ENERGY, CLIMATE AND THE ENVIRONMENT

Off-Grid Solar Electrification in Africa

A Critical Perspective

Edited by Nathanael Ojong

palgrave
macmillan

Energy, Climate and the Environment

Series Editors
David Elliott, The Open University, Milton Keynes, UK
Geoffrey Wood, School of Law, University of Stirling, Stirling, UK

The aim of this series is to provide texts which lay out the technical, environmental and political issues relating to proposed policies for responding to climate change. The focus is not primarily on the science of climate change, or on the technological detail, although there will be accounts of this, to aid assessment of the viability of various options. However, the main focus is the policy conflicts over which strategy to pursue. The series adopts a critical approach and attempts to identify flaws in emerging policies, propositions and assertions. In particular, it seeks to illuminate counter-intuitive assessments, conclusions and new perspectives. The intention is not simply to map the debates, but to explore their structure, their underlying assumptions and their limitations. The books in this series are incisive and authoritative sources of critical analysis and commentary, clearly indicating the divergent views that have emerged whilst also identifying the shortcomings of such views. The series does not simply provide an overview, but also offers policy prescriptions.

Nathanael Ojong
Editor

Off-Grid Solar Electrification in Africa

A Critical Perspective

palgrave
macmillan

Editor
Nathanael Ojong
International Development Studies
York University
Toronto, ON, Canada

ISSN 2947-8561 ISSN 2947-857X (electronic)
Energy, Climate and the Environment
ISBN 978-3-031-13824-9 ISBN 978-3-031-13825-6 (eBook)
https://doi.org/10.1007/978-3-031-13825-6

This Palgrave Macmillan imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Acknowledgements

This book is the product of collaborative efforts. Therefore, I am greatly indebted to everyone who has contributed to the project in any shape or form. First, I acknowledge the financial support of the Social Sciences and Humanities Research Council of Canada as part of its Insight Development Grant programme (2021–2023). Although the project funded (i.e., *The antinomies of renewable energy technologies: Debt, finance capitalism, and solar home systems*) specifically focuses on a few countries in Africa for which research is ongoing, the funding helped me to hire a research assistant who worked to support this final output. Second, I thank all the authors in this volume for putting the effort in this project. I am aware that I asked many of them to make substantive revisions in the light of feedback from the anonymous reviewers. Third, I greatly appreciate the insightful and constructive feedback received from the anonymous reviewers of our book, including Sini Numminen. Their feedback on the different chapters contributed to improving the overall quality of this volume. Fourth, I would like to thank Emmanuel Graham who did a splendid job as research assistant supporting me in finishing this volume. Fifth, I thank Palgrave Macmillan editor Rachael

Ballard for support along the way and for the fruitful collaboration. Furthermore, I wish to thank Redhu Ruthroyoni and Connie Li at Palgrave Macmillan for their editorial assistance, which facilitated the rapid finalization of the book. Sixth, I am fortunate to be working in an environment where I am surrounded by supportive colleagues such as Uwafiokun Idemudia, Gertrude Mianda, Mary Goitom, Mohamed Sesay, Sylvia Bawa, Merouan Mekouar, Denielle Elliott, Eduardo Canel, Pablo Idahosa and Viviana Patroni. Lastly, I am greatly indebted to my spouse, Rita, and daughters, Kezia and Nathania, for their understanding in relation to long hours of work.

Contents

Notes on Contributors

Anugwom Edlyne E. is a Professor of Sociology and Development at the University of Nigeria and currently on fellowship at the Re-Figuration of Spaces Collaborative Research Network at the Technical University, Berlin. He has held positions/fellowships in diverse places such as Leiden, Wassenaar, Birmingham, Bridgewater, Edinburgh, Mainz, and Cape Town. His research interests are in the areas of renewable energy technologies, political sociology of development, social conflict, and terrorism, with a particular focus on Africa. Significant publications include Research Methods in Social Sciences (2006, Fourth Dimension Pub), The Boko Haram Insurgence in Nigeria: Perspectives from Within (2019, Palgrave Macmillan), From Biafra to the Niger Delta Conflict: Memory, Ethnicity and the State in Nigeria (2019, Lexington Books), Development in Nigeria: Promise on Hold (2020, Routledge) and Public Health in Developing Countries: Challenges and Opportunities (edited volume; 2020, Intech Open).

Bisaga Iwona is currently an independent energy access consultant and a Research Fellow at Loughborough University. She also holds an Honorary Lectureship at University College London (UCL), where she is among the founding members of the Energy & Development Group. She specializes in the socioeconomics of energy access in low-income contexts and combines her training in sociology, anthropology, development planning and engineering to address energy needs of rural and marginalized populations through user-centric approaches. Between 2018 and 2020, she headed the research department at one of the major providers of off-grid energy systems in Sub-Saharan Africa. Her experience in the energy sector cuts across non-profit, private and policy sectors, and academia. She holds a PhD in Energy from UCL.

Etienne Emilie is a Ph.D. Candidate at the Université Grenoble Alpes, France. She studies how socio-technical and economic networks surrounding solar mini-grids evolve over time, looking at governance, maintenance and business models. She works within PACTE and GAEL laboratories of the Université Grenoble Alpes, as well as the company Schneider Electric. Prior to her Ph.D., Emilie Etienne worked for ten years as a development practitioner, focusing on appropriate technologies' transfer for urban and rural populations.

Ferrall Isa received her PhD in Energy and Resources Group from the University of California, Berkeley in 2022. She worked alongside Professor Daniel M. Kammen in the Renewable and Appropriate Energy Laboratory. As a scholar of energy justice, Isa centres the concerns of marginalized communities in her work to make energy more accessible, reliable, and clean for all communities. Her research uses computational modelling and data science techniques to gain policy and decision-relevant insights for industry, non-profits, and public regulators. Her dissertation investigates issues of energy access, distribution of energy burdens, the opportunities for solar technology innovations, and fairness of energy decision-making through projects on access to decentralized solar energy in Sub-Saharan Africa and power outages around the world.

Francius Rhosnie is a doctoral candidate at the Université Grenoble Alpes, France. Her research focuses on rural electrification policies in the Global South, including in the development of solar photovoltaic markets. She is interested in the negotiations around the constraints of solvency and non-consumption in the development of energy access policies based on market solutions.

Gill-Wiehl Annelise is currently an NSF Graduate Student Researcher and PhD Candidate in the Energy & Resources Group at the University of California, Berkeley, co-advised by Dr. Daniel Kammen and Dr. Isha Ray. Annelise's research investigates household energy access in low- and middle-income countries utilizing impact evaluation methods. Her dissertation work centres upon a step wedge randomized control trial investigating micro-savings' effect on clean cooking fuel consumption in Tanzania. She also studies the quality of carbon credits from cookstove projects on the voluntary carbon market, the impact of different clean cooking pathways (e.g., biomass pellets vs. LPG) and decentralized electrification solutions in East Africa. Finally, she evaluates her work's implications for energy justice and climate equity, focusing on women and low-income households.

Jacome Veronica is an Assistant Professor in energy geography at Temple University. In her research, she studies energy development and environmental justice through the lens of resource geography and political economy. Her research has investigated the presumptions and precarity imbedded in contemporary electricity systems.

Kammen Daniel is the James and Katherine Lau Distinguished Professor of Sustainability at the University of California, Berkeley, with parallel appointments in the Energy and Resources Group, the Goldman School of Public Policy, and the department of Nuclear Engineering. He is currently serving as the Senior Advisor for Energy Innovation at the United States Agency for International Development (USAID). Kammen was appointed by then Secretary of State Hilary Clinton in April 2010 as the first energy fellow of the new Environment and Climate Partnership for the Americas (ECPA) initiative. In 2016, he began as the Science Envoy for US Secretary of State John Kerry, where he served until August 2017. Kammen is the founding director of the Renewable and Appropriate Energy Laboratory (RAEL; http://rael.berkeley.edu) and was Director of the Transportation Sustainability Research Center from 2007 to 2015. He has founded or is on the board of more than 10 companies, and has served the State of California and US federal government in expert and advisory capacities. Dr. Kammen has served as a contributing or coordinating lead author on various reports of the Intergovernmental Panel on Climate Change since 1999. The IPCC shared the 2007 Nobel Peace Prize. From 2010 to 2011, Dr. Kammen served as the World Bank Group's first Chief Technical Specialist for Renewable Energy and Energy Efficiency.

McWilson Wilson Kodwo is currently a PhD candidate in Urban Sustainability Policy at the Hong Kong Polytechnic University. He earned a MSc Urbanisation and Development from the London School of Economics. He also holds a BSc degree in Real Estate. His research interests are urban political economy, the production of space, and state regulation.

Mensah Gloria is a Chartered Energy Economist with accreditation from the Global Academy of Finance and Management, USA. She also doubles as a Chartered Financial Economist. Gloria holds a degree in MSc Economics and Development Economics from the University of Nottingham, UK. She also holds a master's degree in MSc Business Management from the Hong Kong Baptist University and is currently pursuing postgraduate studies in Human Resource Management and Organisational Behaviour at the Lingnan University in Hong Kong. Gloria's research interests include energy economics, international development, public policy, and business development.

Munro Paul is an Associate Professor in Human Geography within the Environment and Society Group at the University of New South Wales. He has an established research record in the fields of political ecology and environmental history, and has written extensively on the topics of forest governance and energy transitions with a particular geographical focus on Sub-Saharan Africa.

Ojong Nathanael is Assistant Professor of International Development Studies and Deputy Director of the Harriet Tubman Institute for Research on Africa and its Diasporas at York University. He is a member of the Knowledge Network of African Experts established by the United Nations Office of the Special Adviser on Africa to help shape economic and social policy in Africa. His work encompasses renewable energy technologies and finance capitalism, energy and sustainability, urban and rural livelihoods, financial inclusion entrepreneurship, informal economies, socio-cultural influences on health outcomes, and social protection in Africa. He is author of *The Everyday Life of the Poor in Cameroon: The role of social networks in meeting needs* (Routledge, 2020). His research has been published in high-impact journals such as *Energy Research & Social Science*, *Journal of Business Research*, and *Third World Quarterly*, among others. Dr. Ojong is Associate Editor of *Energy Exploration & Exploitation*.

Saini Anjali is a senior professional in renewable energy, climate change and environmental management with over twenty years' experience in a variety of environmental, energy, tourism and conservation related projects in Kenya and across Africa. She has a deep interest in the interface between the private sector and development through innovation and entrepreneurship, and early-stage investing. In addition, she has participated in three separate collaborative research projects over the last decade, with the main theme of energy access in rural areas without electricity grid and with high levels of poverty.

Samarakoon Shanil is a Postdoctoral Researcher at the University of New South Wales, Australia. He holds a Ph.D. in Environmental Humanities from the University of New South Wales (Australia). He has 15 years of experience working on projects relating to energy, cooperatives and agroecology across Malawi and Sri Lanka. His research centres on the social dynamics of energy transitions and issues of energy justice, particularly across the Global South.

Trompette Pascale is a sociologist, CNRS Senior Research Fellow at the PACTE research centre at the University of Grenoble Alpes, France. She works in the areas of economic sociology, sociology of markets and sociology of innovation. Her research interest relates to market-based solutions for public and social concerns. Current projects concern the development of market-based solutions to poverty in developing countries, with a special interest on rural electrification in Senegal. Her most recent publications in English appeared in journals such as *Consumption, Markets & Culture*, *Journal of Cultural Economy*, *Science Studies*, and *Management and Organization History*.

Ulsrud Kirsten is a senior researcher in social science, with specialization on qualitative methods and participatory research. She holds a PhD in human geography from the University of Oslo, Norway, and has 12 years of research experience on conditions for inclusive energy access, gender- and context-sensitive off-grid solar power provision, and geographical transfer of social and technological innovations. She has participated in three major research projects at the University of Oslo and coordinated two of these, in close cooperation with engineers and social scientists from sub-Saharan Africa, South Asia and Northern Europe. Key interests are to identify lessons learned on a diversity of off-grid solar power models including the challenges of long-term operational, economic and institutional sustainability. She also investigates issues of systemic changes and higher level political and economic interests that influence the electricity provision on the ground.

Zalengera Collen is a Senior Lecturer in Renewable Energy Technologies in the Department of Energy Systems at Mzuzu University in Malawi. He is a Profession Engineer (PrEng.) registered with the Malawi Engineering Institution. His teaching, research, and publications are focused on renewable energy innovation and diffusion approaches for enhancement of sustainable livelihoods.

Acronyms

AECF	Africa Enterprise Challenge Fund
ANEV	Agence Nationale des Ecovillages
ASER	Agence Sénégalaise de l'Electrification Rurale
BoP	Bottom of the Pyramid
BRD	Development Bank of Rwanda
CERER	Center for Studies and Research on Renewable Energies
CIF	Climate Investment Funds
CRSE	Commission de Régulation du Secteur de l'Électricité
CSR	Corporate Social Responsibility
DANIDA	Danish International Development Agency
DFID	Department for International Development
DRE	Decentralized Renewable Energy
EAQIP	Rwanda Energy Access and Quality Improvement Project
EARF	Energy Access Relief Fund
ECOWAS	Economic Community of West African States
ECREEE	Regional Centre for Renewable Energy and Energy Efficiency
EDCL	Energy Development Corporation Limited
EDF	Électricité de France
EDPRS	Economic Development and Poverty Reduction Strategy
EnDev	Energizing Development

ERA	Energie Rurale Africaine
ERIL	Electrification Rurale d'Initiative Locale
ESMAP	Energy Sector Management Programme
EUCL	Energy Utility Corporation Limited
FAO	Food and Agriculture Organization
FCDO	Foreign, Commonwealth & Development Office
GDT	Gestionnaires Délégués Transitoires
GEDAP	Ghana's Energy and Development Access Project
GIZ	Gesellschaft für Internationale Zusammenarbeit
GOGLA	Global Off-Grid Lighting Association
GoM	Government of Malawi
GoR	Government of Rwanda
GSMA	Global System for Mobile Communications
IEA	International Energy Agency
IFC	International Finance Corporation
IRENA	International Renewable Energy Agency
JICA	Japanese International Cooperation Agency
KNES	Kenya National Electrification Strategy
KOSAP	Kenya Off-Grid Solar Access Project
LED	Light-Emitting Diode
MAREP	*Malawi Rural Electrification Programme*
MBS	Malawi Bureau of Standards
MCC	*Millennium Challenge Corporation*
MDGs	Millennium Development Goals
MERA	Malawi Energy Regulatory Authority
MoMo	Mobile Money
MRES	Malawi Renewable Energy Strategy
NEP	National Electrification Plan
NGO	Non-Governmental Organization
NREP	Nigerian Rural Electrification Programme
ONE	Office National de l'Electricité du Maroc
PASER	Plan d'Action Sénégalais d'Electrification Rurale
PAYG	Pay-As-You-Go
PNUER	Programme National d'Électrification Rurale
PREM	Programme Energétique Multisectoriel
PUER	Programme d'Urgence d'Électrification Rurale
PV	Photovoltaic
REA	Rural Electrification Agency
REBs	Rural Electrification Boards

REF	Rural Electrification Fund
REG	Rwanda Energy Group
REIAMA	Renewable Energy Association of Malawi
RESIP	Rural Electrification Strategy and Implementation Plan
RURA	Rwanda Utilities Regulatory Authority
SDGs	Sustainable Development Goals
SE4All	Sustainable Energy for All
SENELEC	Société Nationale d'Électricité du Sénégal
SHSs	Solar Home Systems
SIDA	Swedish International Development Cooperation Agency
SMEs	Small- and Medium-Sized Enterprises
SSA	Sub-Saharan Africa
TANESCO	Tanzania Electric Supply Company
TANGSEN	Tanzania Gender and Sustainability Energy Network
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VAT	Value-Added Tax
WTP	Willingness to Pay

List of Figures

List of Tables

1

Energy Justice and Off-Grid Solar Electrification in Africa: Trends, Narratives and Contestations

Nathanael Ojong

1.1 Introduction

Access to sustainable energy remains a major challenge for energy policymakers in Africa. Based on estimates, 600 million people in sub-Saharan Africa (SSA)—about 57% of the population—are without access to electricity (IEA, 2019). Total electricity use for over a billion people in SSA (excluding South Africa) is less than that of Spain (*The Economist*, 2022). Power consumption per capita in SSA (excluding South Africa), estimated at 180 kWh, is very low, compared to 13,000 kWh per capita in the United States and 2000 kWh in other countries in the Global South (AfDB, 2019). According to estimates, in 2019, 90 million, 70 million and 58 million people were without access to electricity in Nigeria,

N. Ojong (✉)
International Development Studies, York University,
Toronto, ON, Canada
e-mail: nojong@yorku.ca

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*,
Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_1

Democratic Republic of Congo and Ethiopia respectively, and globally, they were the largest deficit countries (World Bank, 2021).

Additionally, in several countries in the continent even people who are connected to the national grid face frequent power outages. In the last three decades, more than 500 million people in the continent have experienced power outages, in over 20 countries, including Kenya (Kiprop et al., 2019), Nigeria (Babajide & Brito, 2021), Ghana (Amoah et al., 2019; Boamah & Rothfuß, 2020), and Cameroon (Amadu & Samuel, 2020; Landry, 2018; Muh et al., 2018; Njoh et al., 2019). In Liberia, over 50% of households connected to the national grid report that they never have electricity; in Uganda and Sierra Leone, more than 30% of households connected to the grid never have electricity, while in countries such as Burundi, Guinea and Zimbabwe, more than half of households connected to the grid receive electricity less than 50% of the time (Blimpo & Cosgrove-Davies, 2019). In Cameroon, power outages last at least 1000 hours per annum (Amadu & Samuel, 2020; MINEE, 2015).

Solar power is increasingly regarded as having an important role to play in tackling the continent's energy issues. The attractiveness of solar power is because its 'functioning depends on one of the continent's most abundant resources, namely solar radiation' and '[g]iven its location on the equator, Africa emerges as one of the world's sunniest continents' (Njoh et al., 2019: 17). This abundance of solar radiation in the continent has been used by advocates of renewable energy or solar energy to be more precise, to push for off-grid solar electrification in the continent.

Off-grid solar technologies, that is those solar energy technologies which function outside the national grid such as lanterns, pico-systems, solar home systems, micro- or mini-grids are increasingly being used in Africa to help reduce the electricity access gap as well deal with the limitations of the national grid. This push for off-grid solar electrification in the continent received renewed support, as it is in line with the Sustainable Development Goal 7 (SDG7) that aims 'to ensure access to affordable, reliable, sustainable and modern energy for all'. In SSA, sales of single-light lanterns and small solar home systems of 10 W or less, increased from less than half a million in 2011 to 11.3 million in 2015 (Africa Progress Panel, 2016). Sub-Saharan Africa accounts for 70% of the total global sales of solar home systems (Kizilcec & Parikh, 2020). In East Africa, 2.43 million units of certified off-grid solar products, such as solar lanterns and solar home systems, were sold in the second half of 2019, an increase of 40% over the first half of that year (GOGLA, 2019). In West Africa, 182,000 portable lanterns and 124,000 solar home systems were sold in the second half of 2020 (GOGLA, 2021). In Central Africa, 92,000 portable lanterns were sold in the second half of 2020, that is a 261% increase compared to the first half of 2020 (GOGLA, 2021). After over a decade of using off-grid solar technologies in the continent, the time is ripe to take stock of the off-grid solar energy sector.

More precisely, we aim to take stock of off-grid solar electrification in Africa by examining how political, economic, institutional, and social forces shape the adoption of off-grid solar technologies, including how issues of energy injustice are manifested at different levels and spaces. Hence, with such a vast field before us, we ask a few guiding questions that will begin the debate. How do political, economic, institutional and social forces influence the adoption of off-grid solar technologies in Africa? What are the energy injustices associated with off-grid electrification? And how are these injustices manifested? These are important questions which need answers since off-grid technologies are now part of the energy landscape in Africa and energy systems affect people's lives. Notably, our focus on injustices in the off-grid solar sector in Africa is of particular importance since the energy justice framework is often applied to Global North-based case studies. As Lacey-Barnacle et al. (2020: 123) puts it:

> [T]here are few evaluations of particular energy justice issues or themes arising in developing country contexts, and which therefore either require new theoretical approaches, could start a dialogue to compare these themes with those arising in developed country contexts, or indeed which may offer new lessons for developed country contexts.

To begin, this chapter first focuses on the concept of 'energy justice'. I examine various approaches to energy justice, including engaging with western and non-western perspectives of the concept. The final section of this chapter shows how the different chapters of this volume engage with our guiding questions in three parts: history and politics of off-grid solar electrification, manifestations of energy injustices and enabling uptake.

1.2 Off-Grid Solar and Energy Justice: A Conceptual Framework

As the benefits and impacts of energy systems, including off-grid solar technologies, are distributed highly disproportionately, 'energy justice' as a concept—rooted in environmental justice, that focuses on the uneven and unjust distribution of environmental effects such as pollution and climate change (Agyeman et al., 2002, 2003)—has gained rapid usage in energy-related social science (Jenkins et al., 2021; Sari et al., 2017; Sovacool & Dworkin, 2014). Energy justice focuses on the nexus between energy with respect to generation and delivery on the one hand, and justice on the other hand (Jenkins et al., 2016). It entails critical analyses of where (in)justice occurs within energy systems, including how justice might be attained, especially in the renewable energy sphere (Jenkins et al., 2016; McCauley et al., 2013; Sovacool et al., 2017). Injustices in the energy system may be related to issues such as class, race, ethnicity, age, gender or spatial and economic inequalities (Feenstra & Özerol, 2021; Healy et al., 2019; Hunsberger & Awâsis, 2019; Lee & Byrne, 2019; Ojong, 2021, 2022; Sunter et al., 2019).

Sovacool and Dworkin (2014: 13) define energy justice as 'a global energy system that fairly disseminates both the benefits and costs of energy services, and one that has representative and impartial energy decision-making'. This definition highlights three core elements: costs (i.e., how the hazards and externalities of energy systems are distributed unevenly), benefits (i.e., how access to energy systems and services are often uneven), and procedures (i.e., failure by energy projects to follow due process and representation with respect to decision-making) (Sovacool, 2013; Sovacool & Dworkin, 2014). Put differently, an energy-just community is one which 'promotes happiness, welfare, freedom, equity, and due process for both producers and consumers […]', 'distribute[s] the environmental and social hazards associated with energy production and use without discrimination […]', 'ensure[s] that access to energy systems and services is equitable' and 'guarantee[s] that energy procedures are fair and that stakeholders have access to information and participate in energy decision-making' (Sovacool & Dworkin, 2014: 13).

