major contributor to global emissions. Bio-CCS can reduce power sector emissions, plus provide the much-needed base load required to integrate variable renewable energy.

Bio-fuels are also important from the perspective of transportation sector. Transportation sector emissions constitute a significant share of global emissions, particularly in developed economies, and are growing at a fast pace in developing countries. Globally, this sector is heavily dependent on oil for its energy needs. While electrification is being touted as a critical strategy for decarbonisation of this sector, bio-fuel blending with oil is another strategy that is an important element across countries.

The water foot-print of bio-energy, however, is very high, and could lead to water stress on the region/country. Researchers (Chaturvedi et al. 2015; Hao et al. 2017; ICID undated) highlight that the water consumed in growing bioenergy crops is very high, compared to that consumed when bioenergy is used in the power generation process. A bio-energy dominant energy system will consume high amount of water, mainly for irrigation. This could be problematic for water scarce areas. The Indian experience has been that the much-touted Jatropha plantations for bio-diesel were not successful in meeting the bio-fuel ambition of the country mainly because they were mostly grown on marginal lands with low water available for irrigation.

Along with bio-energy, the CCS technology also has a high-water foot-print compared to other power generation technologies (Macknick et al. 2012; Byers et al. 2016). The CCS system is an addition to a usual power plant system, and hence uses energy for capturing, transporting and storing carbon dioxide emissions from either fossil dependent power plants or industrial facilities. The 'energy penalty' implies that the power plant efficiency will decline, and less power will be available for the grid. In effect, for one unit of electricity that is used in the end-use sectors, higher electricity will need to be generated, and higher water is consumed in the process. No CCS in the power system would imply higher reliance on nuclear or RE, which will again lead to integration related challenges.

12.4 Solar Pumps and Water-Energy Nexus

Irrigation is a critical issue, especially for agriculture dominant economies (Shah et al. 2003; Agarwal and Jain 2018). In Asia, agriculture plays a critical role in supporting livelihoods of millions of people. However, the water situation varies across Asian countries. Generally speaking, south-east Asian countries (Malaysia, Indonesia, Vietnam, etc.) are water surplus countries. Barring the countries in this region, most of the Asian countries face varying levels of water stress. Be it countries in the middle-east, central Asia, or south Asia, all countries are challenged by water availability. Many parts of China, particularly northern China, are also water stressed. However, it is the need for irrigation water that is crucial in terms of people and economies dependent on agriculture. In that sense, one can say that in Asia, it is mostly south Asian economies that are heavily dependent on agriculture, though importance of agriculture cannot be over emphasised for food security of other Asian countries as well.

The role of irrigation pumps has been critical across countries. Surface water infrastructure, i.e. large dams and canal systems, have been fraught with inefficiencies, and opposition on grounds of environmental and social impacts. Agriculture has continued to be significantly dependent on groundwater in south Asian economies. The role of irrigation pumps stands out in India. In a survey done almost two decades ago, the number of irrigation pumps in India far surpassed the number of such pumps in other major agrarian economies in Asia and the world (Table 12.1; Shah et al. 2003).

Irrigation pumps, traditionally, have been powered by either electricity or diesel depending on the availability and affordability of the particular fuel in any particular agricultural region. Both electricity and diesel have been carbon emissions intensive. Provision of electricity for irrigation has also been fraught with financial implications for governments, as electricity for poor farmers has been heavily subsidised.

Especially in India, subsidised electricity has also meant inefficient use of groundwater. Farmers use water inefficiently when they have to pay

Table 12.1 Groundwater usage, number of pumps used and extraction rate, and dependence on groundwater in different countries

Country/ province	*Annual groundwater usage (km^3)*	*No. of pumps (million)*	*Extraction per pump (m^3/year)*	*Population (%) dependent on groundwater*
Pakistan Punjab	45	0.5	90,000	60–65
India	150	21.28	7900	55–60
China	75	3.5	21,500	22–25
Iran	29	0.5	58,000	12–18
Mexico	29	0.07	4,14,285	5–6
USA	100	0.2	5,00,000	<1–2

Sources: Hekmat 2002 for Iran; Mukherji and Shah 2002 for India; Scott et al. 2002 for Mexico; and Shah et al. 2002 for China and Pakistan, quoted in Shah et al. (2003)

little for it. And more importantly, when it is a common property resource (CPR). A CPR is a good that is characterised by rivalry in consumption, and non-excludability. That is, no one can be excluded from consuming this good, and consumption by one person reduces the amount available for use by another user. Unless regulated and managed effectively, there is bound to be inefficient use of water. There is hence a clear nexus between energy pricing and inefficiency of water use in some regions.