Other scholars have defined energy justice as having three central tenets—distribution, recognition, and procedural justice (Heffron & McCauley, 2014; McCauley et al., 2013). Distributive justice focuses on inequities in the distribution of benefits and harms across an energy system (Jenkins et al., 2016; Walker & Day, 2012) and assesses where 'questions about the desirability of technologies in principle become entangled with issues that relate to specific localities' (Owen & Driffill, 2008: 4414). It seeks out injustices and attempts to address them (Jenkins et al., 2016; McCauley, 2018). These harms and benefits are found at various levels of energy systems, that is, extraction, production, consumption, and disposal (Fuller & McCauley, 2016). Framed this way, distributional justice is linked to issues of poverty, inequality, especially as they relate to people in marginalized communities. Here justice entails the distribution of what the influential social theorist, John Rawls (1971: 62), termed the 'primary goods' of 'rights and liberties, powers and opportunities, and income and wealth'. Rawls (1971) contends that these primary goods should be distributed in a manner a hypothetical person would choose if, at that time, they were ignorant of their own status in society. In other words, 'to ask whether a society is just, is to ask how it distributes the things we prize…A just society distributes these goods in the right way; it gives each person his or her due' (Sandel, 2009: 19). This points to 'justice as fairness' or justice as just distribution (Rawls, 1971).

In the renewable energy sphere, justice as just distribution is complex and plays out differently depending on the geographical and historical contexts. The embeddedness of an energy system in these contexts produces injustices. For instance, marginalized people may give away their land to make way for small-scale renewable electricity systems projects, hence depriving them of income generation opportunities (Ojong, 2022; Osunmuyiwa & Ahlborg, 2022). Deprivation of income generation activities could render access to energy services unaffordable (Osunmuyiwa & Ahlborg, 2022).

Beyond issues associated with land ownership and dispossession as they relate to solar projects, justice as distribution encompasses aspects such as financial burdens of off-grid solar technologies which are shouldered by low-income populations (Grimm et al., 2020; Muchunku et al., 2018), post-acquisition support (Davies, 2018; Rolffs et al., 2015; Samarakoon, 2020; Tillmans & Schweizer-Ries, 2011), and disposal of these off-grid technologies (Cross & Murray, 2018; Samarakoon et al., 2022). Distributive justice engages with critical questions of 'local skills, system maintenance, product longevity, and the environmental impacts of mass consumption' (Cross & Murray, 2018: 102). This conception of distributive justice recognizes the mechanisms that increase energy injustice at multiple scales: landscapes of material deprivation, geographic underpinnings of energy affordability, vicious cycles of vulnerability, and spaces of misrecognition (Bouzarovski & Simcock, 2017).

Recognition justice is another tenet of energy justice. Recognition justice considers people whose views are side-lined in an energy system and how they should be recognized (Jenkins et al., 2016). It recognizes that certain populations, such as the chronically poor, ill, or the unemployed may need affirmative action, and 'seeks to ensure the acknowledgment of marginalized and/or disadvantaged groups in relation to energy systems' (Lacey-Barnacle, 2020: 3). From this perspective, recognition justice gives attention to the ways and degree to which different forms of knowledges are valued and incorporated into an energy system (McCauley et al., 2013).

A lack of recognition may manifest itself not only as a failure to recognize, but also as misrecognizing—a distortion of people's views that may appear demeaning or contemptible (Schlosberg, 2003). In other words, it is vital to acknowledge the divergent perspectives rooted in geography, history, cultural, social, racial, gender and ethnic differences (Fraser, 2014; Munro et al., 2017; Schlosberg, 2003). This framing rejects the expert-driven conception of energy access that excludes perspectives of populations who are the beneficiaries of renewable energy projects (Chatti et al., 2017; Munro et al., 2017).

Procedural justice, a third tenet of energy justice, centres on whether decision-making processes regarding energy systems are fair (Jenkins et al., 2016; McCauley, 2018; Yenneti & Day, 2015). It is concerned with equitable procedures that engage all stakeholders in a non-discriminatory way (McCauley et al., 2013; Walker, 2009). As Sovacool et al. (2019: 582), put it:

> [A]ll major socio-technical transitions require open and democratic participation by a wide range of actors (including firms and consumers, as well as civil society groups, media advocates, community groups, city authorities, political parties, advisory bodies, and government ministries) to minimize unwanted impacts.

This is important since democratic decision-making is fundamental to justice and the production of just outcomes (Young, 1990). Democratic decision-making requires meaningful involvement of all regardless of gender, race, class, religion, sexuality, and income (Buckingham & Kulcur, 2009; Bullard & Johnson, 2000; Schlosberg & Carruthers, 2010).

Framed in terms of decision-making processes, procedural justice takes into consideration a particular set of principles. For example, Sovacool et al. (2017: 687) proposed ten principles: (1) availability (sufficient energy resources of high quality); (2) affordability (stable and equitable prices); (3) due process (ensuring stakeholder participation); (4) transparency and accountability (promoting high quality access to information about energy as well as accountable and transparent forms of energy-related decision-making); (5) sustainability (promoting the sustainable use of resources that minimize waste and adverse impacts on the environment); (6) intra-generational equity (fair access to basic energy services among different communities); (7) intergenerational equity (distributive justice between present and future generations); (8) responsibility (duty to protect the natural environment and minimize energy-related social and environmental costs); (9) resistance (actively oppose energy injustices); and (10) intersectionality (encompassing new and evolving identities).

Beyond the three pillars and principles of energy justice, the conception of energy justice in this book highlights 'not only where and how the benefits and burdens' of off-grid solar energy technologies are 'distributed, but also when and who experience these' (Malakar et al., 2019: 17). With respect to 'who', that is, adopters of off-grid solar technologies, their use of these technologies should not be detrimental to others, as such a scenario goes against the *Ubuntu* philosophy.

Ubuntu is a moral theory of humanness (Akinola & Uzodike, 2017; Metz, 2007; Ramose, 1999; Tutu, 2012) and a theory of justice and fairness (Kgatla, 2016; Moeketsi, 2014). According to the *Ubuntu* philosophy, personhood is formed interdependently through community (Battle, 2009; Mupedziswa et al., 2019), and the wellbeing of individuals cannot be 'divorced from communal imperatives' (Petersen, 2006: 55). In other words, a communitarian ethic is foundational to Ubuntu (Biko, 1987; Mandiva & Chingombe, 2013; Mbigi & Maree, 1995; Mkhize, 2008; Ramose, 1999). Common principles and values rooted in the *Ubuntu* philosophy include mutual caring, reciprocity, respect, harmony, shared responsibility, solidarity, trust, generosity and compassion, dignity, deliberative and consensus decision-making, and inclusivity (Broodryk, 2008; Burgess, 2017; Chigangaidze et al., 2022; Kgatla, 2016; Mabvurira, 2020; Ramose, 1999; Tavernaro-Haidarian, 2018; Tutu, 2012).

With respect to off-grid solar electrification, people's use of energy services should not take precedence over communal world. *Ubuntu* stresses 'living well together' (Deneulin & McGregor, 2010 cited in Norren, 2014: 256), 'with the stronger helping the weaker members of the community' (Munyaka & Motlhabi, 2009). Thus, the uneven distribution of the benefits and harms of energy services goes against community cohesion which is central to *Ubuntu* (Chibvougodze, 2016; Sanusi & Spahn, 2020). Also, the uneven distribution of benefits and harms of energy services, including the marginalization of certain individuals/groups in decision-making or failure to consider views (re)produces inequalities in communities. Munyaka and Motlhabi (2009) emphasize that according to the *Ubuntu* philosophy, all people have *isidima* (dignity) and 'no one is either superior or inferior in humanity'. In sum, this conceptual framework engages with western and non-western perspectives of energy justice.

1.3 About the Book

Off-Grid Solar Electrification in Africa contributes to the emerging gaps in energy justice by examining case studies of injustices in the off-grid solar sector in low-income, non-western societies. Thus, the book takes a historical, contemporary and projective outlook. This positions the aim of this book as one that (1) provides novel and non-western examples of how political, economic, institutional, and social forces shape the adoption of off-grid solar technologies, and (2) considers how issues of energy injustice are manifested at different levels and spaces. In executing this project, we bring together real-world experiences from pre- and ongoing electrification communities in countries such as Ghana, Kenya, Rwanda, Sénégal, Malawi, Tanzania and Nigeria.

Beyond the diverse nature of these countries in terms of their geographical location in West, East and Southern Africa, each is quite unique in terms of its colonial history, economic and institutional infrastructure, and level of adoption of off-grid solar technologies. For instance, Kenya, a former British colony, is the largest market in Africa for off-grid solar products (GOGLA, 2019; USAID & Power Africa, 2019), and according to the country's National Electrification Strategy, off-grid solar technologies have a vital role to play in achieving electricity access for all Kenyans (Lighting Africa, 2018a). Based on estimates, 10 million Kenyans have adopted off-grid solar technologies, up from less than a million in 2009 (Lighting Africa, 2018b). Unsurprisingly, the East African country is regarded as a leader for renewable energy in Africa. Sénégal, a former French colony, has hosted the 'largest number of international interventions, bilateral or multilateral, in the field of renewable energy' (Minvielle, 1999: 63 cited in Trompette et al., 2022). Additionally, as Trompette and colleagues note in their chapter in this volume, this West African country has one of the largest mini-grid portfolios in SSA. Malawi is one of the poorest countries in the world and about 50.7% of its population lives in poverty (World Bank, 2022). It has the lowest average population access to electricity (7.2%) in Southern Africa (McCauley et al., 2022), and one of the lowest population access to electricity (13.4%) in Africa (IEA, 2020). Just 3.9% of rural residents in Malawi are connected to the grid (NSO, 2019). Rwanda is recognized as one of the most vibrant SHSs markets in East Africa (Bisaga & Parikh, 2018), with over 20 SHSs providers. Over 800,000 solar products have been sold in the country since 2014 (USAID, 2019). In 2017, SHSs providers in the country received over US$30 million in investments from for-profit investors (USAID, 2019).

The first part of *Off-grid Solar Electrification in Africa* provides historical, political and institutional perspectives on off-grid solar energy in the continent. The second part then engages with real-world manifestations of injustices in the off-grid solar sector. In the third and final part, the book adopts a projective outlook by identifying opportunities and constraints to the uptake of off-grid solar technologies.

1.3.1 History and Politics of Off-Grid Solar Electrification

This first part of the book sheds light on the history and politics behind the growth of off-grid solar electrification on the continent. It begins with Chapter 2, which uses a historical perspective to critically examine the rapid growth of the off-grid solar sector as an influential response to acute energy poverty across SSA. In particular, the chapter delves into the origins of key players, financial flows and critical junctures in the sector's journey to date. It interrogates the degree to which the social mission that catalyzed the expansion of the off-grid solar sector is being undermined by broader structural dynamics of the capital investment upon which it is reliant. The chapter questions the triumphalist narrative of off-grid electricity access success presented by the sector, with a particular emphasis on how its ideological commitment to market-based solutions create inequitable outcomes.

Chapter 3 examines the politics of off-grid electrification in Sénégal. It scrutinizes the role of public policies in shaping the plural landscapes of rural, off-grid electrification in Sénégal in the last two decades, during which successive proactive policies of so-called 'rural electrification' have taken place. The chapter analyses the way in which these policies and their regulations have shaped different market segments involving a diversity of actors (transnational and local small and medium size enterprises) alongside the state-based electricity leader, Société nationale d'électricité du Sénégal (SENELEC), making offers that combine or compete locally. It argues that opening the sector to private operators who, as the neoliberal narrative goes, are more efficient and well placed to accelerate electrification, has paved the way for an unequal geography with significant territorial disparities in both service provision and pricing. The chapter also argues that these inequalities have given rise to social and political controversies, including internal conflicts among the country's political and economic elites.

Chapter 4 is another example of how policies, institutions and regulation shape the diffusion of off-grid solar technologies. It assesses the last decade of the off-grid solar sector in Rwanda and the critical milestones that have steered its shift from a fragmented and unregulated market of solar products to an important contributor to the country's energy access efforts it is at present. It argues that policies put in place have enabled a significant percentage (60%) of the population to have access to electricity in 2021, compared to just 10% in 2010, with almost 16% of households accessing electricity through off-grid energy systems, mostly solar. The chapter takes a closer look at the country's National Electrification Plan and identifies issues related to procedural justice and recognition justice.

1.3.2 Manifestations of Energy Injustices

Part II explores real-world examples of injustices in the off-grid solar sector. Chapter 5, based on a critical review of the scholarly literature on SHSs in Africa, maps out injustices along multiple dimensions. It argues that the upbeat and mobilizing narratives around the use of this off-grid solar technology often obscures the multiple injustices which are noticeable in their inner workings. It highlights distributional, recognition and procedural injustices with regards to energy access. These injustices are manifested at various levels and spaces, including within households. The chapter also engages with the philosophy of *Ubuntu* as it relates to energy access, hence combining western and non-western philosophical notions of energy justice.

Chapter 6 provides examples of distributive, recognition and procedural injustices in the off-grid solar sector in Malawi. It critically investigates the shift in responsibility for energy provision from the state towards households. In particular, it examines the justice implications of the commoditization of electricity as reflected in a two-tiered off-grid solar market—comprised of both certified and uncertified products. It details how end-users experience these two tiers in terms of issues of affordability and quality, consumer literacy and protection, as well as repair and disposal. While recognizing the limitations of a market-based approach to addressing energy poverty, the chapter concludes with recommendations that could help Malawi's off-grid solar market deliver more just and sustainable outcomes for underserved populations.

Chapter 7 draws on a case study from rural Tanzania to investigate the energy justice implications of off-grid solar in relation to gender and low-income households. It shows that there is equality in the adoption of of-grid solar technologies across female-headed and low-income households; however, this does not imply there is equity in the off-grid solar sector. The chapter contends that although these solar technologies do not seem to actively disadvantage women, their deployment is not a clear win for gender equality as was previously promised. It argues that SHSs are promoted as technologies which increase the quality of life and economic prospects for women, children and low-income groups, but, in practice, solar systems beyond lanterns remain out of reach for these segments of the population.

Chapter 8 provides examples of injustices in the grid and off-grid sectors in Kenya. It shows that even though Kenya is regarded as a shining example due to its impressive results in terms of on-grid and off-grid electrification, there are still segments of the population without access to electricity. The chapter identifies segments of the population without access to both the national grid and off-grid solar technologies and shows why these segments of the population are 'left behind'. It shows that the impressive statistics regarding households connected to the centralized grid conceals the fact that, in practice, some of these households do not have access to electricity. Similarly, the chapter notes that while sales data are often used to estimate how many people have access to solar systems, there are still many unknowns, such as how many of the household-level systems are functioning and how many hours per week do people get from energy services such as powering light bulbs, powering a television, charging a mobile phone and powering kitchen appliances.

1.3.3 Enabling Uptake: Constraints and Opportunities

Part III of this volume adopts a projective outlook by examining the constraints and opportunities related to the adoption of off-grid technologies among people without prior solar energy access experience. Chapter 9 draws on a case study in rural Nigeria to examine the constraints and opportunities associated with the adoption of off-grid technologies. It shows that the low-income status of end-users and economic situation of a given location in terms of economic activities influence the likelihood of adopting off-grid solar technologies. It notes that although most rural households expressed willingness to adopt off-grid solar technologies, their economic condition makes it challenging for them to do so. The chapter shows people did not want to adopt SHSs, since installing the solar panels on roofs renders water, often collected from roofs contaminated. It notes that this is a major constraint to SHS adoption since people use water collected from roofs for cooking and other household activities. The chapter also shows that some people were unwilling to adopt off-grid technologies, as doing so would transfer responsibility for electricity provision from the state to individuals.

Chapter 10 draws on a case study in urban Ghana to explore the constraints and opportunities linked to the adoption of off-grid technologies. It shows that various factors such as affordability, availability of solar products on the market, government incentives, product quality and recommendations from other users influenced the likelihood of people adopting off-grid solar electrification technologies.

In sum, the chapters in this book all speak to the issues of energy justice with a particular focus on off-grid solar technologies. As I show in the concluding chapter (Chapter 11), the different case studies covered in this book render it possible to compare and contrast the manifold manifestations of injustices. This 'compare and contrast' exercise enabled the identification of similar transmission mechanisms for off-grid solar energy policy, and it equally brought to the fore similarities and differences with respect to the application of energy justice theorizing. Thereafter, the chapter critically assess the transformative potentials of renewable energy technologies in general and off-grid solar systems in particular.

References

AfDB. (2019). *Estimating investment needs for the power sector in Africa 2016–2025*. AfDB. https://www.afdb.org/en/documents/estimating-investment-needs-power-sector-africa-2016-2025. Accessed 9 May 2022.

Africa Progress Panel. (2016). *Lights power action: Electrifying Africa*. Africa Progress Panel.

Agyeman, J., Bullard, R. D., & Evans, B. (2002). Exploring the nexus: Bringing together sustainability, environmental justice, and equity. *Space Polity, 6*, 77–90.

Agyeman, J., Bullard, R. D., & Evans, B. (Eds.). (2003). *Just sustainabilities: Development in an unequal world*. The MIT Press.

Akinola, A. O., & Uzodike, U. O. (2017). Ubuntu and the quest for conflict resolution in Africa. *Journal of Black Studies, 49*(2), 91–113.

Amadu, I., & Samuel, F. (2020). Power supply and manufacturing growth: Evidence from Cameroon. *Energy Policy, 147*, 111922.

Amoah, A., Ferrini, S., & Schaafsma, M. (2019). Electricity outages in Ghana: Are contingent valuation estimates valid? *Energy Policy, 135*, 110996.

Babajide, A., & Brito, M. C. (2021). Solar PV systems to eliminate or reduce the use of diesel generators at no additional cost: A case study of Lagos, Nigeria. *Renewable Energy, 172*, 209–218.

Battle, M. (2009). *Ubuntu: I in you and you in me*. Seabury Books.

Biko, S. (1987). Some African cultural concepts. In A. Stubbs (Ed.), *I write what I like: A selection of his writings* (pp. 40–47). Heinemann.

Bisaga, I., & Parikh, P. (2018). To climb or not to climb? Investigating energy use behaviour among Solar Home System adopters through energy ladder and social practice lens. *Energy Research & Social Science, 44*, 293–303.

Blimpo, M., & Cosgrove-Davies, M. (2019). *Electricity access in Sub-Saharan Africa: Uptake, reliability, and complementary factors for economic impact*. World Bank.

Boamah, F., & Rothfuß, E. (2020). 'Practical recognition' as a suitable pathway for researching just energy futures: Seeing like a 'modern' electricity user in Ghana. *Energy Research & Social Science, 60*, 101324.

Bouzarovski, S., & Simcock, N. (2017). Spatializing energy justice. *Energy Policy, 107*, 640–648.

Broodryk, J. 2008. *Understanding South Africa: The Ubuntu way of living*. Ubuntu School of Philosophy.

Buckingham, S., & Kulcur, R. (2009). Gendered geographies of environmental injustice. *Antipode, 41*(4), 659–683.

Bullard, R. D., & Johnson, S. G. (2000). Environmental justice: Grassroots activism and its impact on public policy decision-making. *Journal of Social Issues, 56*(3), 555–578.

Burgess, G. J. (2017). Unpacking inclusivity: Lessons from Ubuntu leadership. In *Breaking the Zero-Sum Game* (Building Leadership Bridges) (pp. 379–394). Emerald Publishing Limited.

Chatti, D., Archer, M., Lennon, M., & Dove, M. R. (2017). Exploring the mundane: Towards an ethnographic approach to bioenergy. *Energy Research & Social Science, 30*, 28–34.

Chibvougodze, D. T. (2016). Ubuntu is not only about human: An analysis of the role of African philosophy and ethics in environmental management. *Journal of Human Ecology, 53*(2), 157–166.

Chigangaidze, R. K., Matanga, A. A., & Katsuro, T. R. (2022). Ubuntu philosophy as a humanistic–existential framework for the fight against the COVID-19 pandemic. *Journal of Humanistic Psychology, 62*(3), 319–333.

Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. *Energy Research & Social Science, 44*, 100–109.

Davies, G. (2018). Clean energy product markets in sub-Saharan Africa: Complex market devices and power asymmetries. *Energy Research & Social Science, 42*, 80–89.

Deneulin, S., & McGregor, J. A. (2010). The capability approach and the politics of a social conception of wellbeing. *European Journal of Social Theory, 13*(4), 501–519.

Feenstra, M., & Özerol, G. (2021). Energy justice as a search light for gender-energy nexus: Towards a conceptual framework. *Renewable and Sustainable Energy Reviews, 138*, 110668.
Fraser, N. (2014). *Justice Interruptus*. Routledge.
Fuller, S., & McCauley, D. (2016). Framing energy justice: Perspectives from activism and advocacy. *Energy Research & Social Science, 11*, 1–8.
GOGLA. (2019). *Global off-grid solar market report semi-annual sales and impact data*. Retrieved from https://www.gogla.org/sites/default/files/resource_docs/global_offgrid_solar_market_report_h1_2019.pdf. Accessed 9 Nov 2020.
GOGLA. (2021). *Global off-grid solar market report semi-annual sales and impact data*. https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h2_2020.pdf. Accessed 10 May 2020.
Grimm, M., Lenz, L., Peters, J., & Sievert, M. (2020). Demand for off-grid solar electricity: Experimental evidence from Rwanda. *Journal of the Association of Environmental and Resource Economists, 7*(3), 417–454.
Healy, N., Stephens, J. C., & Malin, S. A. (2019). Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains. *Energy Research & Social Science, 48*, 219–234.
Heffron, R. J., & McCauley, D. (2014). Achieving sustainable supply chains through energy justice. *Applied Energy, 123*, 435–437.
Hunsberger, C., & Awâsis, S. (2019). Energy justice and Canada's National Energy Board: A critical analysis of the line 9 pipeline decision. *Sustainability, 11*, 783.
IEA. (2019). *Africa energy outlook 2019*. France.
IEA. (2020). *SDG7 Data and projections: access to electricity—Covid-19 reverses electricity access progress*. https://www.iea.org/reports/sdg7-data-and-projections. Accessed 12 May 2022.
Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science, 11*, 174–182.
Jenkins, K., Sovacool, B. K., Mouter, N., Hacking, N., Burns, M.-K., & McCauley, D. (2021). The methodologies, geographies, and technologies of energy justice: A systematic and comprehensive review. *Environmental Research Letter, 16*, 043009.
Kgatla, S. T. (2016). Relationships are building blocks to social justice: Cases of biblical justice and African Ubuntu. *HTS Telogiese Studies/ Theological Studies, 72*(1), 1–6.