Solar pumps are being considered across many countries in Asia as a climate friendly alternative to fossil powered irrigation pumps. Moreover, these pumps also reduce reliance on erratic fuel supply throughout the irrigation season. Undoubtedly, there is a significant climate benefit of using solar pumps. There, however, is an equally critical environmental trade-off: that of water. Currently, as highlighted earlier, water is being inefficiently used by farmers because of low price of this resource, or as there is no marginal pricing at many places with farmers paying a lump-sum amount for using power. Thus, the per unit cost of withdrawing water is a critical determinant of how inefficiently irrigation water is used.

Solar pumps, though climate friendly, take away the price associated with withdrawing water. There is an initial capital cost of installing these pumps, which is high compared to traditional irrigation pumps. But once installed, there is no cost of using these for withdrawing water. Unlike the case with electricity or diesel-based pumps, there is no operational cost as solar pumps draw on a freely available resources- solar energy. Zero cost of withdrawing water implies that irrigation water use efficiency can worsen further.

It is important to ensure that the trade-offs in this nexus do not end up deteriorating the water problem, while contributing to climate change mitigation. Researchers have suggested business models for the same (see e.g. Raymond and Jain 2018). The solar pumps could be connected to the grid, which gives farmers incentive to use only the required amount of electricity for water and sell the rest to the grid. There could be other alternative business models as well. What is important is that any such business model changes the incentive structure in such a way that only that amount of electricity is used which is sufficient for the required amount of irrigation water. Water savings hence happens through changing the incentive structure related to the electricity produced using solar pump.

12.5 Framing Water-Energy Nexus Narratives in Asia

Narratives are important in understanding and shaping the world we live in. Narratives essentially are simple stories that people can understand, and narratives in turn help stakeholders get a high-level perspective of things in discussion. It is hence, critical to discuss and understand the emerging narratives around water-energy nexus. The nexus perspective has been used now almost for a decade as a lens for understanding many different issues. Understanding emerging narratives around water-energy nexus that have the potential to shape choices of the future becomes critical.

Along with narratives, frameworks are also critical for understanding an issue. Conceptual frameworks help in understanding the connections between different elements. Based on the discussion in this chapter on the three emerging narratives, we present a conceptual framework to view these emerging narratives (Fig. 12.1). The proposed framework for nexus essentially highlights the trade-offs that we will face as a society as we

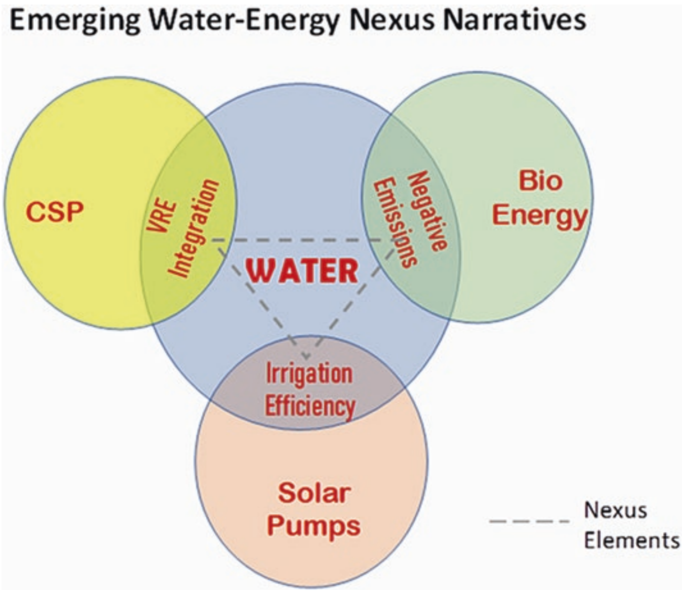

Fig. 12.1 Emerging water-energy nexus narratives. (Source: Author's analysis)

move along the narratives discussed in this chapter. There could be many trade-offs that will emerge in the future in the energy and water debate. We highlight three- negative emissions, VRE integration, and irrigation efficiency. These trade-offs are also the nexus elements in our framework.

This framing, as presented here, is critical for Asia for three reasons. First, significant area in Asia is under arid and desert ecosystem, where the potential for CSP technology is high. But harnessing it is going to be a challenge due to the associated water demand. Thus all the countries in the middle-East, those in central Asia, as well as solar abundant desert and arid regions of south Asia would find themselves grappling with this nexus challenge. This nexus element related to VRE integration is bound to become critical for all these areas.

Second, negative emissions, especially for large industrial nations like China, are going to be important to win the fight against climate change. Without bio-CCS, it is almost given that the world will see a much higher and devastating temperature trajectory. This nexus element has a very interesting implication, that of changing global energy trade. If biomass-CCS becomes critical in the fight against climate change, and if large countries like China and India where future growth is expected to happen need to import biomass due to water constraints, the energy trade pattern would change. Biomass will be imported in these economies where it cannot be produced due to either water or land or any other constraint. This scenario will be beneficial for the water abundant countries like those in south-east Asia, as they could become exporters.

Third, Irrigation efficiency is critical for countries in south Asia- mainly India, Pakistan and Bangladesh, where significant area is under agriculture and is dependent on ground water irrigation for meeting a large part of irrigation water demand. In places where energy pricing policies have an impact on irrigation water use efficiency, any intervention related to irrigation water technologies that impacts the effective shadow price of water is bound to impact irrigation water use efficiency. Interestingly, this narrative also implies that there are many business models that are being experimented to allay the concerns related to the narratives.

Together, this nexus framing for the emerging water-energy nexus narratives addresses some important emerging nexus concerns for most of the Asian countries.

12.6 Conclusion

Water-energy nexus is emerging as a critical theme in the world. Many issues, that were earlier viewed from individual lenses and in silos are now being viewed in an integrated perspective. It is being increasingly realised and accepted that water and energy are very different as resources, however, these resources interact in many situations and impact each other as well as the stakeholders who depend on these resources. The nexus perspective is changing the way we view these resources as well as the policies and strategies that need to devised to manage these resources.

Renewable energy is becoming increasingly critical, especially because of the threat posed by climate change. The scientific as well as policy community has accepted the criticality of renewable energy in the long-term future, and efforts are being made by one and all to enhance the share of renewable energy in the near term. This is true for countries in Asia as well, and this is critical because it has been often argued that Asia will be the driving force of economic growth, and consequentially the most important regions in terms of growth in emissions related to energy use. This chapter argues, that as with other themes, the nexus perspective will also shape how renewable energy will be used in the future, and that policies will need to evolve to encompass the nexus perspective while dealing with renewable energy.

The chapter presents and discusses three emerging narratives related to renewable energy in Asia, which are going to be critical for the future of Asia, as well as narratives that will be impacted by water-energy nexus linkages. The three nexus narratives are related to CSP and grid integration of solar power, bio-energy-CCS and negative emissions, and solar pumps and irrigation water efficiency. Collectively, these three narratives are relevant across all countries in Asia.

If water is not included in any of these three narratives, the story appears to be a comfortable and positive story. That CSP will come in a big way when (and if) costs decline and will be able to reduce concerns related to integration of solar energy in Asia; the CCS technology will help big nations with the geological potential to store carbon dioxide, like China, to achieve significant negative emissions; and that the deployment of solar pumps will rapidly scale up and help in reducing fossil emissions as well as managing the power sector better in developing countries. If, on the other hand, water is introduced in all of these, the narrative changes to a more realistic narrative fraught with newfound challenges that need to be understood and managed. Water constraint could impede the scale up of CSP technology, it could impede the scale up of negative emissions technology in arid and water stressed regions, and it could lead to an even more inefficient use of water for irrigation.

It is imperative to have a nexus view of these emerging narratives, and ensure that policy makers and stakeholders are able to manage the trade-offs that are bound to emerge in the future. Ultimately, the society has to collectively ensure that the goal of rapid mitigation of emissions is achieved and the threat of climate change is addressed as rapidly as possible. The nexus elements, as argued in this chapter, are bound to play a critical role in Asia's fight against climate change.

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CHAPTER 13

Potential Macro-Economic Impact of the Expansion of Hydroelectric Sector in Central Asia

Badri G. Narayanan

13.1 Introduction

All over the world, there has been a combination of synergy and conflict between energy and water. While the synergies are mainly captured in the utilisation of water in generating hydroelectric power, conflicts are mainly due to the tensions between the demand for water by thermal power plants and agricultural sectors (See, for example, Hussey and Pittock 2012), as well as the power subsidies for agriculture that result in excessive usage of water (See for example, Lustgarten and Sadasivam 2015). The cooling process in thermal power plants consumes excessive water,

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potentially resulting in water scarcity. When the farmers are offered power subsidies, they may use more power than needed to activities such as boring wells and excessive use of groundwater, so much so that the water table is depleted.

Given the enormity of the overall subject of energy-water nexus, we focus our attention on the synergistic aspect of hydroelectric power, which gains importance in the context of climate change, global warming and Paris Accord. Renewable energy constituting a small portion of sources in Central Asian countries, which are in general rich in fossil fuels, raises the question of what could be the potential economic impact of expanding this sector. This is particularly relevant for Kyrgyzstan and Tajikistan, which have abundant water resources and mountains. The other Central Asian countries may also be beneficiaries of the power surplus in these two countries, as they cannot generate hydroelectric power given their landscape and lack of water resources.