Kiprop, E., Matsui, K., & Maundu, N. (2019). The Role of Household Consumers in Adopting Renewable Energy Technologies in Kenya. *Environments, 6*, 95.

Kizilcec, V., & Parikh, P. (2020). Solar home systems: A comprehensive literature review for Sub-Saharan Africa. *Energy for Sustainable Development, 58*, 78–89.

Lacey-Barnacle, M. (2020). Proximities of energy justice: Contesting community energy and austerity in England. *Energy Research & Social Science, 69*, 101713.

Lacey-Barnacle, M., Robison, R., & Foulds, C. (2020). Energy justice in the developing world: A review of theoretical frameworks, key research themes and policy implications. *Energy for Sustainable Development, 55*, 122–138.

Landry, S. (2018). *The Potential of Manufacturing and Industrialization in Africa: Trends, opportunities, and strategies*. Africa Growth Initiative at Brookings.

Lee, J., & Byrne, J. (2019). Expanding the conceptual and analytical basis of energy justice: Beyond the three-tenet framework. *Frontiers in Energy Research, 7*, 99.

Lighting Africa. (2018a). *Off-grid energy has key role in Kenya's new electrification strategy*. https://www.lightingafrica.org/off-grid-energy-has-key-role-in-kenyas-new-electrification-strategy. Accessed 11 May 2022.

Lighting Africa. (2018b). *Kenya: A thriving off-grid market*. https://www.lightingafrica.org/country/kenya. Accessed 11 May 2022.

Mabvurira, V. (2020). Hunhu/Ubuntu philosophy as a guide for ethical decision-making in social work. *African Journal of Social Work, 10*(1), 73–77.

Malakar, Y., Herington, M. J., & Sharma, V. (2019). The temporalities of energy justice: Examining India's energy policy paradox using non-western philosophy. *Energy Research & Social Science, 49*, 16–25.

Mandiva, E., & Chingombe, A. (2013). The Shona proverb as an expression of Hnhu/Ubuntu. *International Journal of Academic Research in Progressive Education and Development, 2*(1), 100–108.

Mbigi, L., & Maree, J. (1995). *Ubuntu, the spirit of African transformation management*. Knowledge Resources.

McCauley, D. (2018). *Energy justice: Re-balancing the trilemma of security, poverty and climate change*. Palgrave Macmillan.

McCauley, D., Grant, R., & Mwathunga, E. (2022). Achieving energy justice in Malawi: From key challenges to policy recommendations. *Climatic Change, 170*, 28.

McCauley, D. A., Heffron, R. J., Stephan, H., & Jenkins, K. (2013). Advancing energy justice: The triumvirate of tenets. *International Energy Law Review, 32*(3), 107–110.

Metz, T. (2007). Toward an African moral theory. *Journal of Political Philosophy, 15*(3), 321–341.

MINEE [Ministry of Water Resources and Energy]. (2015). La Situation Energétique du Cameroun, Yaoundé. MINEE, Yaoundé.

Mkhize, N. (2008). Ubuntu and harmony: An African approach to morality and ethics. In R. Nicolson (Ed.), *Persons in community: African ethics in a global culture* (pp. 25–44). University of Kwazulu-Natal Press.

Moeketsi, L. (2014). Ubuntu and justice as fairness. *Mediterranean Journal of Social Sciences, 5*(9), 544.

Muchunku, C., Ulsrud, K., Palit, D., & Jonker, K. W. (2018). Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? *WIREs: Energy & Environment, 7*(3), 1–15.

Muh, E., Amara, S., & Tabet, F. (2018). Sustainable energy policies in Cameroon: A holistic overview. *Renewable and Sustainable Energy Reviews, 82*(3), 3420–3429.

Munro, P., van der Horst, G., & Stephen Healy, S. (2017). Energy justice for all? Rethinking Sustainable Development Goal 7 through struggles over traditional energy practices in Sierra Leone. *Energy Policy, 105*, 635–641.

Munyaka, M., & Motlhabi, M., et al. (2009). Ubuntu and its mora-social significance. In M. F. Murove (Ed.), *African ethics: An anthology of comparative and applied ethics* (pp. 63–84). University of Kwazulu, Natal Press.

Mupedziswa, R., Rankopo, M., & Mwansa, L. (2019). Ubuntu as a Pan-African philosophical framework for social work in Africa. In J. M. Twikirize & H. Spitzer (Eds.), *Social work practice in Africa: Indigenous and innovative approaches* (pp. 21–38). Fountain Publishers.

Njoh, A. J., Etta, S., Essia, U., Ngyah-Etchutambe, I., Enomah, L., Tabrey, H., & Tarke, M. (2019). Implications of institutional frameworks for renewable energy policy administration: Case study of the Esaghem, Cameroon community PV solar electrification project. *Energy Policy, 128*, 17–24.

Norren, E. Y. D. (2014). The nexus between Ubuntu and global public goods; its relevance for the post 2015 Development Agenda. *Development Studies Research. An Open Access Journal, 1*(1), 255–266.

NSO. (2019). *2018 Malawi population and housing: Census main report*. National Statistics Office. http://www.nsomalawi.mw/images/stories/data_on_line/demography/census_2018/2018%20Malawi%20Population%20and%20Housing%20Census%20Main%20Report.pdf. Accessed 12 May 2022.

Ojong, N. (2021). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.

Ojong, N. (2022). Energizing entrepreneurship. *Nature Energy*. https://doi.org/10.1038/s41560-022-01014-9

Owens, S., & Driffill, L. (2008). How to change attitudes and behaviours in the context of energy. *Energy Policy, 36*(12), 4412–4418.

Osunmuyiwa, O., & Ahlborg, H. (2022). Stimulating competition, diversification, or re-enforcing entrepreneurial barriers? Exploring small-scale electricity systems and gender-inclusive entrepreneurship. *Energy Research & Social Science, 89*, 102566.

Petersen, H. P. (2006). Western humanism, African humanism and work organization. *The Journal of Individual Psychology, 31*(3), 54–61.

Ramose, M. B. (1999). *African philosophy through Ubuntu*. Indiana University.

Rawls, J. (1971). *A Theory of Justice*. Belknap Press.

Rolffs, P., Ockwell, D., & Byrne, R. (2015). Beyond technology and finance: Pay-as-you-go sustainable energy access and theories of social change. *Environment and Planning A, 47*, 2609–2627.

Samarakoon, S. (2020). The troubled path to ending darkness: Energy injustice encounters in Malawi's off-grid solar market. *Energy Research & Social Science, 69*, 101712.

Samarakoon, S., Munro, P., Zalengera, C., & Kearnes, M. (2022). The afterlives of off-grid solar: The dynamics of repair and e-waste in Malawi. *Environmental Innovation and Societal Transitions, 42*, 317–330.

Sandel, M. (2009). *Justice: What's the right thing to do?* Farrar, Straus and Giroux.

Sanusi, Y., & Spahn, A. (2020). Exploring marginalization and exclusion in renewable energy development in Africa: A perspective from Western individualism and African Ubuntu philosophy. In G. Bombaerts, K. Jenkins, Y. Sanusi, & W. Guoyu (Eds.), *Energy justice across borders* (pp. 273–296). Springer.

Sari, R., Voyvoda, E., Lacey-Barnacle, M., Karababa, E., Topal, C., & Islambay, D. (2017). *Energy justice—A social sciences and humanities cross-cutting theme report*. SHAPE ENERGY.

Schlosberg, D. (2003). The justice of environmental justice: Reconciling equity, recognition, and participation in a political movement. In A. Light & A. De-Shalit (Eds.), *Moral and Political Reasoning in Environmental Practice* (pp. 125–156). MIT Press.

Schlosberg, D., & Carruthers, D. (2010). Indigenous struggles, environmental justice, and community capabilities. *Global Environmental Politics, 10*(4), 12–35.

Sovacool, B. K. (2013). *Energy & Ethics: Justice and the Global Energy Challenge*. Palgrave.

Sovacool, B. K., Burke, M., Baker, L., Kotikalapudi, C., & Wlokas, H. (2017). New frontiers and conceptual framework for energy justice. *Energy Policy, 105*, 677.

Sovacool, B. K., & Dworkin, M. H. (2014). *Global energy justice*. Cambridge University Press.

Sovacool, B. K., Martiskainen, M., Hook, A., & Baker, L. (2019). Decarbonization and its discontents: A critical energy justice perspective on four low-carbon transitions. *Climate Change, 155*, 581–619.

Sunter, D. A., Castellanos, S., & Kammen, D. M. (2019). Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity. *Nature Sustainability, 2*, 71–76.

Tavernaro-Haidarian, L. (2018). *A relational model of public discourse: The African philosophy of Ubuntu*. Routledge.

The Economist. (2022, May 5). Yemi Osinbajo on the hypocrisy of rich countries' climate policies. *The Economist*.

Tillmans, A., & Schweizer-Ries, P. (2011). Knowledge communication regarding solar home systems in Uganda: The consumers' perspective. *Energy for Sustainable Development, 15*, 337–346.

Trompette, P., Etienne, E., & Francius, R. (2022). At the margins of the grid: The politics of off-grid electrification in Sénégal. In N. Ojong (Ed.), *Off-grid solar electrification in Africa: Renewable energy transformation or renewable energy injustice?* Palgrave Macmillan.

Tutu, D. (2012). *No future without forgiveness*. Random House.

USAID. (2019). *Off-grid solar energy market Rwanda*. https://www.usaid.gov/sites/default/files/documents/1860/PAOP-Market-Assessment-Brief-Rwanda-English.pdf

USAID and Power Africa. (2019). *Off-grid solar market assessment Kenya*. Report. https://www.usaid.gov/sites/default/files/documents/1860/PAOP-Kenya-MarketAssessment-Final_508.pdf. Accessed 11 May 2022.

Walker, G. (2009). Beyond distribution and proximity: Exploring the multiple spatialities of environmental justice. *Antipode, 41*(4), 614–636.
Walker, G., & Day, R. (2012). Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. *Energy Policy, 49*, 69–75.
World Bank. (2021). *Tracking SDG7: The energy progress report 2021*. World Bank.
World Bank. (2022). *The World Bank in Malawi*. https://www.worldbank.org/en/country/malawi/overview#1. Accessed 12 May 2022.
Yenneti, K., & Day, R. (2015). Procedural (in)justice in the implementation of solar energy: The case of Charanaka solar park, Gujarat, India. *Energy Policy, 86*, 664–673.
Young, I. M. (1990). *Justice and the politics of difference*. Princeton University Press.

Part I

History and Politics of Off-Grid Solar Electrification

2

Off-Grid Enterprise: A Critical History of Small-Scale Off-Grid Solar in Sub-Saharan Africa

Paul Munro, Veronica Jacome, and Shanil Samarakoon

2.1 Introduction

In February 2020, the Global Off-Grid Lighting Association (GOGLA) and the World Bank Group's Lighting Global programme hosted the Global Off-grid Solar Forum and Expo in Nairobi Kenya. The meeting

P. Munro (✉) · S. Samarakoon
The University of New South Wales, Sydney, NSW, Australia
e-mail: paul.munro@unsw.edu.au

S. Samarakoon
e-mail: s.samarakoon@unsw.edu.au

V. Jacome
Temple University, Philadelphia, PA, USA
e-mail: veronica.jacome@temple.edu

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_2

was the fourth sector meeting of its kind,[1] which serve as premier events for the international off-grid solar sector working in the Global South, and in particular for sub-Saharan Africa (SSA). The 2020 Forum and Expo, for example, was opened by The Honourable Uhuru Kenyatta, the President of the Republic of Kenya, and hosted more than 1,300 off-grid solar professionals from 75 countries (GOGLA, 2020a).[2] It had sessions on a wide range of topics, including country specific presentations, debates on changing financing models, discussions on the role of public and aid funding in the sector, lessons on how start-up companies might become profitable, as well as sessions on the emergence of off-grid solar appliances, both for household and industrial use. There was a celebratory narrative to the expo, with discussions on how the sector was only about a 'decade-old' yet had grown and achieved so much in this short space of time.

While the off-grid solar products and companies within the sector are diverse (including work relating to mini-grids, productive energy use, among other areas), it has undoubtedly been the rise of what have come to be known as 'branded' (quality-verified) pico-solar products that have been core to the industry's growth. For example, *Greenlight Planet,* a company that designs, manufactures and distributes the SunKing brand of off-grid solar products, was one of the Gold Sponsors of the 2020 Forum and Expo. *Greenlight Planet* got its first break as a company in 2006 when it secured US$27,000 in grant funding. Since this time, the company has managed to secure around US$500 million in investment funding, facilitating the dissemination of its products across a range of Global South markets (Luckanyu, 2020; Moko, 2021; Pothering, 2020). Similarly, another off-grid solar company, *d.light*, was a Silver Sponsor of the conference. Its first break was in winning US$2000 in prize money at an innovation competition in 2007 (Cross, 2013). As of 2021, the company has raised more than US$232 million in investment funding (Mamgain, 2018; Sinha, 2021). This investment parallels the boom in

[1] Previous events were held in Hong Kong (2018: Global Off-Grid Solar Forum & Expo), Dubai (2015: International Off-Grid Lighting Conference & Exhibition) and Dakar (2012: International Off-Grid Lighting Conference and Trade Fair).

[2] This high attendance was despite the emerging Covid-19 pandemic, which at the time prevented many representatives from Chinese off-grid solar manufacturing companies attending.

sales of 'branded' off-grid solar products in SSA markets from around 18,000 products sold in 2009 to more than 5 million being sold in 2019.

One of the key historical moments for this burgeoning African off-grid solar market and industry was the World Bank's and International Finance Corporation's (IFC) establishment of the Lighting Africa programme in 2007 (Baptista & Plananska, 2017; Ockwell & Byrne, 2017; Ockwell et al., 2021). The programme had (and still has) a focus on promoting the development of 'new lighting products and delivery models for Africa's large unelectrified rural off-grid electric market' (Ockwell & Byrne, 2017: 126). In particular, it has had an explicit focus on *market-based* approaches to promoting off-grid solar in Africa: its motto is 'catalyzing markets for modern off-grid electricity'. At the time of its inception, this was a distinct ideological shift for the sector. Previously, the distribution of solar energy systems across SSA largely rested on 'the moral economy of "development gift"' (Cross & Neumark, 2021: 905). Historically, off-grid solar infrastructure in Africa was largely seen as a development tool, not as a traded commodity, and critical for addressing low-access to electricity in rural areas in light of the capital-intensive nature of centralized grid system. To realize its market-focused objectives, the Lighting Africa programme began engaging in numerous activities: offering seed funding for market-based initiatives, hosting off-grid solar business conferences (in Accra [2008], Nairobi [2010] and Dakar [2012]), conducting consumer research and delivering awards for 'outstanding' lighting products (Ockwell et al., 2021).

The focus of the Lighting Africa programme has predominantly been in the realm of the pico-solar products. These are small-scale solar products, usually ranging from 0.1 to 15 watt-peak (Wp), that produce enough electricity to power solar lanterns, or small solar home systems (SHS) with a few lights and phone charging capacity (Keane, 2014). For SHS, most start-up companies in the sector have adopted a plug-n-play (PnP) design, meaning they come with all their components pre-packaged (battery, charge controller, panels, ready-made wiring plugs etc.), and therefore do not require a high-levels of technical expertise to set up. They differ from more 'traditional' component-based systems where the parts of the solar power system (e.g., panels, battery, controllers) are purchased separately and are then (ideally) installed in a house by a qualified technician (Harrington & Wambugu, 2021).

A critical juncture for this pico-solar sector was Lighting Africa's work in establishing a 'quality assurance' system for off-grid solar products. Known then as the Lighting Global Quality Standards (and since rebadged as VeraSol in 2020), this programme was established in 2009 by the World Bank and emerged out of a concern that sub-standard off-grid solar products were increasingly present in SSA markets, undermining the branded solar market (Alstone & Jacobson, 2018). The Lighting Global Quality Standards involved product testing and verification of off-grid solar products (at the manufacturer's request and cost) and giving them a 'quality-certified' approval if they passed them. This ontological category of 'quality verified' ultimately created a bifurcation of the small-scale off-grid solar market that—as we explore in this chapter—would emerge as a critical feature of the photovoltaic turn in SSA: a market divided by 'branded' and 'generic' off-grid solar products.

While there are numerous names to differentiate the two segments of the off-grid solar market (e.g., 'quality-verified' vs. 'not quality-verified'; 'affiliated' vs. 'non-affiliated'), we have chosen the designations 'branded' versus 'generic' due to their straightforward nomenclature. As well, a distinguishing feature of the affiliated segment of the market is the construction and promotion of their product's brand (i.e., branding). Rateau and Jaglin's (2021) framing of off-grid solar products as socio-technical *dispositifs* is useful for appreciating this distinction. They note how off-grid solar in Africa is a piece of electrical infrastructure mediated by different sets of actors, resources, material artefacts, knowledges, values and institutions (cf. Jaglin, 2014). 'Branded' and 'generic' off-grid solar products are not necessarily different in terms of how they function materially, however, through a range of technical reports, company websites, complicated international finance regimes, rhetorical links to sustainable development agendas (e.g., the United Nations Sustainable Development Goal 7 [SDG 7], 'energy access for all') and industry networking conference events, 'branded' solar products are much more 'visible' at an international level and operate within their own distinct political economy.

A discrete international off-grid industry has been developed around the 'branded' off-grid solar products. These products tend to be sold by social enterprise start-up companies (Cross, 2019) who are usually members of the GOGLA. In general, 'branded' products have been certified by international agencies (e.g., Lighting Global, VeraSol) and operate with sophisticated websites promoting their products, usually with rhetoric around green technology and solving the issue of energy poverty (Samarakoon et al., 2021). In some of the literature, they are described as 'affiliated products' (as in, companies affiliated with GOGLA) or as 'quality-verified products' (see Samarakoon, 2020; Munro & Samarakoon, 2022). 'Generic' off-grid solar products—or what GOGLA describes as 'unaffiliated products' (GOGLA, 2020b)—are products that have not been 'quality verified' and for the most part, their dissemination networks are more ephemeral. A 2016 report commissioned by the World Bank describes these are 'products offered by manufactures who are not seeking to build brand value, or that distributors can brand or sell unbranded' (Lighting Global, 2016). These products are sold across Africa through hardware stores, street vendors and informal purveyors (Bensch et al., 2018; Jaglin, 2019; Munro & Samarakoon, 2022; Samarakoon, 2020; Trompette & Cholez, 2022).

In this chapter, we develop a critical understanding of the *how* and the *why* of this rapidly emerging 'branded' off-grid (pico) solar market through a review of its historical development. While this private-sector driven, 'photovoltaic turn' (Munro, 2020) has been celebrated within the sector as an important means to address energy poverty in SSA and contribute to addressing the SDG 7 by 2030 (Bisaga et al., 2021; Hansen et al., 2021; Munro et al., 2017), economic issues are being conflated with ethical values (Cross, 2013). In this chapter, we use a historical perspective of the sector to critically chart the rapid growth of the off-grid solar sector as an influential response to acute energy poverty across SSA. In particular, we delve into the origins of key players, financial flows and critical junctures in the sector's journey to date. We conclude by interrogating the degree to which the social mission that catalyzed the expansion of the sector is being undermined by broader structural dynamics of the capital investment upon which it is reliant. As such, this chapter builds on a recent body of critical scholarship that questions the triumphalist narrative of off-grid electricity access success presented by the sector, with a particular emphasis on how its ideological commitment to market-based solutions create inequitable outcomes (Cross, 2019, 2020, 2021; Cross & Neumark, 2021; Harrington & Wambugu, 2021; Jaglin, 2019; Munro, 2020; Munro & Samarakoon, 2022; Ockwell et al., 2021; Ojong, 2021; Samarakoon et al., 2021, 2022; Trompette & Cholez, 2022).

2.2 Branded Off-Grid Solar in Africa: A History

2.2.1 Origins: 1960s to 2007

The 'branded' small-scale off-grid solar history is part of a much longer and broader history of photovoltaics in Africa. Lorenzo (1997), for example, dates the first photovoltaic installation back to 1968 in Niger, with the French aid-funded installation of a photovoltaic array to power an educational television. Modest markets for solar power emerged across Africa shortly after the oil price shocks of 1973–1974 that spurred interest in renewable energy development (Munro et al., 2016). By the late 1980s, however, despite substantial aid funding to promote solar power in rural areas, their dissemination in SSA remained largely restricted to more affluent sections of the population (Chaurey & Kandpal, 2010; Munro et al., 2016).

One notable exception was in Kenya, where a relatively vibrant off-grid solar market began to emerge in the mid-1980s (Jacobson, 2007; Ockwell & Byrne, 2017). Largely influenced by the work of US-based volunteers who were engaging in household solar power installations, local solar power companies began popping up, and by the early 1990s, there was a considerable increase in solar household installations in the country (Ockwell & Byrne, 2017). While technologically and economically distinct from the later 'branded' PnP solar sector due to their component-based installation approach, this nascent solar power sector would nevertheless foster Kenya's reputation as a frontier market of off-grid solar in Africa during the 1990s and early 2000s (Harrington & Wambugu, 2021; Ockwell & Byrne, 2017; Sergi et al., 2018).

Propelled by this reputation, numerous international aid agencies (e.g., Shell Foundation, World Bank) became involved in experiments with off-grid solar markets in the region (Ockwell et al., 2021). Indeed, from 2002 onwards there were several (unsuccessful) attempts to bring pico-solar lighting technologies to the poorest in Kenya, even including experiments in-country solar manufacturing (Ockwell & Byrne, 2017). Initially, the cost of these products was seen as too high to be economically viable; however, subsequent changes in lighting technology paved the way for the emergence of a pico-lighting market. The development of light-emitting diode (LED) technology was critical. As Ockwell and Byrne (2017: 135) summarize:

> From the mid-2000s, a variant of the PV market expectations – based on solar lanterns – began to take hold. Solar lanterns had been available for many years, and had been subject to various experiments in Kenya, but there were several technical and economic characteristics that made adoption by poorer users difficult […] but technical improvements in lighting technology – especially LEDs – meant that there was an opportunity to later revisit lanterns as a solution to lighting services for the poor.

It was at this historical technological juncture that the World Bank-supported Lighting Africa programme was established in SSA. Set up initially in 2007, Lighting Africa used Kenya as its main case-study country in 2009 (with Ghana as a secondary, less successful, case-study country), and the programme began laying an institutional foundation for the sector through 'market research' and the creation of quality standards (Ockwell et al., 2021). Lighting Africa had a particular focus on the promotion of pico-solar products (Ockwell & Byrne, 2017), and the possibilities of leveraging them to eliminate the use of kerosene lamps in SSA (Lighting Africa, 2011a). Complementing Lighting Africa's work in Kenya, pico-solar initiatives were also beginning to emerge in other parts of Africa.

2.2.2 Emergence: 2006 to 2012

During the first decade of the 2000s, three start-up pico-solar companies—*Barefoot Power*; *d.light* and *Greenlight Planet*—provided a critical foundation for the development of 'branded' off-grid solar industry across broader East Africa. The three companies, effectively founded in parallel, all have similar 'origin stories'.

Barefoot Power was founded by two Australians—Harry Andrews and Stewart Craine. Andrews and Craine had previously been working as engineering and environmental consultants in Australia's largest utility, but ultimately became tired of 'serving the wealthy with more and more electricity', and thus, after inspiration from a six-month consultancy project in Papua New Guinea, they decide to leave their 'cushy jobs' and set up *Barefoot Power* in 2005 (Andrews, 2011: 51). Their plan was to 'disrupt the multibillion-dollar kerosene market in developing countries' with the development of low-cost solar lighting technologies as an alternative (Andrews, 2011: 51). They developed numerous micro-solar products prototypes to help demonstrate their proof of concept. *Barefoot Power*'s first major break came in 2006, when they won a major prize at the Business and Development Challenge run by the Dutch Government in 2006, which subsequently paved the way for the company to make a connection with Oikocredit, one of the world's largest funds for microfinance institutions. Oikocredit 'assisted *Barefoot Power*'s liquidity and governance by providing equity investments and a board director' (Andrews, 2011: 52). With this funding support, *Barefoot Power* established its first Africa office in Uganda in 2008 and set up *Base Technologies (Uganda) Ltd* in 2009 (later renamed *Barefoot Power Uganda*), a Uganda-based company to experiment with different distribution models of *Barefoot Power*'s solar products. A second office was soon after established in neighbouring Kenya.

Greenlight Planet was founded by Patrick Walsh in 2004. Walsh was an engineering student at the University of Illinois, the inspiration for *Greenlight Planet* came from an electrification project that he worked on in rural India through his local Engineers Without Borders chapter. Similar to Andrews and Craine's early conceptions with *Barefoot Power*, Walsh returned from the trip 'thinking about the problems associated with the usage of kerosene lamps' and 'hypothesized that solar power could be a viable alternative'. In 2006, Walsh secured US$27,000 in grant funding to 'build prototype lanterns and test them in India' (Kher & Streeter, 2013). Two more University of Illinois engineering students—Mayank Sekhsaria and Anish Thakkar—joined Walsh to become belated co-founders of *Greenlight Planet* in early 2007, and subsequently, they collectively began applying for grants and other funding for the start-up. By the time they had graduated from their undergraduate degrees in 2007, they managed to secure US$100,000 in seed funding. *Greenlight Planet* formally launched their products in early 2009, selling solar lanterns in three Indian states (Bihar, Karnataka and Orissa), before expanding their business to South-East Asia and sub-Saharan Africa (Counts et al., 2011; IFC, 2012).

d.light was founded in 2007 by two MBA students from Stanford University: Sam Goldman and Ned Tozun. The company's early inspiration for creating a solar lamp as an alternative to kerosene reportedly came Sam Goldman's experience as a United States Peace Corp volunteer in Benin during 2004, where he witnessed a neighbour being badly burnt by a kerosene lighting accident (Cross, 2013; Goldman & Tozun, 2010). Goldman then met Tozun in 2005 in a graduate course on 'Entrepreneurial Design for Extreme Affordability' (at Stanford University) where—in collaboration with three engineering students—they developed plans for 'an affordable lighting product that would offer an alternative to kerosene lanterns for people living in places without electricity' (Cross, 2013: 374). In early 2007, Ned Tozun won US$2000 in Stanford's annual Entrepreneur Idol competition with a pitch based on his solar lantern idea. *d.light*'s first source of external funding. By the second half of 2007, drawing on Silicon Valley contacts (Cross, 2013), the *d.light* start-up had amassed US$1.5 million in funding from a small group of angel investors. In 2008, they secured a further US$4.5 million through multiple equity investors, including the US-based international venture capital fund Acumen. Subsequently, in June 2008, *d.light* launched its first solar lantern in India and Tanzania.

The initial products for each of these three companies were remarkably similar: the development of small LED lanterns with integrated photovoltaic modules. All three companies rapidly branched out beyond solar lanterns to develop SHS, which usually comprised of a few lights, battery, controller, panel and a mobile phone charging outlet. The rapid boom in mobile subscriptions across SSA from around 2010 onwards help to augment demand for solar products beyond just basic lighting needs (Munro & Schiffer, 2019; Porter, 2012; Samarakoon et al., 2017). Furthermore, the founders of all three companies were able to draw on existing contacts and networks in the 'Global North' to be able fund and set up their companies. A challenge for all three companies, however, was the development of networks to promote and distribute their products (Andrews, 2011; Counts et al., 2011; Cross, 2013; Goldman & Tozun, 2010). As Andrews, *Barefoot Power*'s co-founder, observed: 'we could have the best solar lighting product on the planet, … [however] … if we didn't have a strong model to distribute the products, we were little more than travelling salesmen peddling our widgets' (Andrews, 2011: 52). In his memoir, Dirk Kam. who was the CEO of *Barefoot Power Uganda* (nee *Base Technologies (Uganda) Ltd*) between 2011 and 2013, detailed some of the challenges in setting up distribution. He claimed that after some initial modest success in selling solar lanterns through local distribution channels, there was ultimately a 'dramatic collapse in direct sales to agents and dealers' (Kam, 2015: 50). Ultimately, to survive—much to his chagrin—*Barefoot Power* 'had no choice but to deal with NGOs' (Kam, 2016: 52), and, in particular, win large tenders with United Nations agencies and other large organizations. Ultimately, *Barefoot Power*'s strategy of selling units directly to NGOs, who would in turn distribute them without charge, would become the norm for these early off-grid solar companies (cf. Cross, 2020). By buying solar power units by the 'thousands', humanitarian organizations were in effect propping up these start-up companies, 'allowing them to recruit staff and rent premises to scale up operations' (Cross, 2020: 114).

Simultaneously, a couple of not-for-profit organizations that specialized in energy projects played a key role in facilitating the dissemination of these 'branded' pico-solar products during this period. *Energy for Opportunity* (EFO), founded in 2008 in Sierra Leone became an important distributor of renewable energy across the West African region. Much of its work centred around macro, off-grid solar installations (e.g., solar power installed in health clinics), but also community charging station networks (Kemeny et al., 2014). Co-opting existing charging station models established mainly by young local entrepreneurs who saw a market for charging mobile phones, EFO either upgraded existing or set up similar charging stations across Sierra Leone—using solar power instead of diesel generators. However, in addition to charging phones, EFO's stations sold pico-solar products, preferring *Barefoot Power* products because their photovoltaic module could be separated from the lamp. EFO could then hold the module as collateral while the lamp was paid off in instalments. Between 2010 and 2018, more than 100 charging stations were set up by EFO across Sierra Leone. During this time, an estimated 30,000 off-grid solar products were sold.

In East Africa, the United Kingdom (UK) registered charity *SolarAid*, along with its social enterprise arm *SunnyMoney,* would become the region's largest distributor of 'branded' pico-solar products. The initial premise for *SolarAid* was that the company Solar Century, which sold solar products in the UK (and is now their largest solar company), would donate 5% of its profits to the charity to promote renewable energy in the Global South. After being founded in 1998, Solar Century eventually became profitable in 2006 and subsequently *SolarAid was* formally set up (Leggett, 2019), with notable support from Australian actress Cate Blanchett who became the charity's first patron. Similar to the off-grid pico-solar manufacturers, *SolarAid* had an objective 'to eradicate kerosene light from Africa by the end of the decade (31 December 2019)' (Keane, 2014: 148). Initially, the charity focused its work in Malawi and Tanzania. Like with EFO, *SolarAid* worked to install macro-solar installation in schools and other public buildings; however, it also set up small factories in Mzuzu (Malawi) and Iringa (Tanzania) that would assemble solar lanterns from local and imported parts (Paisley & Keane, 2008; Sireau, 2011). With the emergence of branded pico-solar products, however, *SolarAid* quickly switched to selling off-grid solar products made by *Barefoot Power, Greenlight Planet* and *d.light*. To facilitate these sales, in 2008, *SolarAid* set up *SunnyMoney*, a for-profit company wholly owned by *SolarAid* that would sell off-grid solar products on a profitable basis. *SunnyMoney* used a range of avenues to sell these products, but its most successful distribution avenue was through working closely with schools and teachers to sell products (Leggett, 2019). By 2008,

Table 2.1 Lighting Award winners (Lighting Africa, 2010a)

	1st Place	2nd Place
Task Lighting	Greenlight Planet—SunKing	Barefoot Power—Firefly LED 12
Top Performance	Barefoot Power—Powapack	Sun Transfer—Sun Transfer 2
Ambient/Room Lighting	Barefoot Power—Powapack	d.light Design—Nova s200
Best Value	Barefoot Power—Firefly LED 12	Greenlight Planet—SunKing

SolarAid/SunnyMoney had established offices in Malawi, Tanzania, Kenya and Zambia, rapidly expanding the reach of its venture. Sales in off-grid products skyrocketed in the subsequent years. In just one year alone, between the 2010/2011 and 2011/2012 fiscal years, *SunnyMoney*'s off-grid solar product sales rose from 18,000 to 51,811 (Leggett, 2019; also see Keane, 2014).

The work of these two pico-solar distributors—*Energy For Opportunity* and *SolarAid/SunnyMoney*—and three pico-solar manufacturers—*Barefoot Power*, *Greenlight Planet*, *d.light*—would ultimately intersect with that of Lighting Africa in Kenya. All five organizations attended Lighting Africa's International Business Conference and Trade Fair in Nairobi in 2010 (Lighting Africa, 2011b). Collectively, *Barefoot Power, Greenlight Planet, d.light* pico-solar products won 7 out of the 8 'outstanding product awards' that Lighting Africa presented at the conference (see Table 2.1). There were 24 applications for these awards from firms making off-grid solar products (Lighting Africa, 2010a). The pico-products from the three companies also passed Lighting Africa's minimum quality standards,[3] and were subsequently allowed to use Lighting Africa endorsed logos on their packaging materials (Lighting Africa, 2010a). Thus, by the early 2010s, a fledgling market 'branded' pico-solar market in SSA was being established, with dedicated manufacturers, organizations focused on dissemination, and with the Lighting Africa programme providing broader institutional support.

[3] Aside from the award winners, two other products passed the Lighting Global quality-verification test at the conference: The Udaymini solar lamp, made by the multinational lighting company Phillips; and the LED-50 solar lamp made by the German-based company Solux (Lighting Africa, 2010a).

2.2.3 Boom: 2012 to 2016

From 2012 onwards, the 'branded' solar market experienced an unprecedented expansion in sub-Saharan Africa. Critical institutional, technological and financial changes aided considerably in the facilitation of the boom. At an institutional level, the establishment of GOGLA was a pivotal moment for the industry. Informally launched by the Lighting Africa programme at their May 2010 International Business Conference and Trade Fair in Nairobi (Lighting Africa, 2010a), GOGLA was up and running by 2012 with the backing of the World Bank and the International Finance Corporation (IFC), and the United States Department of Energy and the United Nations Environment Programme (UNEP) (Harper, 2021). Its founders saw GOGLA as a public–private initiative, a 'neutral independent, not-for-profit association' that would promote lighting technologies and business models in 'developing and emerging markets' (Keane, 2014: 114), 'specifically geared to support the private sector in increasing access to modern off-grid solar energy' (Harper, 2021). GOGLA's initial membership was made up of seven off-grid solar manufacturers selling products in East Africa, among other markets. Since this time, it has grown to have over 200 members, who range from new start-ups to multinational companies, representing both off-grid solar manufacturers and distributors, as well as appliance and productive use companies. Practically, GOGLA has supported the off-grid industry by establishing working groups to provide guidance and recommendations on policies, quality standards, recycling and business models, to publishing key data on the off-grid industry and its growth (e.g., GOGLA, 2021b). It regularly hosts (around every 2 years) an Off-Grid Solar Forum and Expo (a follow on from earlier Lighting Africa conferences) where off-grid solar industry representatives can present products and network, including the one mentioned in this chapter's introduction. Finally, it has continued work on the quality assurance of pico-solar products that Lighting Africa initiated. Although ostensibly a global organization, with a head office in the Netherlands, the majority of GOGLA's work has been focused on SSA.

In terms of critical technological and financial changes, the development and widespread adoption of pay-as-you-go (PAYG) solar model as a financial technology (or 'fintech') helped pave the way for substantial investments in the 'branded' off-grid solar. PAYG solar involves a remote locking technology that allows solar enterprises to render the use of their solar products useless unless regular payments (usually via mobile money) are made by the purchaser (Munro & Samarakoon, 2022; also see Ockwell et al., 2019). In effect, the PAYG fintech offered a relatively efficient means to financialize energy-poor markets and proved to be an attractive proposition for Global North investors wanting to invest in Africa off-grid solar markets companies using PAYG solar fintech generally use one of two models to disseminate their products. The first, and most common in Africa, is the 'rent-to-own' model. Customers pay an initial deposit for the PAYG off-grid solar system, and then continue to pay off the system over a designated period with regular payments (often with mobile money). After this period is complete, the customer then becomes the owner of the system, and the remote locking technology is disabled. The second is the 'energy-as-a-service' model (also variously known as 'perpetual lease', 'usage-based' or 'micro-utility' model), whereby the off-grid company maintains ownership of the off-grid solar product, and customers pay an ongoing usage fee in exchange for its use (Adwek et al., 2020; GOGLA, 2018a; GSMA, 2016; Lighting Global, 2016). For the most part, PAYG solar has tended to be used for SHSs rather than for solar lanterns, as the former have higher overall costs and therefore more amenable to fintech financing strategies. 'Branded' solar lanterns have thus still predominantly been sold through direct cash sales.

One of the earliest companies to design and implement PAYG solar technology was a Cambridge University spin-out company *Eight19*. In partnership with *SunnyMoney*, and with support from a charitable fund, *Eight19* launched its PAYG solar technology in Kenya in September 2011. Around 4000 units were sold through this pilot (University of Cambridge Enterprise, 2012), which in part helped *SunnyMoney* to grow rapidly during this period. Sales of their off-grid products jumped to 338,298 in the 2012–2013 financial year (from 51,811 in the previous year), and then to over 600,000 in both the 2013–2014 and 2014–2015 financial years. By 2014, *SunnyMoney* would set up its fifth African office in Uganda (Leggett, 2019).

SunnyMoney was not the only company experimenting with PAYG solar fintech as a means to disseminate solar products. Numerous off-grid solar manufacturing and distribution (or companies that did a combination of the two) emerged during this period, and by 2015 around 20 companies were involved in manufacturing and/or distributing PAYG solar products in sub-Saharan Africa, most of them working in East Africa (Lighting Global, 2016). Ultimately, PAYG solar fintech was a catalyst for the mass expansion of Africa's 'branded' off-grid solar market.

Starting in 2012, investments began pouring in for the off-grid sector, with nearly 90% of those investments being focused on off-grid solar companies using the PAYG solar fintech model (Lighting Global, 2016). Almost all of the off-grid companies were founded in the Global North (cf. Tromptte & Cholez, 2022)—including a number in San Francisco (e.g., *Angaza, Fenix International, d.light, ZOLA Electric*)—and their founders were able to draw on strategic financial networks to source investment capital (cf. Cross, 2013). Figure 2.1 shows, these larger-scale private sector investments in the off-grid solar sector began to occur in 2012 and 2013, with around US$40 million in investments across these two years. The majority of these early investments were equity investments (i.e., impact investors purchasing stakes in off-grid solar companies) (Clowes et al., 2019). Then, between 2014 and 2016, equity investments dramatically increased in the sector, and were followed by debt investors (i.e., companies providing loans). More than half a billion dollars was invested in the sector over these three years (see Fig. 2.1; also see Lighting Global, 2020). These new investors were diverse. A report in 2015, for example, noted that an initial $70 million of investment comprised over 60 unique investors providing a range of equity, debt, and philanthropic investments (Alstone et al., 2015)—and most were based in either Europe or North America, and included impact investors such as Acumen, Khosla Impact and responAbility, and corporate investors such as Total and ENGIE (Lighting Global, 2016). The majority of this investment was channelled into the East African off-grid solar market (Lighting Global, 2016). Ultimately, this finance underpinned the rapid emergence of a range of new start-up companies in Africa's off-grid sector.

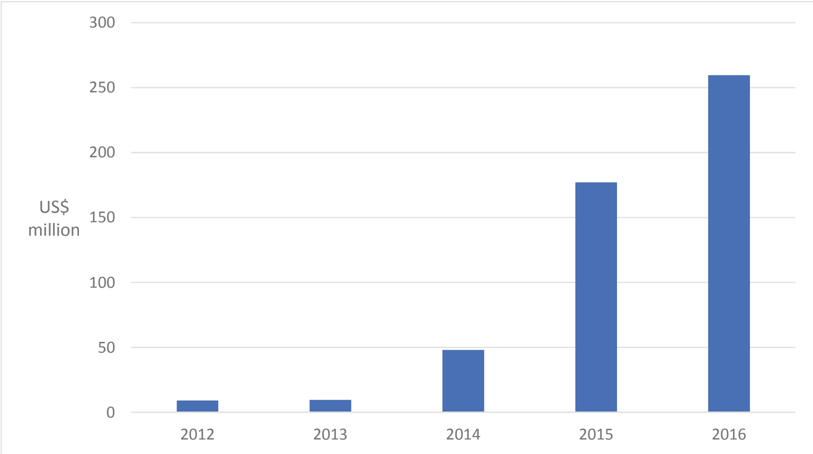

Fig. 2.1 International investment in sub-Saharan Africa's off-grid solar sector (data sourced from GOGLA, 2021a)

These new start-ups included companies such as *Fenix International* and *ZOLA Electric* (also known as *Off-Grid Electric*), both with founding offices in San Francisco, and who initially set up PAYG off-grid solar distribution markets in Uganda and Tanzania respectively. *Bboxx,* a start-up off-grid solar company founded in 2011 by three students at London's Imperial College, set up operations in Rwanda. *Eight19,* who provided the PAYG solar technology for *SunnyMoney*'s PAYG solar pilot, set up its off-grid solar manufacturing company called *Azuri Technologies* in 2012, and began working with distributors across SSA to sell its PAYG solar products. The earlier generation of 'branded' pico-solar companies—*Greenlight Planet* and *d.light*—also adopted PAYG solar fintech into their products during this period, and were successful in securing additional investment. *Greenlight Planet*, for example, secured US$4 million in venture funding from the commercial private equity firm Bamboo Capital Partners in 2012 (FinSMEs, 2012), while *d.light* secured US$11 million in funding from a range of venture capital investors in 2014 (FinSMEs, 2014).

However, it was the start-up company *M-Kopa* that was most successful in the early years between 2012 and 2016, in terms of disseminating off-grid solar products. *M-Kopa*, which was commercially launched as an off-grid solar company in Kenya in late 2012, initially sold *d.light* PAYG solar off-grid products before launching its own 'branded' products in 2015 (Alstone et al., 2015; Rastogi, 2018). The catalyst for *M-Kopa*'s dominance was its success in securing US$10 million in financing—a combination of equity and grants—from the UK's Department for International Development (DFID), the Bill & Melinda Gates Foundation, and the Shell Foundation in 2014 (Fehrenbacher, 2014; Price, 2016). With this funding, *M-Kopa* was also able to secure a further $10 million loan from the Commercial Bank of Africa in 2014. By the end of 2015, the company had sold more than 250,000 off-grid PAYG solar products in Kenya. More than 50% of PAYG solar sales in SSA at the time (Scott & Miller, 2016). *Mobisol,* a Berlin start-up off-grid solar company that was founded in 2010, was another company that would dominate the PAYG solar market early on. It initially piloted its products in Tanzania in 2013, partnering with the mobile phone telecommunication company Vodacom Tanzania to sell around 1000 off-grid solar products. The company then rapidly expanded its operations in 2015, selling around 40,000 PAYG off-grid solar products, equating to around 16% of all PAYG solar product sales in Africa at the time (Scott & Miller, 2016). By 2017, *Mobisol* had secured nearly US$120 million in international funding, from a wide variety of debt, equity and grant investors, to finance and expand its PAYG solar operations across East Africa (Lighting Global, 2018).

Mobisol and *M-Kopa*'s market share, however, would dissipate as other companies increasingly secured finance to expand their operations. The Netherlands-based *Nova Lumos* secured US$50 million in 2016 to expand PAYG solar operations in Nigeria (Shanklemen, 2016). *ZOLA Electric* managed to secure US$77 million in funding in 2015 alone, building on a US$23 in equity funding it had obtained in 2014 to expand its PAYG solar operation in East Africa (Wesoff, 2015). Similarly, across 2015 and 2016, *BBoxx* managed to secure US$55 million in equity and debt funding to expand its existing operations in Rwanda and Kenya, as well as to create expansions into the West African market (Clover, 2016).

Overall, the decade from 2006 to 2016 represented a radical change for the off-grid solar branded market in SSA. From negligible beginnings, with around 18,000 branded products sold in 2009, it became a thriving sector with nearly 4 million products sold in 2016. The sector had grown from around 60 participating companies in 2010 to more than 330 in 2017 (Lighting Global, 2018). Stuart Davidson, an Acumen[4] board member, recounts this change succinctly:

> I have seen the off-grid sector grow from a handful of scrappy entrepreneurs trying to change the world to a sector reaching over 800 million people, from a trickle of investment to nearly half a billion dollars invested last year alone. I've seen companies, governments and investors collaborate, de-risking companies and entire markets to bring light to hundreds of millions of off-grid customers' homes. (Clowes et al., 2019: 3)

The bulk of products sold during this growth period were cash sales of solar lanterns (see Table 2.2), which was unsurprising given their low price in comparison to other, larger products. Nevertheless, PAYG fintech SHS sales increased substantially from 2013 onwards, and dominated the market (see Table 2.2). For example, in 2018, while PAYG solar products represented around 39% of overall sales in terms of volume of 'branded' products (versus cash sales which account for 61% of the volume), they represented nearly 85% of the financial value of the market, with more than US$335 million worth in sales (GOGLA, 2018b, 2019a). Supporting this boom in PAYG products was the increasing complexity of off-grid solar product portfolios. For instance, starting in 2015, most of the major companies were selling SHS packages that included televisions, and in general, were moving beyond the pico-solar sphere in terms of technology size and functionality.