After reviewing the literature on hydroelectric energy in Central Asia, we identified a gap in terms of this broader question, particularly considering the backward and forward linkages of the hydroelectric sector. The broad question we attempt to answer in this analysis is as follows: if the hydroelectric sector is expanded in the Central Asian countries, what could be the implications for the economies of these countries, at a macro level? The sub-questions may include the following: What could be the impact on the Gross Domestic Product (GDP) of these economies? What could happen to international trade? What may be the impact on investment and consumption? Would the consequent economic expansion, if any, stem from increased exports, cheaper intraregional (Central Asian) imports, investments or consumption, or all of these? Therefore, we focus on answering these questions using a widely used global CGE (Computable General Equilibrium) model, namely the GTAP (Global Trade Analysis Project: Hertel 1997). This chapter is organised as follows: Sect. 13.2 reviews the literature on energy-water nexus issues in Central Asian countries; Sect. 13.3 explains the methodology and data sources; Sect. 13.4 discusses the findings from our analysis on the expansion of hydroelectric power, and Sect. 13.5 explains the potential adverse environmental impact of such expansion, while Sect. 13.6 concludes.

13.2 Discussions on Energy-Water Nexus in Central Asia

The discussion on energy-water nexus in the region covers areas including ‘challenges for renewable energy generation, electricity exports, water conflicts, and geopolitics and water management.

13.2.1 Challenges for Renewable Energy Generation in Central Asia

A paper by Karatayev et al. (2016) studies the potential for renewable energy usage in Kazakhstan as well as reasons for their lack of development in the country. Kazakhstan has a huge potential for investing in and developing renewable energy resources; however, presently renewable energy only contributes less than 1% to overall energy generation. In order to explore barriers to adoption in Kazakhstan, the authors interviewed 23 stakeholders in the country's energy sector in addition to analysing current literature on Kazakhstan's energy systems. In order to establish the relative importance of these barriers, the authors used a model approach based on an Analytic Hierarchy Process developed by RW Saaty. The authors find that one of the main barriers to development is the high price of generation. Since fossil fuel resources are abundant in Kazakhstan their usage in the power generation process is relatively cheap. Another barrier is the reliance on poor physical infrastructure and an underdeveloped electrical grid along with the inability to store excess energy produced. Additionally, the country lacks proper legal and regulatory frameworks for the renewable energy sector. Other barriers include lack of research and development support, lack of public awareness and information barriers, social poverty, and the business environment. A paper by Eshchanov (2019b) estimates theoretically how much hydro-electricity could be generated in each of the five major Central Asian republics. This is based on the potential for generation based on their existing landscapes and water resources.

13.2.2 Electricity Exports

According to Peyrouse (2007), China is looking to Central Asia as a source of electricity especially due to shortages in a majority of their provinces. Most of the electrical infrastructure in Central Asia was developed during the Soviet era; therefore, the countries are looking for external investors to help improve their systems. China is partnering with Central Asian countries in order on power projects in exchange for the power generated. This chapter details various power projects China is financing in the region. China is investing in both renewable and non-renewable methods of power generation in the region. Central Asia being a major part of the One Belt One Road initiative, China plays a vital role in this region, in all sectors, and the power sector is no exception to this.

13.2.3 Water Conflicts Across the Countries

According to Ito et al. (2016), any of the dams and reservoirs constructed in Central Asia were developed during the time of the Soviet Union. With the dissolution of the USSR and the creation of new states, many of these resources have now fallen under multinational jurisdiction leading to conflicts between states on the use of these shared resources. Conflict is especially prominent between the upstream water-abundant nations (Kyrgyzstan and Tajikistan) and the downstream nations (Kazakhstan, Turkmenistan, and Uzbekistan). The conflict over the Rogun Hydropower plant in the Amu Darya basin between Tajikistan and Uzbekistan is emblematic of this systemic problem. This study analyses the conflict between the two countries regarding the production of this dam as well as providing solutions to resolve this conflict through a review of the literature and various interviews. Uzbekistan wants to prevent the construction of this dam as it would affect downstream runoff and impact its irrigated agriculture. Tajikistan's infrastructure is closely linked with that of Kyrgyzstan and Uzbekistan. Therefore it must maintain friendly relations with these countries. Tajikistan needs to build the Rogun plant in order to provide power during the winter and reduce its dependence on other countries. Uzbekistan is worried about a water shortage as a result of the dam that could harm its agriculture and potentially lead to a 2.2% reduction in its GDP. The authors suggest that Tajikistan include Uzbekistan as a beneficiary in the project in order to resolve the conflict.

Thermal power plants consume a considerable amount of water for various processes including wet cooling. Such use of water for electricity generation may lead to water scarcity. Increased water scarcity due to expansion in electricity generation could adversely affect crop outputs and food products through reduced water availability for irrigation. Dry-cooling technologies could help to cut the growth in future demand for water by the power sector. However, dry-cooling electricity generators need more capital than wet-cooling power plants; furthermore, it may also mean restructuring and changes in capital stock in the power sector. In many cases, building dry-cooling power plants is more capital intensive than building the new wet closed-loop cooling generators. Therefore, shifting towards dry cooling could change the relative prices of primary factors in favour of capital. Thus, it may be advisable to take an intermediate step between open-loop wet cooling and dry cooling, by introducing and expanding closed-loop wet cooling systems.