Moreover, companies in the off-grid solar sector became increasingly diverse. Some companies focused on manufacturing or on distribution, while others mainly focused on the development of PAYG payment platforms (see Table 2.3). Other companies, such as *Fenix International*,

[4] Acumen has been a major investor in the off-grid solar sector in Africa, as well as being one of the earliest, with investments in d.light as early as 2008.

Table 2.2 Branded off-grid solar sales in sub-Saharan Africa

Year	PAYG solar sales	Total 'Branded' solar products	PAYG share of branded market (# of products) (%)
2009	0	18,000	0
2010	0	146,000	0
2011	4000	336,000	1.2
2012	6000	884,000	0.7
2013	50,000	2,740,000	1.8
2014	120,000	3,470,000	3.5
2015	300,000	3,266,430	9.2
2016	640,000	3,827,631	16.7

Notes Data source from GOGLA (2016a, 2016b, 2017a), Lighting Global (2016, 2018, 2020), Alstone et al. (2015), Scott and Miller (2016), Rastogi (2018), Price (2016), University of Cambridge Enterprise (2012)

were vertically integrated, meaning they dealt directly with all segments of the off-grid solar commodity chain. Some companies had a specialized focus on solar lanterns and/or smaller SHS, while others had an exclusive focus on the large plug-play SHS segment. A small number of companies did both. Different companies tended to focus on different country-level markets. Overall, the 'branded' off-grid solar market had a strong East African focus. Towards the end of this period between 2012 and 2016, ten PAYG solar companies were operating in Kenya; Uganda and Tanzania each had six PAYG solar companies, while Rwanda had three. Across the rest of SSA, no other country had more than two active PAYG solar companies (Alstone et al., 2015), underscoring the influence of the East African region on the off-grid solar market during these years.

2.2.4 Wobble: 2016 to 2021

While the early story of the 'branded' off-grid solar sector was a narrative of expansions and booms, from 2016 onward the story becomes ambivalent and tepid. *Mobisol*, one of the early leaders in the off-grid PAYG solar field, and widely considered a 'rockstar' in the PAYG solar industry, filed for insolvency in 2019 (Cross & Neumark, 2021; Dizzard, 2019). This financial fate occurred despite the company being successful in securing more than US$120 million in equity and debt financing since

Table 2.3 List of some of the key off-grid solar manufactures, distributors and PAYG technology platform design companies in sub-Saharan Africa

Company name	Year founded	Manufacturing	PAYG technology	Distribution
Greenlight Planet	2004	Y	N	Y
Barefoot Power	2005	Y	N	Y
d.light	2007	Y	Y	N
SunnyMoney	2008	N	N	Y
Energy For Opportunity	2008	N	N	Y
Fenix International	2009	Y	Y	Y
Solar Works	2009	N	N	Y
Angaza	2010	N	Y	N
Mobisol	2010	Y	Y	Y
Ominvolatic	2010	Y	N	N
Fosera	2011	Y	N	N
BBoxx	2011	Y	Y	Y
ZOLA Electric	2011	Y	Y	Y
Azuri	2012	Y	Y	N
M-Kopa	2012	Y	Y	Y
PEG Africa	2013	N	N	Y
Solaris Off-Grid	2014	N	Y	N
BrightLife	2014	N	N	Y
Oolu	2015	N	N	Y
Baobab+	2015	N	N	Y
Zuwa Energy	2016	N	N	Y
EasySolar	2016	N	N	Y
ENGIE Energy Access	2018	Y	Y	Y

its founding, as well as supplying more than 600,000 people in Africa with off-grid solar products. The company was ultimately unable to convert its market share into a profitable enough venture to pay off debts (Dizzard, 2019). *SunnyMoney*, the pioneer distributor of pico-solar products in SSA, and who had in 2013 been the largest distributor of brand off-grid solar products (Alstone et al., 2015; Lighting Africa, 2013), saw its sales drop precipitously in 2015 (see Fig. 2.2). In response, over the next couple of years, it had to close three of its African offices (Tanzania, Uganda, Kenya), and subsequently focused its distribution on the smaller markets of Malawi and Zambia. In the 2018–2019 financial year, *SunnyMoney* sold just 44,000 off-grid solar products, just seven percent of the 624,468 that were sold in 2014–2015 (see Fig. 2.2). Finally, *Barefoot Power*, one of the pioneering branded off-grid solar manufacturers, entered voluntary liquidation in Australia in 2018. The company was bought out in the end by its local Ugandan subsidiary.

The reasons behind these off-grid sectorial 'wobbles' in SSA are complex. In broad terms the major challenge these companies faced was a relative stagnation in the growth of off-grid solar sales starting in 2015.

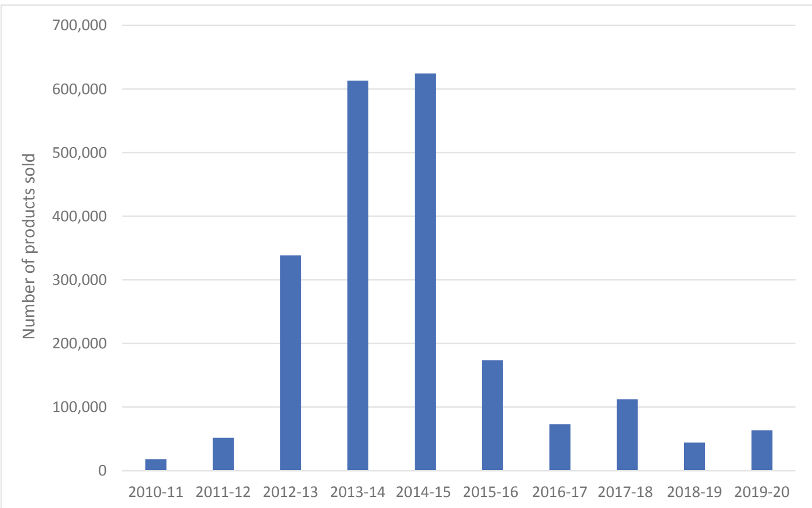

Fig. 2.2 Off-grid solar product sales by SunnyMoney: 2010–2020 (Data sourced from Leggett, 2019; SolarAid, 2021)

Between 2010 and 2014 (albeit from a relatively low base), the market grew by more than 2000%; between 2014 and 2018 the market only grew by seven percent. Even then, this growth was mainly driven by PAYG solar expansion; there was a 22% decline in branded off-grid solar lanterns (see Fig. 2.3).

In general, the off-grid solar companies (and their investors) did not predict this stagnation. On the one hand (understandably), they were buoyed by the astronomical increase in sales during the sector's early years; on other hand, they were using relatively crude and simplistic mathematics to project the sector's future market expansion: simply calculating the number of people without direct access to grid-electricity, or even those with unreliable grid access, and equating a number with the 'untapped market' for the booming 'branded' off-grid solar sector. Overall, this framing made the sector highly attractive to (impact) equity investors, as noted in a recent *Acumen* report, the 'off-grid sector generated significant excitement when it emerged because it posed a high-impact solution to a global issue that could also provide significant

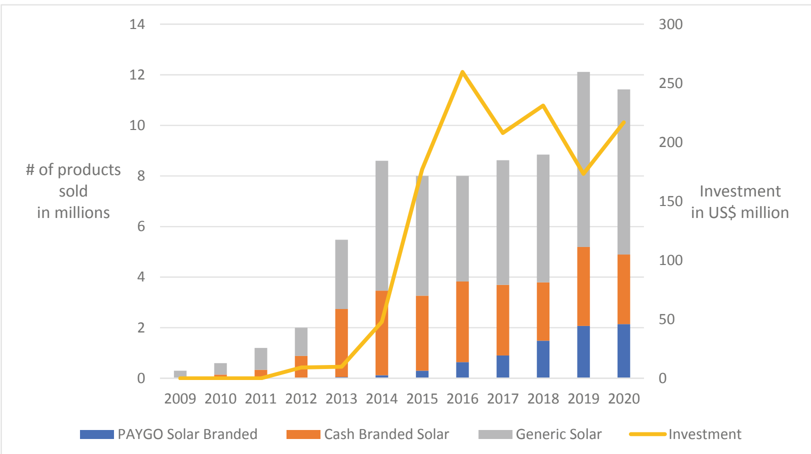

Fig. 2.3 Off-Grid Sales and Investment in sub-Saharan Africa (Data source from Alstone et al., 2015; GOGLA, 2016a, 2016b, 2017a, 2017b, 2018b, 2018c, 2019a, 2019b, 2020b, 2020c, 2021a, 2021b, 2021c; Lighting Global, 2016, 2018, 2020; Price, 2016; Rastogi, 2018; Scott & Miller, 2016; University of Cambridge Enterprise, 2012)

financial returns to investors' (Clowes et al., 2019: 20). Nevertheless, the sector's high reliance on equity investments during its early phase (rather than loans) ultimately 'led to a significant number of companies being overvalued', in particular, as a lack of available debt financing meant that companies would have to 'aggressively push for higher valuations to raise funds for operations' (Clowes et al., 2018: 21).

In combination with this overvaluation was what the Acumen report calls the 'challenging geographies' of the off-grid solar market in SSA that led to underperformance for many companies. Ultimately, the energy poor proved to be much more complicated than reductionist quantitative statistics that off-grid market reports often presented them as (Munro & Schiffer, 2019). Most critically, geography mattered, the energy poor—and the social, political, economic and cultural contexts in which they were situated—varied considerably across SSA. Thus, what happened, was that many companies moved 'rapidly into new markets' in SSA without fully understanding the total 'cost of serving customers with different aspirations in these geographies, yielding higher than expected operating costs' (Clowes et al., 2018: 21). Subsequently, given these challenges, investment in the sector has slowed, and for the most part the vast majority of start-up 'branded' off-grid solar companies are still not currently profitable, rather they are running their operations on their equity investments and loans (Clowes et al., 2018).

Ultimately, inter- and intra-country variations, 'natural' disasters, and competition from cheaper 'generic' products in some markets have in different ways curtailed the expansion of the 'branded' off-grid sector. For example, in terms of the PAYG off-grid solar market, high-levels widespread mobile phone banking was often a critical prerequisite for successful ventures to ensure effective repayment for their products (Bisaga et al., 2017). Kenya, for example, the longest and most successful market for off-grid solar products, also has the longest history and highest adoption of mobile banking. Indeed, the PAYG off-grid solar *M-KOPA* company was an offshoot of Kenya mobile operator M-PESA. Founded in 2007, 'Kenya's M-PESA was the first mobile money operator [...] to achieve mass adoption', by 2016, around '80 percent of Kenya's adult population' were using the platform (Lepoutre & Oguntoye, 2018). In contrast, Nigeria—a country that has similar levels of 'economic development' and 'mobile phone adoption' to Kenya, only had one percent of its adult population actively using mobile money in 2016 (Lepoutre & Oguntoye, 2018). East Africa has a higher level of (as well as a long history of) mobile phone banking (Andresson-Manjang & Naghavi, 2021), and this has undoubtedly played a critical role in underpinning its more lucrative PAYG solar market.

While many off-grid solar enterprises advertise their PAYG solar model as an innovative way to offer 'last mile distribution' to 'cash-constrained rural off-grid customers' (GOGLA, 2020b), recent research indicates that it is actually majority urban and peri-urban customers that are buying their products (see for example Barry & Creti, 2020; Cross & Neumark, 2021; Munro & Samarakoon, 2022; Trompette & Cholez, 2022). With differences in access to disposal (and cash) incomes, trade routes (e.g., roads and transit options), and mobile banking use and infrastructure, as well as differences in overall economies of scale and the number of creditworthy consumers, it is no surprise that urban areas became more lucrative for off-grid enterprises selling PAYG products using mobile repayment plans (Munro & Samarakoon, 2022). For indebted start-up companies selling branded solar products, their quest for profitability meant moving away from their poverty-alleviating backstory. Indeed, representatives from PAYG solar companies explicitly noted that 'the urban, peri-urban is really the successful areas for the branded products', and that when they 'try and go outside [urban areas], try to go more rural, the daily price [for PAYG repayments] is still just too high' (cited in Munro & Samarakoon, 2022). The poorest of the energy poor is no longer a key target 'market' for many companies (Cross & Neumark, 2021).

Natural disasters have also created additional challenges for companies selling products to rural populations. The 2016–2017 East African drought, for example, was noted as contributing to the downfall of *Mobisol* as the drought placed additional economic stress on many of its rural customers, undermining their ability to complete their PAYG solar repayments (Dizzard, 2019). The Mozambique-based PAYG solar start-up company *Epsilon* found that it faced 'a 75% reduction in [PAYG solar] payments and a six-month halt to new sales' after Cyclone Idai hit the region in 2019 (Kennedy, 2019). The cyclone caused widespread damage to Epsilon's customer's crops 'and they were suddenly without any source of income for payments or deposits' (Kennedy, 2019). More recently, the Covid-19 pandemic has had a major impact on off-grid solar companies across SSA (Castán Broto & Kirshner, 2020). There have been supply disruptions, lower sales, and overall failed repayments due to the pandemic's socio-economic impacts (Bieber, 2021; Cross, 2021). Public sector funding has come to the rescue for many companies in the sector, with grant funding support at an all-time high in 2020 (Hall, 2021; also see Fig. 2.4). This included an unprecedented partnership between investor companies, private foundations, government donors and multilateral and development finance institutions coming together to set up the US$80 million Energy Access Relief Fund (EARF) to help off-grid companies weather the global recession caused by the pandemic (Bieber, 2021).

Furthermore, since 2015, the sector has become increasingly worried about competition from generic off-grid solar products (Lighting Global, 2020). A 2016 Lighting Global report, for example, note that not only

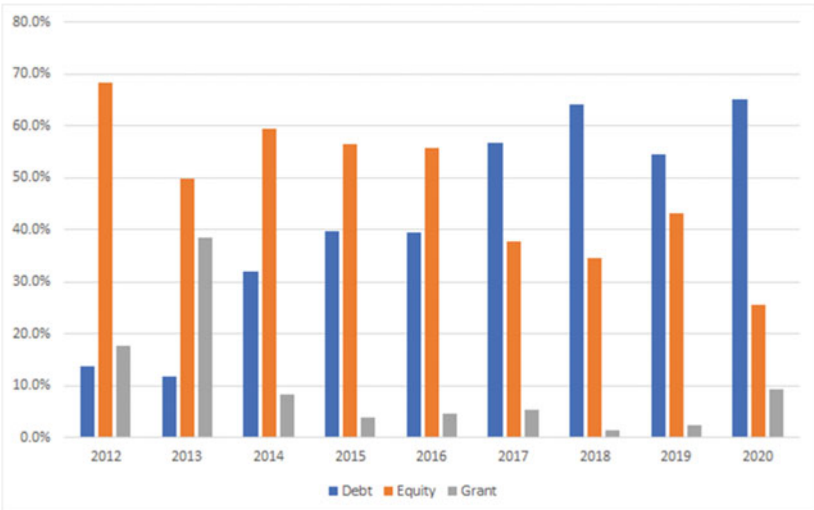

Fig. 2.4 Investment ratios between Equity, Debt and Grants for the Off-grid solar sector (Sourced from GOGLA, 2021a). Note these are global figures, but the vast major (~85%) of these funds have been invested in sub-Saharan Africa

was the generic share of the market likely growing to 'account for at least half of the pico-solar market', but also generic off-grid solar manufacturers were producing copycats (products design look similar to popular branded products) or even counterfeits (generic products purporting to be made by widely recognized brands) (Lighting Global, 2016). Indeed, *SolarAid* notes that the reason it closed its Tanzania office in 2015—its largest market to date—was due to the rapid increase in competition from cheaper generic products (SolarAid, 2015). This competition was also likely a partial factor in *Mobisol*'s decline as well. Although numbers are difficult to calculate, due to the ephemeral nature of the generic off-grid solar market, the most recent estimates suggest that it has grown to have a 72% share of the off-grid solar market (Lighting Global, 2020).[5] As they are sold at cheaper price points than branded, the continual growth of the generic off-grid solar market could represent an existential threat for many off-grid companies, particularly those dealing in solar lanterns and smaller SHSs. Indeed, despite start-up companies framing these generic off-grid solar products as being inferior, some recent studies have indicated that generic products in many cases can be of equal, or even higher, quality than branded products (see Bensch et al., 2018; Grimm & Peters, 2016; Trompette & Cholez, 2022). As Trompette and Cholez (2022) note, these generic products offer a wider range of product options for the energy poor and logistically on the ground they been better at reaching the poorest, and as such they therefore 'also reflect the 'inclusiveness' claimed' by the start-up off-grid sector. They are a frugal innovation operating in the wake of the 'branded' off-grid solar sector (Trompette & Cholez, 2022).

Overall, the 'branded' off-grid solar sector is structured by a considerably different political economy in 2021 compared to in 2016. The early boom in funding and sales of off-grid solar products has come up against the complexities of SSA's energy-poor geography. The radical exuberance of impact investors that dominated investment in the early years

[5] The competition from 'generic' products differs considerably from country to country due to a range of historical and policy factors. A recent survey, for example, found that generic only had 7.6% of Rwanda's market (i.e., versus 92.4% for branded). In Zambia the generic share was 31.8%, in Kenya it was 46%, in Nigeria it was 67%, in Ethiopia it was 71.2%; in Uganda it was 77.5%, in Niger it was 86%; and in Togo it was 93.3% (see Lighting Global, 2020).

of the sector is now less prominent, with more conservative financial models emerging: in particular with debt loans (Fig. 2.4), with the vast majority of this funding is going to 'large, First-Generation companies that attracted early equity investments' (e.g., *BBoxx, d.light, Greenlight Planet, M-KOPA, Azuri Technologies*), with newer start-ups struggling to attract finance (Lighting Global, 2020: 64). The French multinational utility company, ENGIE, has also entered the sector and has acquired *Fenix International* and the insolvent *Mobisol* in 2019 (Cross & Neumark, 2021), placing both companies under the broader banner of *ENGIE Energy Access*. As a result of these acquisitions, *ENGIE Energy Access* is active in selling PAYG solar products in at least nine different countries across Africa.

Sale volumes of branded off-grid solar have experienced stagnation and some decline across most of East Africa since 2018 (GOGLA, 2021a). This decline has been countered by the broader sector with a more rapid expansion into West Africa. Since 2016, more investment has flowed into West African PAYG solar initiatives—including West African focused start-up companies, and with East African companies expanding into new West African markets (e.g., *ZOLA Electric, BBoxx, Fenix International*). The year 2020 was a record year for investment into the West African market, the first-time investment in the region was higher than in East Africa (see Fig. 2.5). This regional shift has been aided by a rapid increase in mobile banking use across the West African region.[6]

2.3 Past Reflections—Future Trajectories

Although the history of the 'branded' off-grid solar products in sub-Saharan Africa is relatively nascent—emerging during the first decade of

[6] West Africa's mobile banking has grown in both absolute and relative terms. There were about 7.8 million registered mobile banking accounts across West Africa 2012 (about 16.7% of accounts in all of sub-Saharan Africa), which compared at the time to 48.5 million across East Africa (about 76.10% share) (Pénicaud, 2012). The two regions have a nearly equal in terms of population (West Africa is home to 36.8% of sub-Saharan Africa's population; East Africa is home to 40.6%). By 2020, West Africa's number of mobile banking account grew to 293 million registered accounts (about 35.9% of the share in sub-Saharan Africa (Andersson-Manjang & Naghavi, 2021).

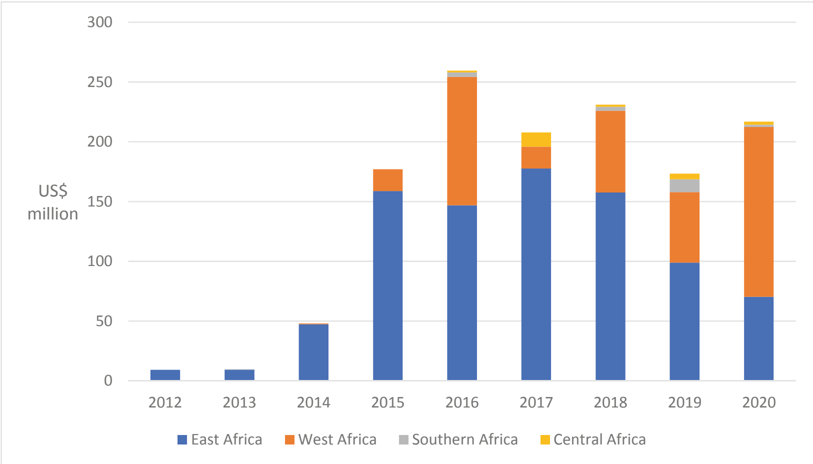

Fig. 2.5 Branded off-grid solar investment, showing regional variation (Data sourced from GOGLA, 2021a)

the 2000s as we have shown in this chapter, it has been a dynamic and impactful industry. From early experiments at the beginning of 2000s, to rapid an influx of international investment from 2012 onwards on the back of PAYG solar fintech innovations, to contemporaneous 'wobbles' due the stagnation of sales and investments, the sector has undoubtedly played a critical role in reshaping the 'daily choreographies of energy use' across SSA (Castán Broto, 2019: 85). Initially framed as the answer to address the long-term obstinate issue of rural energy poverty in SSA, the financial structure of the sector, along with the diverse challenges of Africa's energy landscape, have caused these claims to become more circumspect.

At its inception, the branded off-grid solar energy transition was framed in quite specific justice terms. The widespread use of kerosene lighting—and the hazards and burdens that it entails—was cast as a key injustice in the origin stories of the sector's pioneers. The *Barefoot Power* co-founders set out on their mission wanting to disrupt the 'multibillion-dollar kerosene market in developing countries' (Andrews, 2011), while the founders at *Greenlight Planet* and *d.light* began their companies describing similar tales of witnessing a troubling relationship between kerosene lamps and impoverished communities. Overtime, a broad community of development practitioners and entrepreneurs would come together to see kerosene as the problem and solar lanterns as the potential solution, while the market would be the engine by which SSA's energy landscape could be transformed. A burgeoning industry has grown in the wake of the pioneering efforts of off-grid organizations, which have certainly played a role in disrupting the kerosene lighting industry. An estimated 35 million branded off-grid products have been sold since 2009 (GOGLA, 2021a), the vast majority of which have been small solar lanterns, and have undoubtedly shaped how, and how often, kerosene lamps are used. Much to the chagrin of some of the companies in the sector, the larger wave of generic off-grid solar products, which have often piggybacked on branded product success, have also contributed to a new, non-kerosene based, energy world and arguably have been much more successful in terms of penetrating rural households and businesses (Barry & Creti, 2020; Munro, 2020; Munro & Bartlett, 2019).

At the same time, SSA's energy landscape, and justice-oriented debates therein, has been evolving with broader changes in the political economy. Sino-African trade has drastically increased in recent years—including an estimated 21-fold rise in trade between 2000 and 2014 (Guan & Ping Sheong, 2020). A by-product of this increased trade is that cheap battery-powered torches have flooded Africa rural markets. These new products have either completely displaced kerosene (Munro et al., 2020), or at the very least caused a steady decline in its use (Bensch et al., 2017). As a result, new energy justice framings have emerged in Africa's lighting sector, namely calls for off-grid solar power over battery-powered torches (due to costs and pollution associated with disposable batteries), and branded off-grid solar products over generic off-grid solar products (due to the presumed lower-quality of the latter). Still, even with the branded off-grid sector there are increasing concerns relating to solar waste (Cross & Murray, 2018; Hansen et al., 2021), as most pico-solar products only have a shelf life over around three years.

As the industry has grown, justice framings still thread across the sector. As Cross notes:

> [F]or many management and business executives in off-grid solar companies, selling solar power to people living in chronic energy poverty presents itself as an ethical-economic utopia: the opportunity to express care for others and the environment at the same time as fulfilling a fiduciary duty of care to investor. (Cross, 2019: 48)

Most companies in the sector saw themselves as 'social enterprises'—adopting for-profit activities to realize a social objective. Yet, at the same time, the mass influx of capital investment into the sector has arguably weakened the social justice credentials of some of these companies. The 'human-rights goals' of 'access to basic electricity' have come into conflict with the 'cost-recovery goal' (and even mass-profit goals) of market-based models (Jacome & Ray, 2018). For many of these (venture-capital-backed) companies, 'providing off-grid energy to precarious populations had lost its shine' and in its place a more engrained commitment to economic growth, and in particular by 'scaling up their operations beyond the poor' (Cross & Neumark, 2021: 911). The vast majority of off-grid companies working in the branded off-grid sector are not yet profitable, and thus are running operations on debt that needs to be paid (Clowes et al., 2019; Groenewoudt & Romijn, 2022; Lighting Global, 2020). The boom in international investment in the sector came with a Faustian Pact—giving power to investors who might not share the original mission of their enterprise. Instead, profit became the key driver. This is something Cross and Neumark (2021) observe in their recent research on the sector:

> Reflecting on a decade of growth, both the senior managers and the executives we interviewed across the global [branded off-grid] solar industry described a similar process: one in which the pursuit of social, environmental and economic goals in the solar industry had been gradually displaced by the pursuit of financial returns on investment. For many, new inflows of investment had brought about something greater than simply 'mission drift'; it had led to a wholesale change in purpose and values. (Cross & Neumark, 2021: 912)

The result has been that many of the larger companies in the sector have now shifted their focus up-market, selling larger solar home systems (that include appliances like televisions) to middle-class markets across

SSA (Cross & Neumark, 2021; Pothering, 2020). A less risky and more profitable venture than providing off-grid power to precarious rural populations (Cross & Neumark, 2021).[7] Even Acumen, an early financial investor in the sector, has lamented this transition: 'The focus on more expensive products and aggressive lending practices jeopardizes the social impact thesis that drew many impact investors like Acumen to the sector in the first place' (Clowes et al., 2019: 22). To be clear, not all companies in this sector have gone down this route, and many of the smaller companies (not heavily indebted to conservator investors) certainly maintain a strong social objective. For instance, for *SolarAid*'s social enterprise, *SunnyMoney,* who have yet to take on venture capital funding, most recent initiatives have focused on driving down the cost of basic (quality-verified) solar lanterns, as well as engaging in projects to improve the repairability of their products (SolarAid, 2016, 2021).

Supported by development actors and global networks of capital, the off-grid solar sector has extended the reach of electric lighting and charging to millions across sub-Saharan Africa. Traditionally the domain of the state, who are in effect ceding responsibility of providing electricity services to foreign businesses, these new electricity products come with a complex set of trade-offs. While their reach has undoubtedly offered new energy possibilities for many impoverished communities, the sector's win–win approach to addressing energy poverty (doing good and making money) has implications for the spread of inequities across the continent. Ultimately, the question remains as to whether these market-based approaches can in fact provide just and sustainable paths for the energy poor.

[7] Indeed, recent willingness-to-pay studies have indicated that branded solar products (even with long PAYG solar repayment periods) are ultimately unaffordable for SSA's rural populace (Grimm et al., 2020; Sievert & Steinbuks, 2020).

References

Adwek, G., Boxiong, S., Ndolo, P. O., Siagi, Z. O., Chepsaigutt, C., Kemunto, C. M., Arowo, M., Shimmon, J., Simiyu, P., & Yabo, A. C. (2020). The solar energy access in Kenya: A review focusing on Pay-As-You-Go solar home system. *Environment, Development and Sustainability, 22*(5), 3897–3938.

Alstone, P., & Jacobson, A. (2018). LED advances accelerate universal access to electric lighting. *Comptes Rendus Physique, 19*(3), 146–158.

Alstone, P., Gershenson, D., Turman-Bryant, N., Kammen, D. M., & Jacobson, A. (2015). *Off-grid power and connectivity Pay-As-You-Go financing and digital supply chains for pico-solar*. Market Research Report. University of California, Berkeley and Lighting Global.

Andersson-Manjang, S. K., & Naghavi, N. (2021). *State of the industry report on mobile money 2021.* GSMA.

Andrews, H. (2011). Barefoot power: A case study in Uganda. In N. Sireau (Ed.), *Microfranchising: How social entrepreneurs are building a new road to development* (pp. 50–69). Routledge.

Baptista, I., & Plananska, J. (2017). The landscape of energy initiatives in sub-Saharan Africa: Going for systemic change or reinforcing the status quo? *Energy Policy, 110*, 1–8.

Barry, M. S., & Creti, A. (2020). Pay-As-You-Go contracts for electricity access: Bridging the 'last mile' gap? A case study in Benin. *Energy Economics, 90*, 104843.

Bensch, G., Peters, J., & Sievert, M. (2017). The lighting transition in rural Africa—From kerosene to battery-powered LED and the emerging disposal problem. *Energy for Sustainable Development, 39*, 13–20.

Bensch, G., Grimm, M., Huppertz, M., Langbein, J., & Peters, J. (2018). Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso. *Renewable and Sustainable Energy Reviews, 90*, 1060–1068.

Bieber, S. (2021, September 1). How blended finance helped to keep energy supplies flowing during COVID-19. *World Economic Forum.* Retrieved November 16, 2022, from https://www.weforum.org/agenda/2021/09/how-blended-finance-has-helped-to-keep-energy-supplies-flowing-during-covid-19/

Bisaga, I., Parikh, P., Tomei, J., & To, L. S. (2021). Mapping synergies and trade-offs between energy and the sustainable development goals: A case study of off-grid solar energy in Rwanda. *Energy Policy, 149*, 112028.
Bisaga, I., Puźniak-Holford, N., Grealish, A., Baker-Brian, C., & Parikh, P. (2017). Scalable off-grid energy services enabled by IoT: A case study of BBOXX SMART Solar. *Energy Policy, 109*, 199–207.
Broto, V. C. (2019). *Urban energy landscapes*. Cambridge University Press.
Castán Broto, V., & Kirshner, J. (2020). Energy access is needed to maintain health during pandemics. *Nature Energy, 5*(6), 419–421.
Chaurey, A., & Kandpal, T. C. (2010). Assessment and evaluation of PV based decentralized rural evaluation of PV based decentralized rural electrification: An overview. *Renewable and Sustainable Energy Reviews, 14*, 2266–2278.
Clover, I. (2016, August 20). BBOXX raises $20m funding to boost African off-grid solar presence' *PV Magazine*. Retrieved November 7, 2021, from https://www.pv-magazine.com/2016/08/30/bboxx-raises-20m-funding-to-boost-african-off-grid-solar-presence_100025942/
Clowes, J., Hu, I., Labruto, L., Masters, H., & Mutegi, L. (2019). *Lighting the way: Roadmap to exists in off-grid energy.* Acumen, Open Capital Advisors.
Counts, A., Arnold, J., Advies, M. N., Thorne, H., & Armacost, N. (2011). Towards reinventing microfinance through solving the 'last-mile problem.' In S. Daley-Harris & A. Awimbo (Eds.), *New pathways out of poverty* (pp. 185–228). Kumarian Press.
Cross, J. (2013). The 100th object: Solar lighting technology and humanitarian goods. *Journal of Material Culture, 18*(4), 367–387.
Cross, J. (2019). The solar good: Energy ethics in poor markets. *Journal of the Royal Anthropological Institute, 25*(S1), 47–66.
Cross, J. (2020). Capturing crisis: Solar power and humanitarian energy markets in Africa. *The Cambridge Journal of Anthropology, 38*(2), 105–124.
Cross, J. (2021). Viral solarity: Solar humanitarianism and infectious disease. *South Atlantic Quarterly, 120*(1), 123–136.
Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. *Energy Research & Social Science, 44*, 100–109.
Cross, J., & Neumark, T. (2021). Solar power and its discontents: Critiquing off-grid infrastructures of inclusion in East Africa. *Development and Change, 52*(4), 906–626.
Dizzard, J. (2019, May 2). Mobisol: Cautionary tale for impact investors.' *Financial Times*. Retrieved November 9, 2021, from https://www.ft.com/content/8832bffc-f319-36fa-a720-fadaaf86e4f4

Fehrenbacher, K. (2014, April 10). *How M-KOPA unlocked pay-as-you-go solar in rural Kenya*. GIGACOM. Retrieved November 2, 2021, from https://gigaom.com/2014/04/10/how-m-kopa-unlocked-pay-as-you-go-solar-in-rural-kenya/

FinSMEs. (2012, April 18). *Greenlight planet closes $4M investment*. Retrieved November 2, 2021, from https://www.finsmes.com/2012/04/greenlight-planet-closes-4m-investment.html

FinSMEs. (2014). *d.Light completes $11m series C financing*. Retrieved November 2, 2021, from https://www.finsmes.com/2014/02/d-light-completes-11m-series-c-financing.html

GOGLA. (2016a). *Global off-grid solar market report semi-annual sales and impact data July–December 2015.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2016b). *Global off-grid solar market report semi-annual sales and impact data January–June 2016.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2017a). *Global off-grid solar market report semi-annual sales and impact data July–December 2016.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2017b). *Global off-grid solar market report semi-annual sales and impact data January–June 2017.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2018a). *Providing energy access through off-grid solar: Guidance for governments*. Global Off-Grid Lighting Association.

GOGLA. (2018b). *Global off-grid solar market report semi-annual sales and impact data July–December 2017.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2018c). *Global off-grid solar market report semi-annual sales and impact data January–June 2018c.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2019a). *Global off-grid solar market report semi-annual sales and impact data July–December 2018.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2019b). *Global off-grid solar market report semi-annual sales and impact data January–June 2019.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2020a). *The global off-grid solar forum and expo 2020—Evaluation survey results*. GOGLA.

GOGLA. (2020b). *Global off-grid solar market report semi-annual sales and impact data July–December 2019.* Public Report. Lighting Global. World Bank Group.

GOGLA. (2020c). *Global off-grid solar market report semi-annual sales and impact data January–June 2020.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2021a). *Investment data' global off-grid lighting association (GOGLA).* Retrieved November 20, 2021, from https://www.gogla.org/access-to-finance/investment-data

GOGLA. (2021b). *Global off-grid solar market report semi-annual sales and impact data July–December 2020.* Public Report. Lighting Global, World Bank Group.

GOGLA. (2021c). *Global off-grid solar market report semi-annual sales and impact data January–June 2021.* Public Report. Lighting Global, World Bank Group.

Goldman, S., & Tozun, N. (2010). Solar lanterns lighting up the world. *Appropriate Technology, 37*(3), 29–31.

Grimm, M., & Peters, J. (2016). Solar off-grid markets in Africa. Recent dynamics and the role of branded products. *Field Actions Science Reports. The journal of field actions, 15*, 160–163.

Grimm, M., Lenz, L., Peters, J., & Sievert, M. (2020). Demand for off-grid solar electricity—Experimental evidence from Rwanda. *Journal of the Association of Environmental and Resource Economists, 7*(3), 417–454.

Groenewoudt, A. C., & Romijn, H. A. (2022). Limits of the corporate-led market approach to off-grid energy access: A review. *Environmental Innovation and Societal Transitions, 42*, 27–43.

GSMA. (2016). *Mobile for development utilities: Assessing the opportunity for pay-as-you-go solar in Nigeria*. GSMA.

Guan, Z., & Sheong, J. K. F. I. P. (2020). Determinants of bilateral trade between China and Africa: a gravity model approach, *Journal of Economic Studies, 47*(5), 1015–1038.

Hall, M. (2021, April 15). Focus of off-grid funding shifts in Africa. *PV Magazine*. Retrieved November 16, 2021, from https://www.pv-magazine.com/2021/04/15/focus-of-off-grid-funding-shifts-in-africa/

Hansen, U. E., Nygaard, I., & Dal Maso, M. (2021). The dark side of the sun: Solar e-waste and environmental upgrading in the off-grid solar PV value chain. *Industry and Innovation, 28*(1), 58–78.

Harper, P. (2021). Spotlight on off-grid solar energy. *Africa Outlook Magazine,* 91, 8–9.14–15.

Harrington, E., & Wambugu, A. W. (2021). Beyond technical standards: Creating an ecosystem for quality and repair in Kenya's off-grid solar sector. *Energy Research and Social Science, 77*, 102101.

International Finance Corporation (IFC). (2012). *From gap to opportunity: Business models for scaling up energy access*. World Bank Group.

Jacobson, A. (2007). Connective power: Solar electrification and social change in Kenya. *World Development, 35*(1), 144–162.

Jacome, V., & Ray, I. (2018). The prepaid electric meter: Rights, relationships and reification in Unguja, Tanzania. *World Development, 105*, 262–272.

Jaglin, S. (2014). Regulating service delivery in southern cities: Rethinking urban heterogeneity. In S. Parnell & S. Oldfield (Eds.), *The Routledge handbook on cities of the global south* (pp. 343–447). Routledge.

Jaglin, S. (2019). Electricity autonomy and power grids in Africa: From rural experiments to urban hybridizations. In F. Lopez, M. Pellegrino, & O. Coutard (Eds.), *Local energy autonomy: Spaces, scales, politics* (pp. 291–310). London.

Kam, D. (2015). *Illuminating Africa: Reflections on Light, Life and Development* (Createspace Independent Publishing Platform: Scotts Valley).

Keane, J. (2014). *Pico-solar electric systems: The earthscan expert guide to the technology and emerging market*. Earthscan.

Kemeny, P., Munro, P. G., Schiavone, N., van der Horst, G., & Willans, S. (2014). Community charging stations in rural sub-Saharan Africa: Commercial success, positive externalities, and growing supply chains. *Energy for Sustainable Development, 23*, 228–236.

Kennedy, K. (2019, July 9). Expanding the horizons of Pay-as-You-Go solar. *CGAP*, Retrieved November 16, 2021, from https://www.cgap.org/blog/expanding-horizons-pay-you-go-solar

Kher, R., & Streeter, D. (2013). Greenlight planet: Made in China or Made in India? *Journal of the International Academy for Case Studies, 19*(7), 31–37.

Kizilcec, V., Parikh, P., & Bisaga, I. (2021). Examining the journey of a Pay-as-You-Go solar home system customer: A case study of Rwanda. *Energies, 14*(2), 330.

Leggett, J. (2019). *SolarAid: An updated history in pictures and charts to mark the sale of our 2 millionth solar light*. SolarAid.

Lepoutre, J., & Oguntoye, A. (2018). The (non-) emergence of mobile money systems in Sub-Saharan Africa: A comparative multilevel perspective of Kenya and Nigeria. *Technological Forecasting and Social Change, 131*, 262–275.

Lighting Africa. (2010a, July 1–July 30). *Lighting Africa progress report: Building market momentum.* IFC and World Bank.
Lighting Africa. (2010b). *Solar lighting for the base of the Pyramid: Overview of an emerging market.* IFC and World Bank.
Lighting Africa. (2011a, *February*). *The off-grid lighting market in Sub-Saharan Africa: Market research synthesis report.* IFC and World Bank.
Lighting Africa. (2011b). *2nd International business conference and trade fair: Conference report, May 18–20, 2010.* IFC and World Bank.
Lighting Africa. (2013). *Lighting Africa market trends report 2012 overview of the off-grid lighting market in Africa*. International Finance Corporation, World Bank.
Lighting Global. (2016). *Off-grid solar market trends report 2016*. Bloomberg New Energy Finance, Lighting Global, World Bank, GOGLA.
Lighting Global. (2018). *Off-grid solar market trends report 2018: January 2018*. Dalberg Advisors and International Finance Corporation.
Lighting Global. (2020). *Off-grid solar: Market trends report 2020, March 2020*. World Bank, GOGLA, ESMAP.
Lorenzo, E. (1997). Photovoltaic rural electrification. *Progress in Photovoltaics: Research and Applications, 5*, 3–27.
Luckanyu, M. (2020, September 25). Kenya's greenlight planet raises $90M to expand energy access across sub-Saharan Africa. *Techmoran.* Retrieved November 14, 2021, from https://techmoran.com/2020/09/25/kenyas-greenlight-planet-raises-90m-to-expand-energy-access-across-sub-saharan-africa/
Mamgain, P. (2018, December 18). Inspired evolution-led group invests $41m in solar products maker d.light. *Deal Street Asia*. Retrieved November 14, 2021, from https://www.dealstreetasia.com/stories/inspired-evolution-dlight-114250/
Moko, X. (2021, October 27). Standard Bank et Citi signalés dans une opération de financement de $75 millions, au profit de Greenlight Planet Kenya. *Agence Ecofin.* Retrieved November 14, 2021, from https://www.agenceecofin.com/electricite/2710-92689-standard-bank-et-citi-signales-dans-une-operation-de-financement-de-75-millions-au-profit-de-greenlight-planet-kenya
Munro, P. G. (2020). On, off, below and beyond the urban electrical grid the energy bricoleurs of Gulu Town. *Urban Geography, 41*(3), 428–447.
Munro, P. G., & Samarakoon, S. (2022). Off-Grid Electrical Urbanism: Emerging Solar Energy Geographies in Ordinary Cities. *Journal of Urban Technology*: Early online. https://doi.org/10.1080/10630732.2022.2068939

Munro, P. G., & Bartlett, A. (2019). Energy bricolage in Northern Uganda: Rethinking energy geographies in Sub-Saharan Africa. *Energy Research & Social Science, 55*, 71–81.

Munro, P. G., & Schiffer, A. (2019). Ethnographies of electricity scarcity: Mobile phone charging spaces and the recrafting of energy poverty in Africa. *Energy and Buildings, 188*, 175–183.

Munro, P. G., Samarakoon, S., & van der Horst, G. A. (2020). African energy poverty: A moving target. *Environmental Research Letters, 15*(10), 104059.

Munro, P., van der Horst, G., Willans, S., Kemeny, P., Christiansen, A., & Schiavone, N. (2016). Social enterprise development and renewable energy dissemination in Africa: The experience of the community charging station model in Sierra Leone. *Progress in Development Studies, 16*(1), 24–38.

Munro, P., Van Der Horst, G., & Healy, S. (2017). Energy Justice for All? Rethinking sustainable development goal 7 through struggles over traditional energy practices in Sierra Leone *Energy Policy ,105*, 635–641.

Ockwell, D., & Byrne, R. (2017). *Sustainable energy For all: Innovation, technology and pro-poor green transformations*. Earthscan.

Ockwell, D., Atela, J., Mbeva, K., Chengo, V., Byrne, R., Durrant, R., Kasprowic, V., & Ely, A. (2019). Can Pay-As-You-Go, digitally enabled business models support sustainability transformations in developing countries? Outstanding questions and a theoretical basis for future research. *Sustainability, 11*(7), 2105.

Ockwell, D., Byrne, R., Atela, J., Chengo, V., Onsongo, E., Todd, J. F., Kasprowicz, V., & Ely, A. (2021). Transforming access to clean energy technologies in the Global South: Learning from lighting Africa in Kenya. *Energies, 14*(14), 4362.

Ojong, N. (2021). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.

Paisley, C., & Keane, J. (2008). Tanzanians take to microsolar panels. *Appropriate Technology, 35*(1), 42–43.

Pénicaud, C. (2012). *State of the industry: Results from the 2012 global mobile money adoption survey*. GSMA.

Porter, G. (2012). Mobile phones, livelihoods and the poor in Sub-Saharan Africa: Review and prospect. *Geography Compass, 6*(5), 241–259.

Pothering, J. (2020, September 27). Greenlight planet raises $90 million to bring off-grid solar to new energy users'. *ImpactAlpha*. Retrieved November 14, 2021, from https://impactalpha.com/greenlight-planet-raises-90-million-to-bring-off-grid-solar-to-new-energy-users/

Price, D. (2016). Banking on the poor: Using the off-grid solar revolution to unlock credit for low-income customers in Africa. In D. Bank (Ed.), *Making markets work for the poor* (pp. 13–15). Bill Gates Foundation.

Rastogi, C. (2018). M-Kopa solar: Lighting up the dark continent. *South Asian Journal of Business and Management Cases, 7*(2), 93–103.

Rateau, M., & Jaglin, S. (2021). Co-production of access and hybridisation of configurations: a socio-technical approach to urban electricity in Cotonou and Ibadan. *International Journal of Urban Sustainable Development*: Early online.