Motamed et al. (2013) analyse the Syr Darya river basin in Central Asia, specifically the competition for water resources between Kyrgyzstan for energy production and Uzbekistan for agricultural purposes. The study used the USDA-ERS (United States Department of Agriculture Economic Research Service) Country-Commodity-Linked system. By constructing a model for Uzbekistan and overlaying that with GIS (Geographic Information Software), the authors simulated the heightened energy demands as a result of the Kyrgyz Republic's Toktogul reservoir and reduced Uzbekistan's area in cotton by 10, 25, and 50 percent. The authors found that all three shocks led to a decrease in cotton production. In the most severe case, cotton production fell by 17% and cotton exports fell by 21% relative to baseline projections. These impacts are only felt modestly in international markets. This study demonstrates that there is always competition amongst water resources and the construction of a hydropower plant in one country can lead to significant economic impacts in its downstream neighbours.

13.2.4 Geopolitics and Water Management

Rivotti et al. (2019) study the implications of Kazakhstan's energy policy on its water resources. Kazakhstan currently generates much of its power from fossil fuel resources which rely on huge quantities of water throughout the generation process. Additionally, Kazakhstan is looking at switching to the usage of nuclear power which also relies on huge quantities of water for power generation. By analysing currently available water resources and various projections based on Kazakhstan's goals under the Kyoto energy protocol. Their study concludes that future changes to Kazakhstan's energy policy as predicted would require a significant increase in usage of the country's water resources. The authors conduct a basin-by-basin analysis and show that usage would vary across each location based upon policy preference.

A study by Eshchanov et al. (2019a) compares and contrasts the domestic renewable energy policies of Central Asian states. It illustrates what policies and incentives each country has in order to promote the development of renewable energy. Based on the data, Turkmenistan and Uzbekistan have the least developed renewable energy policy.

Abdolvand et al. (2015) look at how geopolitical interests play a role in the management of water resources in Central Asia and how capacity building measures can be taken to ensure sustainable management of these resources. Kyrgyzstan and Tajikistan are the main suppliers of water for the region as 90% of their territory is covered in mountains from which the water originates. Many of their downstream neighbours rely on this water for agricultural purposes as agriculture forms the backbone of their economy. Central Asian states lack the capacity to manage these resources efficiently such as a limited knowledge base, a small number of skilled professionals in the water sector, and a lack of laws and regulations able to deliver favoured outcomes. After the dissolution of the USSR, the Soviet system for managing these resources was no longer viable due to the fact that many of these resources were now shared by newly created nations. However, Russia still maintains close ties to the region and is the most important international actor shaping Central Asian geopolitics. Russia still invests in many projects in the region. Similarly, China, Iran, and Pakistan are looking to Central Asia as a source of power generation for their respective citizens. At the same time, internal conflict between states slows down progress on power projects as states decide whether to support hydropower or agriculture. Afghanistan, Kyrgyzstan, Pakistan, and Tajikistan have formed the Central Asia South Asia Energy Market (CASAREM) with the help of the Asian Development Bank. The Central Asian countries are working with Germany as a part of the Berlin Process in order to build their capacity for water resource management by expanding knowledge for water management as well as facilitating the networking of water experts from Germany, the EU and Central Asia.

13.3 Hydroelectric Power and Its Impact on the Ecosystem and Water Scarcity

Though hydroelectric power stations such as dams are considered to be producing clean energy, they adversely affect the marine ecosystem in reality.[1] These hydroelectric plants cause pollution through their chemical build-up and by altering the temperature of the water which causes a deadly impact on animals living in water reserves. Even small dams can unsettle fish life by blocking their passage. Not just the wildlife, but the whole ecosystem in the river is negatively impacted by such hydroelectric plants. Poor quality of water, water scarcity and adverse effects on the fertility of the land, etc., are some more of their side effects. Therefore, having 66% hydroelectricity would increase the number and operations of these units leading to more destruction of biodiversity.

Also, World Energy Council (2016) has warned that 'the UN has noted a 40% shortfall of worldwide water availability by 2030 and this would be reflected in the supply of energy in the near future.'