Samarakoon, S. (2020). The troubled path to ending darkness: Energy injustice encounters in Malawi's off-grid solar market. *Energy Research and Social Science, 69*, 101712.

Samarakoon, S., Bartlett, A., & Munro, P. G. (2021). Somewhat original: Energy ethics in Malawi's off-grid solar market. *Environmental Sociology, 7*(3), 361–378.

Samarakoon, S., Christiansen, A., & Munro, P. G. (2017). Equitable and quality education for all of Africa? The challenges of using ICT in education. *Perspectives on Global Development and Technology, 16*(6), 645–665.

Samarakoon, S., Munro, P. G., Zalengera, C., & Kearnes, M. (2022). Socio-technical afterlives of off-grid solar: The spatial and ethical dimensions of repair and e-waste in Malawi. *Environmental Innovation and Societal Transitions, 42*, 317–330.

Scott, A., & Miller, C. (2016). *Accelerating access to electricity in Africa with off-grid solar the market for solar household solutions.* ODI, GOGLA, Practical Action, SolarAid.

Sergi, B., Babcock, M., Williams, N. J., Thornburg, J., Loew, A., & Ciez, R. E. (2018). Institutional influence on power sector investments: A case study of on-and off-grid energy in Kenya and Tanzania. *Energy Research and Social Science, 41*, 59–70.

Shanklemen, J. (2016, December 1). *Nova Lumos raises $90 million for off-grid solar in Africa Bloomberg*. Retrieved November 7, 2021, from https://www.bloomberg.com/news/articles/2016-12-01/nova-lumos-raises-90-million-for-pay-as-you-go-solar-in-africa

Sievert, M., & Steinbuks, J. (2020). Willingness to pay for electricity access in extreme poverty: Evidence from sub-Saharan Africa. *World Development, 128*, 104859.

Sinha, V. (2021, October 22). Solar products maker d.light raises $15 mn afresh to expand Africa business. *The Capital Quest.* Retrieved November 14, 2021, from https://thecapitalquest.com/2021/10/22/solar-products-maker-d-light-raises-15-mn-afresh-to-expand-africa-business/

Sireau, N. (2011). Introduction. In N. Sireau (Ed.), *Microfranchising: How social entrepreneurs are building a new road to development* (pp. 1–6). Routledge.

SolarAid. (2014). *Impact report Autumn 2014*. SolarAid.

SolarAid. (2015, September 22). *Tanzania and the price of success.* Retrieved November 13, 2021, from https://solar-aid.org/news/tanzania-and-the-price-of-success/

SolarAid. (2016). *Market update: December 2016.* SolarAid, SunnyMoney.

SolarAid. (2021). *Annual report and financial statement: 1 April 2019–31 March 2020.* SolarAid.

Tracy, J., & Jacobson, A. (2012). *The true cost of kerosene in Rural Africa.* Lighting Africa.

Trompette, P., & Cholez, C. (2022). Frugal innovation and the global markets of pico-solar systems. In C. van Beers, A. Leliveld, P. Knorringa, & S. Bhaduri (Eds.), *Capturing frugal innovation* (forthcoming). Edward Elgar Publishers.

University of Cambridge Enterprise. (2012, January 18). *Eight19 launches new fund to bring affordable solar power to rural Africa*. Retrieved November 1, 2021, from https://www.enterprise.cam.ac.uk/news/eight19-launches-new-fund-to-bring-affordable-solar-power-to-rural-africa/

Wesoff, E. (2015, December 17). Off-grid electric raises $45M in debt for African micro-solar leasing platform'. *GreenTech Media*. Retrieved November 5, 2021, from https://www.greentechmedia.com/articles/read/Off-Grid-Electric-Raises-45M-in-Debt-For-African-Micro-Solar-Leasing-Platf

3

At the Margins of the Grid: The Politics of Off-Grid Electrification in Senegal

Pascale Trompette, Emilie Etienne, and Rhosnie Francius

3.1 Introduction

Access to energy is a major challenge in Sub-Saharan Africa, which is characterized by low electrification rates, unreliable grids and high-cost electricity. Since the late 1990s, the promise of off-grid solar solutions, such as mini-grids and solar home systems (SHS), has been promoted as

P. Trompette (✉) · E. Etienne · R. Francius
Univ. Grenoble Alpes, CNRS, Sciences Po Grenoble, Pacte, Grenoble, France
e-mail: pascale.trompette@umrpacte.fr

E. Etienne
e-mail: emilie.etienne@umrpacte.fr

R. Francius
e-mail: rhosnie.francius@umrpacte.fr

E. Etienne
Schneider Electric, Grenoble, France

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_3

a way to address the challenges of electrification for poor and dispersed rural areas ill-suited to the grid economy. International aid programmes to achieve UN Sustainable Development Goal (SDG) 7, related to energy, not only look to increase electrification rates, but also support the development of the (mini-)solar technology industry, organizing Sub-Saharan African markets of energy access. Senegal is an interesting area in which to analyze these electrification markets at the margins of the grid. On the one hand, the country has one of the largest mini-grid portfolios in Sub-Saharan Africa, to which can be added the thousands of (pico-) solar home systems[1] provided by public or private suppliers. On the other hand, it confirms the still very limited expansion of such small solar projects driven by public policies.[2] This modest public expansion contrasts with the dynamics of unregulated and informal markets for stand-alone power equipment, including small-scale, low-cost solar technologies.

This chapter examines the role of public policies in shaping these plural landscapes of rural, off-grid electrification in Senegal. It focuses on the last two decades (1998–2021), during which successive proactive policies of so-called 'rural electrification' have taken place. Rural electrification is understood as an administrative category corresponding to the provision of energy to areas not covered by the grid (Guillou, 2022). We analyse the way in which these policies and their regulations have shaped different market segments involving a diversity of actors (transnational and local Small and Medium Enterprises [SME]) alongside the national electricity leader, Senelec, making offers that combine or compete locally (Cholez & Trompette, 2016; Guillou, 2022; Jaglin, 2019). We examine how the politics of (market-based) electrification raises issues of energy justice in different ways: in the controversies and negotiations concerning the implementation of neo-liberal reforms; the power asymmetries between energy suppliers associated with market

[1] In this paper, we use the term 'solar home system' or SHS to refer generically to solar domestic installations. The term 'solar kit' refers to pre-packaged (plug and play) equipment, usually based on paygo (prepayment) systems, supplied by private or public service providers as a product-service (maintenance) or product only.

[2] The 2019 report of the Système d'Information Energétique du Sénégal (SIE) estimates the share of photovoltaics at 7.51% of the rural electrification rate in 2018.

regulations; and territorial and social disparities in terms of price and service quality for the off-grid population. Finally, we consider the way in which energy justice issues are put on the agenda of public authorities and give rise to new forms of regulation.

Energy policy has long been addressed from the perspective of enabling environments for private investment and scaling-up mechanisms (Williams et al., 2015). However, such a perspective relates to a technical–economic approach of disseminating socio-technical innovations and does not sufficiently take into account the intrinsically political dimension of market making and how this raises issues of energy justice.

Our analysis explores how policies are converted into the regulations, instruments, technologies and accounts (e.g., tariffs, business models) (Halpern et al., 2014) that configure socio-technical energy systems in practice and, as such, enact different forms of energy justice (Jenkins et al., 2016; Latour & Venn, 2002). These policy instruments configure the infrastructures connecting citizens to public services (Von Schnitzler, 2008) according to the way in which service provision has been defined as a public concern. We further conceptualize the politics of energy as a collective space not only conducted by governments or administrations but also involving a plurality of actors (Smith, 2016), including donors, NGOs, private actors and citizens who can, via trade unions or social movements, contribute to the debates and controversies surrounding the paths to electrification. Conceptualizing politics as a collective space of value confrontation puts energy justice at the core of policy design, rather than considering it a consequence. The political work undertaken by the various stakeholders involves competing aspects of energy justice; i.e., what it concerns (distribution justice), whom it affects (recognition justice) and how it is processed (procedural justice) (Jenkins et al., 2016).

The chapter is organized as follows: the first section goes back in time to trace the history of electrification in Senegal up to 1998, a period dominated by the grid expansion and interconnection, until the emergence of the first experimental off-grid solar initiatives. The second section focuses on the electricity reform of the early 1999s, introducing a partition between Senelec's electrified perimeter and a new area of rural electrification, which was opened up to private investment and actors. The negotiated implementation of this electrification has led to the coexistence of policies and counter-policies, resulting in a territorial patchwork in the supply of electricity services. Taking a close look at how the diverse actors are trying to respond to the challenge of off-grid electrification, Sect. 3.3 delves into energy justice for the implementers of rural electrification. Section 3.4 turns to self-electrification markets based on stand-alone solar systems, which compensate for the absence or failures of (mini-)grids, while at the same time competing with public electrification programmes based on solar kits. The variety of electrification schemes is examined from the villagers' perspective in Sect. 3.5, which shows how rural customers experience exacerbated service discrimination at different scales. Finally, Sect. 6 reports on recent governmental efforts to coordinate, harmonize and regulate the various configurations of electrification.

3.2 A Political History of Off-Grid Electrification in Senegal

3.2.1 Before 1998: The Predominance of Senelec, the National Electricity Company, for Rural Electrification

Off-grid electrification, as small-scale decentralized electricity production (mini-grid or individual kit), is a relatively recent concept in the history of energy access policies in Senegal. The first, very experimental, projects appeared in the 1960s, led by scientific pioneers in solar energy (Caille & Badji, 2018; Minvielle, 1999). However, it was only at the turn of the century that off-grid solutions became part of public policy in the wake of a major reform in 1998, followed by a first rural electrification plan, Plan d'Action Sénégalais d'Electrification Rurale (PASER). This set up a specific institutional framework for rural electrification by integrating mini-grids (diesel, solar or hybrid) and SHS as possible technical options alongside the grid.[3] To understand the development of these two related

[3] Report of Japanese International Cooperation Agency (JICA by its initials in French), L'Étude du Plan d'Electrification Rurale par voie Photovoltaïque en République du Sénégal, 2001.

notions of 'off-grid' and 'rural electrification', this section looks at the background, revealing a history of electrification long dominated by the grid-model. The incompletion of the grid and the crisis in the energy sector prompted the creation of an alternative approach to the so-called 'sub-sector of rural electrification'. It is on the genesis of this partition that we will focus in this section, since this is what has conditioned off-grid governance and regulation.

Throughout the twentieth century, the development of the grid played a role in supporting economic development in the colonial context and subsequently in the national construction of Senegal, even though it failed to socially integrate the country's sub-regions (Ardurat, 2002; Coquery-Vidrovitch, 2002; Diedhiou, 2016; Robert, 2016; Saupique, 2002). The 'age of the grid' (Coutard & Rutherford, 2009) took off in the post-World War One world, with the concentration of several private concessionaires in a large electricity company: the West African Water and Electricity Company (EEOA in French) created in 1929 (Saupique, 2002). The combination of public and private capital favoured investment in electricity grid extension to foster the economic development of the colonies, previously confined to an economy of rent-seeking (Saupique, 2002). Alongside the interconnected network, secondary towns, such as Djourbel and Ziguinchor, were electrified from 1925 with decentralized power stations.[4] Upon its independence in 1960, Senegal inherited an embryonic system of electricity production and service distribution, which was nonetheless one of the most advanced in French-speaking West Africa (Saupique, 2002). For two decades, the post-colonial socialist government aimed to become economically independent through industrial development and growth, a strategy that heavily relied on the expansion of the electricity grid (Coquery-Vidrovitch, 2002; Robert, 2016). In this endeavour, the Senegalese government increased public investment and control over the electricity sector with the creation of Senelec in 1971 and its nationalization

[4] Rapport de Mission en Afrique Occidentale Française, Électricité de France, Service des Etudes d'Outre-Mer, 1948–1949. In the context of the Plan de Modernisation et d'Equipement des Territoires d'Outre-mer (Modernization and Equipment Plan for the Overseas Territories) initiated by the French government in 1946, the report reviews the existing infrastructure in Senegal and other countries of French-speaking West Africa (Togo, Guinea, Sudan, etc.).

in 1983. Electrification followed urban growth and remained focused on industrial development and public lighting, while also increasingly satisfying domestic needs (Minvielle, 1999; Robert, 2016).

Throughout this first century of infrastructure development, the rural world remained a no-man's land for electrification, limited to traditional energies, with a perceived limited energy demand (Robert, 2016). In the 1980s and 1990s, when the rural population's electricity needs were first considered a legitimate issue, the aim was above all to support the primary sector, although these merely economic objectives gradually gave way to a social project to improve the living conditions of the population. Nonetheless, the integration of rural areas into the political geography of electrification was inhibited by the crisis of the energy sector. At the turn of the 1990s, the sole maintenance of an ageing interconnected urban grid absorbed most of the electricity investment, while the quality of service deteriorated (Niang, 2011; Robert, 2016).[5] In his analysis of the electrification policies of this period, Robert (2016: 310) concludes: 'Rural electrification is thus the big loser of the energy policy of the 1980s. With the difficult economic context, Senelec does not have the capacity to invest in it'. Profitability constraints and the misconception that the rural population needed little electricity resulted in energy poverty.

The first tentative steps towards rural electrification remained modest, with only 5–8% of the rural population electrified by the end of the 1990s (Mawhood & Gross, 2014). Twenty-four secondary centres and just over 100 villages benefited from this first wave of electrification by Senelec in the mid-1990s. A few dozen more were electrified by non-governmental organizations (NGOs) and private actors (e.g., Isofoton) or international cooperation (notably the German Cooperation agency GIZ[6] and the Japanese government) (Ndiaye, 2011; Robert, 2016). It was in this context that the concept of 'off-grid' first appeared, referring to decentralized electricity production, with limited capacity (mini-grid or individual kit); it was based on mini diesel-power plants but with

[5] The ambition of grid expansion was hampered by sectorial difficulties as well as debt crises, combined with galloping urbanization linked to the rural exodus, oil shock and recurrent agricultural droughts.

[6] Gesellschaft für Internationale Zusammenarbeit (GIZ).

the idea of being combined with or, more importantly, substituted by renewable energy mini-grids, notably solar ones.

Senegal is described as one of the cradles of photovoltaic (PV) electrification, with research and innovations developed since the early 1960s (Caille & Badji, 2018; Minvielle, 1999). Pioneering technological research was initiated within the framework of collaboration between French and Senegalese researchers, resulting in the creation of the Center for Studies and Research on Renewable Energies (CERER). In addition, a large number of renewable energy projects were initiated by bi- or multilateral cooperation (Minvielle, 1999).[7] All these initiatives resulted in pilot pumping stations, irrigation systems and small solar power plants. Nevertheless, the off-grid PV concept was not yet mature; installation and operating costs were high with the result that off-grid solar energy remained limited to scattered, experimental initiatives.

Until the reforms of the 2000s, rural electrification stood out as the poor cousin of the grid story. Too far from urban centres, long ignored and then hard hit by austerity policies, rural citizens benefited at most from piecemeal interventions, mostly from international aid. Solar projects surfaced mostly as innovative experiments in the context of development aid, and despite the political interest of public authorities, they remained at the margin of electrification policies.

3.2.2 The 1998 Reform: The Fragmentation and Privatization of Rural Electrification, with the Emergence of New Actors and Regulations

At the end of the 1990s, against the background of the debt crisis, the Senegalese government came under strong pressure from international institutions, in particular the World Bank, to reform the electricity sector. The subsequent reforms aimed to increase private investment and performance through partial deregulation (Diouf & Miezan, 2021; Mawhood and Gross, 2014). The national electricity company, Senelec,

[7] 'Senegal is the country with the largest number of international interventions, bilateral or multilateral, in the field of renewable energy' (Minvielle, 1999: 63) [translated by the authors].

considered by international experts unable to overcome a chronic deficit and even less able to be reformed,[8] was marginalized in the electrification plans targeting off-grid areas, to the benefit of private investors. Law no. 98–29 of 14 April 1998 established a new legislative framework for the electricity sector in Senegal, limiting Senelec's prerogative to already electrified territories, which were overwhelmingly covered by the grid. Under the authority of the new Senegalese Rural Electrification Agency (Agence Sénégalaise de l'Electrification Rurale [ASER]), the areas to be electrified were open to public–private partnerships through concession contracts. Since the 1998 reform, the whole sector has been regulated by the Regulatory Commission for the Electricity Sector (Commission de Régulation du Secteur de l'Electricité, [CRSE]).

The first electrification plan, PASER,[9] was launched in 2002, dividing the country into concessions.[10] Concessions[11] are vast territories with a radius of approximately 100 km, covering hundreds of localities or villages in several departments and regions, with an estimated market potential of 10,000 to 30,000 connections each. Tenders have been offered to increase the share of private investment, with companies competing to connect the largest number of customers on the basis of a pre-agreed public subsidy. Enthusiastically supported by international donors, the reform initially fulfilled its promise by attracting substantial funds (De Gouvello & Kumar, 2007; Mawhood & Gross, 2014).[12] Total financial commitments were twice as high as initially required. Large national corporations from Morocco (ONE), Tunisia (STEG),

---

[8] Between 1996 and 2002, under pressure from the World Bank, Senelec underwent several privatization attempts, which gave rise to violent social conflicts with the important Sutelec union (one of the main Senegalese trade unions) (Ndiaye, 2017; Sene, 2013). The successive failures of private partnerships (e.g., Elyo and Hydro Quebec) led the State to take back a majority share in the company which, since the 1998 reform, had operated as a concessionaire (Sene, 2013).

[9] The PASER aimed to raise the electrification rate from 8% in 2005 to 30% by 2015, and 60% by 2022.

[10] See: Lettre de Politique de Développement du Secteur de l'Energie, 9 April 2003 (LPDSE), CRSE.

[11] The number and limits of these concessions were stabilized only in 2010.

[12] 'PASER has attracted offers of finance from donors in excess of $159 million (ASER, 2012) (…). The winning bids secured a contract of [USD] 52m in private finance, representing 49% of the total investment' (Mawhood & Gross, 2014).

and France (EDF), as well as the large Spanish solar company Isofoton, in partnership with Senegalese companies in the solar sector (LCS, Matforce, ENCO and LCL) bade for these concessions. Benefiting from an additional subsidy, off-grid solutions (mini-grid and SHS) based on renewable technologies have been a possible option for concessionaires, in addition to grid extension. For remote villages, cheap SHS or solar kits for areas far from the grid have been favoured at the expense of grid extension or mini-grids.

This planning approach has been complemented by a scheme supporting local initiatives for rural electrification, known as Electrification Rurale d'Initiative Locale (ERIL), in localities excluded from the priority plans of concessionaires, even those located within the geographical perimeter of the latter. ERIL has provided a policy frame for scattered small-scale projects of domestic electrification.[13] Such initiatives were designed for a maximum of 200 customers and could be carried out by partnerships between the state, local authorities, village community groups, NGOs, associations of consumers or migrants, or local private companies (Law no. 2006, dated 18 June 2006). ERIL projects have also been initiated by Senegalese small and medium companies in response to ASER's calls for tender. ERIL has become the go-to ground for off-grid solutions (diesel or solar powered mini-grid, SHS), and can be subsidized up to 80% by the Senegalese state or external donors.

The 1998 reform and the first rural electrification plans drew a political division between three areas with different governance of electricity service provision. Firstly, there was the interconnected urban grid (completed by secondary power plants), operated by a company (Senelec) still controlled by the state, with only a few mini-grids (diesel

[13] The same policy frame for multi-sectorial energy programme, called PREM in French (Programme Energétique Multisectoriel), applies to non-domestic applications. The PREM relates to off-grid micro-infrastructure for public institutions, social or community facilities and productive enterprises in certain villages awaiting an effective public electricity service. In 2008, the EcoVillage National Agency (ANEV) was launched. Attached to the Sustainable Development and Environment Ministry, ANEV promotes the creation of 'ecovillages', combining renewable energy with agroforestry and water management. In 2013, the National Agency for Renewable Energies (ANER) was also created. ANER is in charge of PREM-like projects, such as specific solutions for productive uses and solar streetlights.

or hybrid solar-diesel). Secondly, there was the rural electrification sub-sector, brought into being by a mosaic of private investment and using diversified technical solutions. These involved a third division, namely schemes based on large concessions and those entailing localized projects (ERIL). The next section examines the implementation of this grid and off-grid patchwork, highlighting the challenges of a system with multiple actors, complex public–private entrenchments and evolving regulatory environments.

3.2.3 The Bumpy Implementation of the Mosaic of (Off-)Grid Electrification

A Clunky Start for the Concession Model

The first electrification plan in the first decade of the new century sketched out this new political map of rural electrification by multiplying the mechanisms for activating private investment with 'à la carte' off-grid solutions. It nonetheless turned out to be more chaotic and laborious than suggested by initial funding successes. There were extensive delays[14] in starting up concessions, and as time passed, electricity connections remained far below initial projections, making it difficult for concessions to achieve profitability.[15] The enthusiasm for the concession model, which had made Senegal the 'darling' of donors, gave way to disillusion. Several studies have attempted to understand the failure of the concessions (Diouf & Miezan, 2021; Mawhood & Gross, 2014; Robert, 2016), from which we shall retain two key arguments.

The first encompasses the major political tensions within the government itself and with Senelec executives over the ousting of the national company. Senelec's resistance to the 1998 reform[16] does not only reflect a

[14] Contracts signed between 2008 and 2016, with inception phases of two to three years (Cour des Comptes Report, 2016).

[15] See: Document de consultation publique: Révision des conditions tarifaires de ERA (2019–2023) et Comasel (2021–2025), CRSE.

[16] Senelec, influenced by its powerful Sutelec union, defends a different conception of public service (Sene, 2013). Some actors, including the World Bank, suspected Senelec of delaying or even blocking private actors' integration into the electricity sector.

power struggle in the control of the sector vis-à-vis transnational private actors. It also brought to the fore a conflict of justice as to equality in electricity service, baring territorial disparities that disfavoured rural populations. The political controversy over the unequal public service provision put pressure on a government that was regularly exposed to the social rumblings of its population, particularly on energy issues (Caille & Badji, 2018; Sene, 2013). Popular protests are more likely to be led by urban youth, who contest power cuts and the cost of electricity in cities. Yet the need to provide rural electrification is also one of the issues raised by local elected officials and rural populations, particularly in pre-electoral periods. The second argument relates to the relative failure of the concession model as a market-based solution for rural areas suffering from economic precariousness.[17] It was not until 2013 that six out of the ten concessions open to tender were awarded, to ONE, ERA, STEG International Services and ENCO-Isofoton Maroc (CRSE, Avis 2018–03).[18] Failing to attract private investors, the remaining four were awarded to Senelec in 2018 (CRSE, Notice 2018/02). The medium-term requirement of profitability also weighs on technical and financial choices. It has led concessionaires to take advantage of the principle of technological neutrality to favour individual photovoltaic systems, considered less risky and less expensive than mini-grids.[19]

[17] The large companies in charge of concessions enter this challenging market with objectives that go beyond immediate profitability (Mawhood & Gross, 2014; Mostert, 2008; Robert, 2016). They hope to gain a strategic positioning within one of the most dynamic countries in West Africa or aspire to contribute to the company's social responsibility programme.