Hydroelectric power may be generated in three different ways; firstly, they may use the natural run of the river, or nature downstream movement of the water, without the need for developing any artificial body of water; secondly, they may be based on artificial reservoirs created specifically for this purpose of hydroelectric power generation; thirdly, they may involve the creation of artificial reservoirs that are used for multiple purposes, such as irrigation for agriculture, drinking water, industrial and other civic supplies, etc. In many cases, hydroelectric power requires the creation of artificial reservoirs—falling either under dedicated or multipurpose categories discussed above. They also result in evaporative flux into the atmosphere, thereby leading to excessive water use, depriving the downstream sectors such as agriculture of water. Moreover, Lampert et al. (2016) claim that water consumption in a dedicated reservoir was 10.2 gallons and in multi-purpose reservoirs, it was 22.7 gallons per kWh of power produced. These large quantities of water can be used in scarce areas for consumption and agriculture purpose.

[1] See this website for example, for some discussion in this regard: www.hydroeforum.org

13.4 Methodology and Discussion

We employ the multi-sector multi-region global CGE model extension of GTAP, namely the GTAP-POWER model and database, which is explained in Peters (2016). Figure 13.1 represents the overall accounting linkages captured in the GTAP model, in a simplified representation, at the risk of oversimplification. While households purchase commodities from markets, they also supply factors (land, labour, capital and natural resources), whose endowment is fixed. Activities or firms consume these inputs as well as intermediate inputs purchased among themselves to produce goods and services, which are sold to the consumers, government and rest of the world. The government collects the revenue from different types of taxes and spends on subsidies/income transfers and public procurement of goods and services, both domestically and internationally. The residual that remains of the regional income, after private consumption and government expenditure, is regional savings, which is then accumulated across the countries, to get the global investment, which is then reallocated to each country based on the movements of rates of return on investment.

Production in this model is assumed as multi-nested CES (Constant Elasticity of Substitution) function, wherein primary factors do not substitute intermediate inputs, while there could be substitution among the different primary factors. Private households follow a Constant Difference

Fig. 13.1 A Simplified representation of the GTAP model. (Source: Author)

Elasticity (CDE) demand system, wherein they have an income elasticity and cross-price elasticities of demand for all goods and services. We also follow the Armington assumption, which entails product heterogeneity within each GTAP sector, both within and across the countries, so that domestic production ad imports are not perfect substitutes or perfect complements, but somewhere in between the two extremes.

In contrast with the standard GTAP Data Base and model, introduced in studies such as Aguiar et al. (2016) and Aguiar et al. (2019), GTAP-Power data and model captures the disaggregated details of the different types of power generation. In particular, as relevant for our study, it includes the base and peak load generation of hydroelectric power as distinct sectors, among others. It also captures the substitution between different sources of energy and emissions generated by the production and consumption of fossil fuels for various activities across the world. We employ this dataset and model for this study, by first aggregating the 141 regions to 7 regions, giving due importance to the Central Asian countries and then aggregating the 76 GTAP sectors into 19 sectors, giving due importance to electricity generation sectors. Table 13.1 shows the regions and countries in our study. Table 13.2 shows the sectors in our study. While the base year of our data (GTAP 10 Database) is 2014, we update it to 2019, using the macro data from the World Bank dataset. We mainly focus on covering all the Central Asian countries, as well as some of the major economic groups in the world: EU and NAFTA, while folding all the other countries into an aggregated region called ROW, viz, Rest of the World. We keep food, manufactures and other services as non-energy sectors, which have been aggregated from a much more granular sectoral structure in GTAP. However, we keep the energy sectors in their levels of

Table 13.1 Regions used in the model

No	*Region*	*Description*
1	NAFTA	NAFTA members
2	EU	EU members
3	kaz	Kazakhstan
4	kgz	Kyrgyzstan
5	tjk	Tajikistan
6	TkmUzb	Turkmenistan and Uzbekistan
7	ROW	Rest of the world

Source: Author

Table 13.2 Sectors reflected in the model

No	*Sector*	*Description*
1	Food	Agriculture, forestry and fisheries
2	Coa	Coal
3	Oil	Oil
4	Gas	Gas
5	Mnfc	Manufacturing
Power generation sectors		
6	TnD	Transmission and distribution
7	NuclearBL	Nuclear Base load
8	CoalBL	Coal Base load
9	GasBL	Gas Base load
10	WindBL	Wind Base load
11	HydroBL	Hydro Base load
12	OtherBL	Other Base load
13	OilBL	Oil Base load
14	GasP	Gas peak load
15	HydroP	Hydro peak load
16	OilP	Oil peak load
17	SolarP	Solar peak load
Other sectors		
18	Gdt	Gas distribution
19	Serv	Other services

Source: Author

full disaggregation so as to capture the intersectoral linkages and competition among different sources of energy.

With this aggregation, we pursue a hypothetical simulation wherein the hydroelectric sector (both base and peak load) in all the Central Asian countries is increased by 66%. We recognise that this is an extreme possibility from an investment perspective and a realistic possibility from a resource availability perspective in some of these countries. Therefore, we consider a Systematic Sensitivity Analysis (SSA), wherein the shocks are drawn from a uniform distribution with a lower bound of 33% and an upper bound of 99%, implying an almost doubling of this sector. Our results are all shown in terms of lower and upper bound, computed based on Chebyshev's inequality using the means and standard deviations from this SSA exercise.

To begin with, a cursory look at Table 13.3 suggests that hydroelectric power is quite large in the case of Kyrgyzstan and Tajikistan and quite tiny

Table 13.3 Initial Data of Hydroelectric sectors (Hydro Electric Power) in 2019, as calculated from GTAP 10 Data Base

Country	*2019 Hydro Electric Power Peak Load in Billion $*	*2019 Hydro Electric Power Base Load in Billion $*	*2019 total Hydro Electric Power Output in Billion $*	*2019 total Hydro Electric Power Output in %*
Kazakhstan	0.32	0.00	0.32	0.18
Kyrgyzstan	0.16	1.23	1.39	17.15
Tajikistan	0.08	0.88	0.96	11.83
Turkmenistan and Uzbekistan	0.00	1.02	1.02	0.94

Source: Author

in the case of Kazakhstan, Turkmenistan and Uzbekistan. Therefore, we may expect large macroeconomic impact in the first two countries and a relatively small impact in others.

13.5 Potential Impact of a Hypothetical Expansion of Hydroelectric Power Sector

Our macro-economic results suggest that GDP may increase quite considerably in Kyrgyzstan and Tajikistan, while the increase may be relatively small in others, just as expected based on our observation from Table 13.2. The more interesting aspect here is, when we look at the upper bound, which may be close to doubling of the Hydroelectric Power sectors in these countries, the percent changes are much higher than the Hydroelectric Power sector's contribution to GDP in Kazakhstan, Kyrgyzstan and Tajikistan; however, for Turkmenistan and Uzbekistan, GDP impact may be relatively smaller than the relative size of Hydroelectric Power sectors therein. The multiplier effect that we can infer from these numbers are in the range of 1.25–1.5 for the first three countries, and about 0.9 for the other two. Overall, in the whole region, we can expect a GDP boost of 2–5.7 billion $, coming from this expansion of Hydroelectric Power sectors.

Table 13.5 shows the macroeconomic results in relative terms, for other variables. In terms of private consumption and government expenditure, the changes are relatively small and consistent with our expectations that the Hydroelectric Power sector may not directly contribute to these two final demand categories. In all countries except Tajikistan, there is a secular expansion in all the GDP components, with greater positive action happening in investment, exports and imports. Given the relatively large and diverse manufacturing and services sectors in these countries, the demand for imports does not increase hugely, while the demand for exports increases to a similar extent. Furthermore, for Kazakhstan, Turkmenistan and Uzbekistan, given the small share of Hydroelectric Power in their economy, the impact on these macroeconomic variables is not extraordinarily high. Given the high share of Hydroelectric Power in Kyrgyzstan, the results are much more pronounced, but they are still positive for all variables because this country has large and diverse manufacturing and services sectors, which can chip in for additional domestic demand supplementing the increasing imports, without having to eat into the supply available for exports.

However, the most striking results are the huge increase in imports and investment, accompanied by a heavy fall in exports, in Tajikistan. The reason for this is that this country depends a lot on imported manufactures both for investment demand and for the Hydroelectric Power sector, as well as other sectors. When the Hydroelectric Power sector gets a major push as we are simulating herein, its demand for imported inputs from the manufacturing sector increases tremendously, which is all the more important given its huge contribution to GDP in this country. Furthermore, the forward and backward linkages ensure that there is a demand increase for many other sectors as well as supply capacity expansion across the board because electricity is an important ingredient to all production. The excessive demand for all products in Hydro Electric Power and other sectors imply greater absorption of domestic production within the economy, to further supplement the increased imports. This reduces the room for exports, which falls. In order to match the steep increase in trade deficit coming from increased imports and decreased exports, investments pour in from rest of the world, with a rather static savings expansion.

Like any economic modelling analysis, this modelling exercise is not without limitations and assumptions that may be hard to defend as being realistic. Firstly, Turkmenistan and Uzbekistan may possess strikingly different economic structures, but we consider them together here due to data limitations. Secondly, we may not capture the nuances of hydroelectric power generation, such as the impact on ecosystem and water scarcity, in the model, so we discuss them at length in the next section. Thirdly, the

Table 13.4 GDP results of the expansion of Hydro-electric sectors in Central Asia

Country	*2019 GDP in Billion $*	*Lower Bound Change Billion $*	*Upper Bound Change Billion $*	*Lower Bound Change in %*	*Upper Bound Change in %*
Kazakhstan	170.33	0.22	0.42	0.13	0.25
Kyrgyzstan	8.09	1.00	2.06	12.35	25.48
Tajikistan	8.15	0.52	2.36	6.34	28.98
Turkmenistan and Uzbekistan	108.49	0.24	0.84	0.23	0.78

Source: Author

Table 13.5 Other macro results for a 66% expansion of Hydroelectric Power (in % changes)

Country	*Investment*	*Private consumption*	*Government expenditure*	*Exports*	*Imports*
Kazakhstan	0.25	0.22	0.42	0.43	0.51
Kyrgyzstan	2.29	1.00	2.06	18.96	10.26
Tajikistan	13.80	1.52	2.36	-14.91	19.10
Turkmenistan and Uzbekistan	0.49	0.24	0.84	0.41	0.43

Source: Author

set of elasticities and datasets employed in this model are well documented and publicly available, having gone through many peer-reviewing processes, and yet may not be completely free from errors and defects. Therefore, our analysis should be taken in the context of overall high-level economic impact and their drivers. This cannot be taken as a forecasting or prediction exercise with sacrosanct stature given to the numbers in Tables 13.4 and 13.5. Therefore, we focus on the insights provided by these numbers, rather than the numbers themselves, per se.

13.6 Conclusions

Energy-water nexus debate has multiple dimensions, such as water use in thermal power plants, power subsidies in agriculture resulting in water depletion and water use in hydroelectric power plants. While the first two are the negative aspects of this nexus, the hydroelectric power is a predominantly positive synergy between water and energy, as it is one of the cleanest ways of power generation. Therefore, we focus on this topic in the context of water-energy nexus in general. Furthermore, in Central Asia, two of the five countries are water-abundant and have mountainous landscapes that are extremely well suited for hydroelectricity without much need for artificial reservoirs. These realities motivated us to focus on the potential for expansion in this sector, to boost the power generation capacity, and hence the entire economy in this region.

We employ a widely used multi-country multi-sector Computable General Equilibrium model, which captures the interrelationships, competitions, complementarities and synergies between different sectors across the world. This is the GTAP-Power model, which enhances the standard GTAP model with the ability to distinguish between the different sources of electricity generation. We mainly focus on a scenario in which the hydroelectric power sector in all the Central Asian Countries is expanded by 66%, while we consider the macroeconomic impact of such expansion by 33–99%, in other words, expansion by a third to almost twice.

From the results of this study, of the expansion of the Hydroelectric Power sector in Central Asian countries, we may conclude that broadly speaking, such a proposition can have a profound positive macroeconomic impact. In the case of Kazakhstan, while the impact may not be huge, we may still observe significant increases in GDP ranging from 0.22 to 0.42 billion USD, coming from increases in all components of GDP. For Turkmenistan and Uzbekistan put together, the results may be from a larger range of 0.24–0.84 billion USD.

Kyrgyzstan and Tajikistan, which currently depend a lot of Hydroelectric Power sectors, may see enormous macroeconomic expansion in their GDP in the light of Hydroelectric Power expansion. For the former, it may be 1–2 billion USD, while for the latter it maybe 0.5–2.4 billion USD. However, the nature of expansion could be very different in these two countries. Kyrgyz economy, being more diverse than the Tajik economy, may witness a more stable and secular increase in all GDP components. Tajik economy, on the other hand, may witness a turbulent transition, with a huge decrease in exports, coupled with a huge increase in imports and investments.

While the increase in investments and imports are welcome, the decrease in exports may be a difficult impact that may be acceptable to the policymakers. Therefore, in order to avail the enormous benefits from the expansion of the Hydroelectric Power sector in Tajikistan, concerted efforts may be needed to expand the domestic supply chains in manufacturing and services. Perhaps reduced tariffs, investments in productivity increases and improving the investment climate and facilitation environments for the Hydroelectric Power expansion may go a long way in ensuring a smooth transition to Hydroelectric Power-powered economy in Tajikistan.

An important word of caution needs to be expressed about the fact that hydroelectric power generation is not completely free of environmental impact and emissions. In contrast, it affects biodiversity by affecting the natural water flow and also causes several other challenges such as reducing the water available for other sectors, for example. Therefore, this study should not be misconstrued to mean that we are strongly recommending a huge expansion of hydroelectric power generation sector. We recognise these limitations and propose to the policymakers a meticulous environmental impact assessment before starting any single hydroelectric power project, to comprehensively understand the impact on biodiversity, water availability for other sectors, possibilities to reduce evaporation related flux, advanced eco-friendly technologies that may be employed to minimise the social and economic damage caused as a result of the environmental adversities and possibility to share power with other countries to avoid expansion of artificial reservoirs dedicated for hydroelectric power generation in water-scarce countries in the region.

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[1] Note: Page numbers followed by 'n' refer to notes.

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