[18] All concessions associate international companies and Senegalese ones: Office National de l'Electricité du Maroc (ONE) from Morocco is associated with Comasel (Senegal); ERA (Energie Rurale Africaine) was created by EDF from France and Matforce (Senegal); Isofoton, a Spanish company, was associated with Enco from Senegal to create Kolda Energie and Electricité du Rip (EDR), while STEG International Services from Tunisia created the Senegalese company SCL Energie Solutions with the Senegalese companies Coselec and les Câbleries du Sénégal (LCS). (CRSE, Report 2015–2016); (CRSE, Notice 01–2013); (CRSE, Notice 2015–02); (CRSE, Decision 2019–13); (CRSE, Decision 2019–12).

[19] This minimalist option was criticized by the Cour des Comptes report (2016) on ASER's setbacks: 'The concessionaires consider that the connection of these villages would entail significant unprofitable investments. This is why the populations of these localities do not have access to electrical services, especially since the alternative solution taken by the concessionaires by installing photovoltaic systems in these distant localities is not viable' (p. 145).

The partial failure of the concessions has provided legitimate grounds for the Senegalese government to initiate 100% state-funded emergency programmes, thereby reducing its dependency on external donors. In 2008 and 2015, two emergency programmes[20] for rural electrification replaced the initial PASER plan with grid extension and off-grid projects, prioritizing the main districts within areas generally allocated to concessions. The plan was to connect nearly 6000 villages to the grid, as well as to construct mini-grids for 400 villages. The management of these programmes was put in the hands of 'transitional delegated managers' (Gestionnaires Délégués Transitoires [GDT]),[21] and was meant to be handed back to the concessionaires once the concession contract was in place. The GDTs include SSER, a subsidiary of Senelec created in 2004, along with three private Senegalese companies.[22] This emergency plan also envisaged small programmes from bilateral cooperation (i.e., India Phase 2 and Spanish Debt Cancellation). Electrification plans intensively carried out by the government have therefore reinstated local actors, especially Senelec, as key players in rural electrification. They have also restored the grid as the primary means of access to energy for villages (Table 3.1).

Small-Scale Initiatives and ERIL Projects: Innovative Solar Projects Within Unfinished Regulations

As a counterpoint to large rural electrification plans, targeted and small-scale off-grid projects burgeoned from various programmes and initiatives (Fig. 3.1). Pilot projects were initiated within bi- or multilateral cooperation programmes, in particular Spanish-Senegalese cooperation (Delta Saloum electrification), German-Senegalese cooperation

[20] These two programmes respectively are called Programme d'urgence d'électrification rurale (PUER) and Programme national d'électrification rurale (PNUER).

[21] The status of GDT was created by the Senegalese government in 2005 (CRSE, decision 2005–01), one year after Senelec set up its subsidiary SSER (Robert, 2016). This subsidiary enabled Senelec to participate in the state's calls for tender concerning rural electrification, from which it had been excluded, particularly for ERIL.

[22] The other GDT are the Société Sénégalaise pour l'Equipement et l'Energie (SS2E), the Groupement Sénégalais de Réalisation et de Maintenance (GSERM) and Equip Plus. The last withdrew from its concession in 2012 (CRSE, annual report 2015–2016).

Table 3.1 Operator contribution to rural energy supply

Operator	Number of clients	Percentage
Senelec*	239,425	73.4
Concessionaire	18,876	5.7
ERIL	9757	3
GDT	5404	1.7
Individual systems**	52,911	16.2
Total	326,173	100

*The number of Senelec urban and rural clients in 2016 was 952,018 clients
** Others than those provided by concessionaire.
Source MPE—Information system of energy, December 2017, in: Sénégal, Notes de Politique Économique et Sociale, Groupe de la Banque Mondiale, 2019, 43.
Note This table, part of a World Bank analysis of rural electrification policy, shows that Senelec still plays a central role in rural electrification (the number of customers mentioned includes customers already electrified before the successive plans), while the progress of the concessionaires remains very modest, especially compared to ERIL. The category 'Individual systems' refers to solar kits sold in the private stand-alone market. Most market surveys and data were produced by GOGLA—Lighting Global and World Bank (sec 4).

(PERACOD and PED programmes) and the EU PASES project[23] (Kébé, 2013). The ERIL concept was intended to provide a framework for bottom-up approaches started by village groups or local communities. But stimulated by international funding, the dynamics of these projects mostly relied on ad-hoc programmes targeting specific territories and supervised by the ASER.

Off-grid projects provide opportunities for Senegalese SMEs to develop their pool of mini-grids, spread over different areas. SMEs operate either in response to ASER's calls for tender or on their own initiative, seeking external funding by themselves. Coseer, Energie R,

[23] The Spanish-Senegalese programme has provided 10,000 households with SHS of 50 Wp and 10 village centres with solar power plants. The ERSEN project (Electrification Rurale au Sénégal) of the German-Senegalese cooperation is a component of the PERACOD programme (Promotion des énergie renouvelables, de l'électrification rurale et l'approvisionnement durable en combustibles domestiques), which was replaced in 2017 by the PED (Programme Energies Durables). ERSEN has been implemented by EnDev, a partnership created by Dutch and German cooperation agencies. The European Union funded a similar project called PASES-Programme 'Projet d'accès aux services électriques des localités de petite taille dans la région de Sédhiou' (Project for access to electrical services for small localities in the Sedhiou region) (Kébé, 2013). In total, the ERSEN and the PASES projects electrified 285 villages: 97 by mini-grids, 172 by SHS and 16 by grid extension (Niane, 2018).

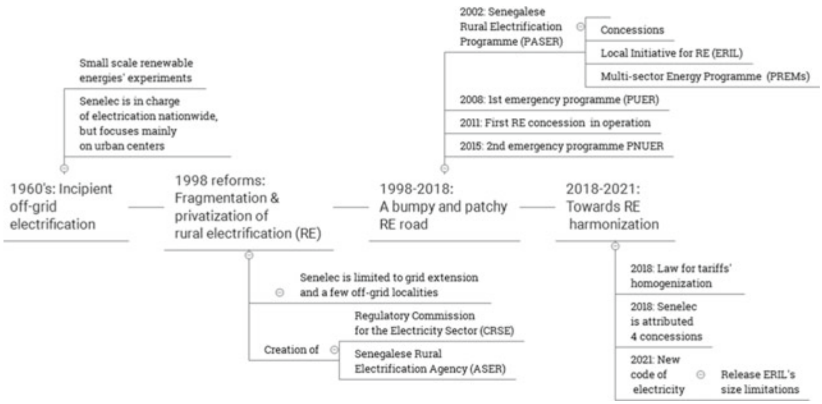

Fig. 3.1 Critical dates in Senegal's off-grid electrification

Faye Solaire, NS Resif, Sud Solar System and Salensol are among the Senegalese companies that have developed a growing expertise in the management of mini-grids, with varying degrees of success (see Sect. 3.4). 'There are many mayors who have contacted me to propose their villages. I have a database of villages asking for electrification and at the first opportunity, we try to go and search in these villages, and then it's our job to contact the mayors, the village chiefs…' (Chief Executive Office (CEO), SME2 with an ERIL portfolio, October 2016). Among ERIL operators, only one (Enersa) is a joint venture with a foreign company (Inensus) (Ulsrud et al., 2018a, 2018b). The contracting delays with the ASER[24] have placed SMEs in a kind of 'institutional void' or at least a grey area.

Although they are often considered marginal in rural electrification policies, targeted and small-scale projects open a space for alternative dynamics, bringing expertise in local governance and renewable energies, in particular solar technologies. While SHS remain a favoured option for ERIL, the share of mini-grids is greater than SHS in the concessions.

[24] As for concessions, the design of the institutional framework for ERIL experienced the same political tensions. According to our information, cross-referenced with administrative data (CRSE, 2019) and a recent report (Semis, 2020), only one company (Enersa) has been officially labelled ERIL, and that was due to privileged relationships. The others have started the procedure without being approved and are still waiting for regularization.

Small projects thus contribute to social and/or technical innovations, even if their viability is not totally secured (see Sect. 3.3) (Semis, 2020). However, as explained in Sect. 3.5, this also leads to price disparities that are barely acceptable to users, especially as mini-grids offer a limited and sometimes inferior service.

3.2.4 The Fragmented Landscapes of Rural Electrification

Although rural electrification is making progress, it is therefore in a dispersed order. Concessionaires entered gradually, hindered by governance conflicts and the risk of non-profitability, and these delays have provided legitimacy for public funding, emergency state plans and the return of Senelec. This policy also tends to re-establish the primacy of the grid electrification option (Guillou, 2022), while rural and remote villages are set up as secondary or experimental areas of solar off-grid electrification.

Rural electrification policies give way to multiple configurations of actors (Olivier de Sardan, 2011) and public service provision. Senelec, GDTs, concessionaires and ERILs all operate according to different rules while their respective geographical area of intervention may overlap over the course of successive electrification plans. Opportunities are driven by international aid-funded programmes and changes in public rules. All actors are faced with the challenge of very unlikely profitability, although Senelec benefits from a subsidized price per kWh along with the state's support in compensating for financial losses. Private operators, whether concessionaires or ERIL schemes, must ensure their economic viability by charging tariffs to at least cover their operating costs.

Turning to pricing, various problems are encountered. In addition to the above-mentioned difference in price per kWh, concessionaire and ERIL charge consumer tariffs according to a less user-friendly system of monthly flat-rate payments. This is based on levels of service (S1, S2, S3, S4[25]) depending on the power scale,[26] regardless of effective consumption.[27] Tariffs also include the repayment of internal installations that were pre-financed by the concessionaire to facilitate household connections. Mini-grid and SHS options for remote villages add a further constraint to this tariff inequality by offering limited electricity time slots. Because of these differences in price and service, the population shows a certain reticence towards private actors, especially when their areas of intervention overlap with those of Senelec. In their reports, concessionaires mention the need to carry out awareness-raising campaigns and offer reduced-cost subscriptions for SHS to attract new customers. These strategies, however, sometimes prove unsuccessful in overcoming the drawbacks with shortened product lifetime and competition from other SHS private sellers.

The CRSE states that after installing 398 SHS in 128 localities between 2013 and 2017, i.e., 21% of its target, Comasel-Louga has resiliated all these contracts.

> According to the operator, the structuring of the offer had become unsuitable due to "*competition from suppliers who offered lower quality products within the concession area, fraud on the installations which led to deep discharges of the batteries before the end of the contract*". This situation, again, according to the operator, "*led to unpaid bills of 44 million CFA francs that subscribers refused to pay*" (CRSE, Révision des conditions tarifaires de Comasel-Louga 2021–2025).

As seen above, the implementation of state-led rural electrification in Senegal is dominated by three main actors: Senelec, large companies allied with foreign partners in charge of concessions, and Senegalese SMEs contracted to electrify specific villages through ERIL-like schemes.

---

25 In ERIL villages, the highest level of service (S4) corresponds to a monthly flat-rate payment, unlike in concession area, where payments for S4 depend on electricity consumption.

26 Comasel services: S1 = 50w–50wc, S2 = 90w–75wc, S3 = 180w–150wc. The concessionaire tariff is the same whatever the mode of electrification (grid or solar kit).

27 It is interesting to note that for these modest consumers, the concessionaires' tariffs were established by the CRSE with the hypothesis that grid-connected customers would use only 30% of what they are entitled to. This projection proved to be false, resulting in profitability losses for concessionaires.

This fragmentation of the governance of a public service raises issues of energy justice for implementers, as described in the next section.

3.3 Energy Justice for Rural Electrification Implementers: Highlighting Systemic Vulnerabilities for Small and Medium Senegalese Companies

The concept of energy justice has focused mainly on justice for final consumers (Sareen & Haarstad, 2018), while the position of the producers has not yet appeared as a priority research area (Sovacool et al., 2017). Opening up energy justice to the parties implementing rural electrification may shed light on inequalities in distribution, recognition and procedure (Jenkins et al., 2016). Indeed, while Senelec, concessionaires and Senegalese SMEs contracted under ERIL projects are entrusted with the same objective, namely connecting rural consumers to a reliable, affordable source of electricity, there are vast differences in their perimeter in terms of geography and clients, together with the regulation and delegation framework within which they operate. This inevitably affects their financial stability. In addition, the remoteness of the villages where the SMEs work tends to increase over time, while these companies also have to deal with ageing and at times undersized infrastructure, leading them to lose customers. This differentiation gives rise to equality issues, which are closely related to energy justice (Pellegrini-Masini et al., 2020).

According to rural electrification policies, distance from the grid and population density are the main criteria for deciding whether users will be electrified through the grid or decentralized solutions. Decentralized solutions are then targeted at villages that are the most distant from the grid, which often also means being far away from cities and paved roads. The remoteness of off-grid villages generates higher costs not only for maintenance, but also for collecting feeds. Pay-as-you-Go technologies are still incipient in Senegal, sometimes requiring companies to visit every village several times per month to distribute energy invoices and collect payments (CEO, SME3 with an ERIL portfolio, September 2021).[28] Unlike Senelec and concessions companies, who work both on grid-extension and off-grid technologies, SMEs in charge of implementing the ERIL scheme work only in off-grid villages, increasing the average costs of operations and maintenance. Another source of inequality lies with the types of villages that each actor can electrify; until recently, ERIL projects were limited to 200 clients, capping the potential for economies of scale. It is therefore much harder for SMEs to break even cost balance in electrification activities,[29] partly because they work in smaller villages and also with their pool of clients being capped and relatively remote.

This profitability challenge is further aggravated by grid extension. When the grid reaches a village electrified through off-grid solutions, pre-existing operators are pushed to even more remote areas and also have to bear the costs of dislocation and transport of infrastructure. Operators can in theory receive compensation for the relocation costs but this does not seem to happen, as outlined by one of the operators interviewed: 'We are not compensated at all. We have to simply come and dismantle our equipment' (CEO, SME5 with an ERIL portfolio, October 2021). This is a consequence of their fuzzy legal status. Contrary to concession companies, Senegalese SMEs continue to evolve in a blurry legal framework, as only one of these companies, Enersa, has a full contract with the state (Semis, 2020). Lack of contracting results in difficulties accessing external funding, for example through loans (CEO, SME4 with an ERIL portfolio, September 2021) and also weakens incentive and sanction mechanisms. An expert from a cooperation agency summarized the reputational, financial and legal discrepancies between concessions and Senegalese SMEs:

> "Concessionnaires are players who are a little more solid. ERA is associated with EDF; Comasel is associated with ONE, and ONE with Morocco and SCL; it is STEG in Tunisia. These are players who have reputational issues behind them and who anyway have the funding to

[28] Some ERIL companies pay local villagers to collect electricity fees.

[29] Infrastructure costs are mostly covered by state-led programmes, but SMEs are expected to cover operations, maintenance and equipment replacement with customers' monthly payments.

make it work …]. They also have real licence contracts, real contractual commitments, the State follows the achievements of these concessionaires. (Cooperation Agency Representative, June 2021)" (extracted from an interview)

Furthermore, many mini-grids run by SMEs are undersized. The largest Senegalese mini-grid projects, ERSEN I and II, installed infrastructure in some 100 villages without tailoring the capacity to economic activities and population size.[30] All the mini-grids have a capacity of roughly 5 kWc photovoltaic and 10 kVA from a genset. Enthusiastic new electricity clients often buy or receive equipment, such as TV and fridges, overloading a limited capacity mini-grid,[31] interrupting electricity services for the whole village and shortening the mini-grid's lifespan. Undersizing due to project design is the reason most commonly given by SMEs to explain the fast deterioration of technical systems. The founder of one of these SMEs explains:

"When we met [with the cooperation programme], it was our worries, I was thinking that it would be better to have two big mini-grids than ten mini-grids that do not meet people's needs […]. But well, as we are not involved in the [feasibility] studies, we do not have a say. […] Batteries are often overused and every day that God makes, the diesel generator is turned on because batteries are empty. (CEO, SME5 with an ERIL portfolio, October 2021)" (extracted from an interview)

The interruption or fading of electricity leads consumers to refuse to pay, preventing companies from saving enough to replace expensive components such as batteries and inverters. In addition, poor services sometimes result in highly conflictive situations between villagers and companies, with physical or witchcraft threats towards SME technicians.

30 These programmes were designed as pilots and expected to increase the capacity of mini-grids over time but, several years after their implementation, this has not yet happened. Most of these mini-grids were installed between 2010 and 2014.

31 Each household is equipped with a power balancer to prevent the mini-grids from overloading, but it is not uncommon for rural customers to unplug these controlling devices.

The premature failure of off-grid systems is frequent worldwide and Senegal is no exception.[32] An extensive study in 2020 led by the Petroleum and Energy Ministry, GIZ and ASER found that half of the 98 hybrid mini-grids installed through the ERSEN I and II programmes are no longer working. Most ERSEN mini-grids started to operate between 2010 and 2014, and the average duration before breakdown is six years. Mini-grids which are still operational usually have a reduced service with an average of three hours of electricity per day instead of the initially-planned minimum of six hours (Semis, 2020). The Senegalese state, with support from funding agencies, is adopting a proactive approach with an ambitious rehabilitation programme (Sous-Commission Cadre Favorable à L'électrification Rurale Hors Réseau, 2021) for these inoperative mini-grids. In the meantime, rural consumers in the dark are going back to traditional devices or buying private systems when they can afford it. The pictures below illustrate the hybridization of a dysfunctional mini-grid connection and privately owned SHS systems to provide lighting and TVs in a Koranic school in a small village in Casamance, South Senegal (Figs. 3.2 and 3.3). This school accommodates around 150 young students and combines several electricity systems. The school was first connected to the village mini-grid (see the cable in the right-hand picture) but given reduced electricity time per day. SHS with a lease-and-own scheme as well as independent solar panels were added (SHS are visible in the left-hand picture, while individual solar panels can be seen in both). They provide the school with night lighting and TV so that children are less inclined to wander outside at night (Field Study in Southern Senegal, 2021).

---

32 The figures, admittedly disparate, question the sustainability of decentralized access to electricity: 34% of off-grid systems are reported as inoperative in Peru (Feron & Cordero, 2018), almost 20% of tracked solar products are said to have ceased to function after 18 months in Kenya (Cross & Murray, 2018), 90% of the systems stopped functioning after ten years in Bolivia (Dávalos & Herrera, 2019). Analyzing a sample of 50 mini-grid projects, implemented worldwide between 1994 and 2017 and selected from the CoSMMA database, Berthélemy and Maurel (2021) estimate that about 50% of those mini-grids have failed. Disconnection rates of up to half the users of certain mini-grids in Madagascar are also reported (André-Bataille et al., 2020; Cholez & Trompette, 2019).

Fig. 3.2 Koranic school in a village in South Senegal is connected to the village mini-grid and has bought stand-alone solar panels (Field Study in Southern Senegal, 2021)

In this section, it has been seen how rural electrification stakeholders, particularly SMEs which do not have the support of private or public shareholders, are trapped in a vicious circle. Costs for collecting fees tend to rise as villages targeted for new mini-grids become increasingly remote due to grid expansion; tariffs fail to secure enough income to replace expensive equipment for mini-grids with a short remaining lifetime. Furthermore, SMEs suffer from a loss of consumers either because the mini-grids do have not enough capacity to connect new users, or because of unreliable or non-functional mini-grids. As for the concessionaire's SHS installations, dissatisfied villagers abandon the service provided under the ERIL scheme and turn to the private self-electrification market.

Fig. 3.3 The same school is also equipped with Baobab+ solar panels to cope with the mini-grid unreliability (Field Study in Southern Senegal, 2021)

3.3.1 Self-Electrification Through Stand-Alone Solar Systems: A Flourishing Market Weakening Energy Justice

The Market for Household Solar Systems: A Political Response for the Supply of 'Essential Goods and Services'

While public electrification programmes have been struggling to scale up access to energy for remote populations and grid deficiencies have persisted, the market of stand-alone solar systems offers an alternative, substitute or complementary solution to the grid. This self-electrification market is not radically new. Generator sets, (second-hand) car batteries or even simple electric torches have long been complementary solutions to traditional energy sources, such as wood and kerosene. However, being green technologies, household solar systems have received major political support as solutions to the challenge of electrification.

In the 1990s, NGOs first contributed to promoting and distributing lamps and solar panels by greatly subsidizing their installation. Ten years later, as seen in the PASER plan, they became a technical option for public electrification programmes. In Senegal, as in other Sub-Saharan countries, the formal market of stand-alone solar systems (SHS, solar kits, solar lamps) has been stimulated by the offensive of the 'solar off-grid industry',[33] in particular via the GOGLA federation and the support of the World Bank (Lighting Africa). Although these systems provide limited power, according to several surveys by the Energy Information Services in Senegal of WAEMU[34] (2013 and 2019), they have been promoted as a providential response to the challenge of universal access to 'essential goods and services' (Ndour & Boidin, 2012), mentioned in the UN Millennium Development Goals (MDGs) and Sustainable Development Goals (SDG). In 2017, Senegal's Petrol and Energy Ministry estimated that individual systems covered 16% of electrified rural consumers, without taking into account those installed by concessionaires.[35] More recently, the development policy letter (2019–2023) of Senegal energy sector mentioned the need to promote the deployment of SHS while the new electricity code designates SHS as an 'activity related to the electrical sector' (Article 53, Code de l'Energie). Despite this cautious wording, private SHS have been included in energy statistics after the 2013 population census showed the prevalence of these systems (Thiam Sow, 2021).

It is also interesting to observe that the dissemination of SHS or solar kits as a market-based solution intertwines the public and private sectors. The same technical option (SHS) can be provided in the framework of public electrification programmes by concessionaires or an ERIL project, as a public utility, or as a sale through the purely private segment of social business, as part of the Corporate Social Responsibility (CSR) programmes of start-ups or multinationals. Indeed, it is not

[33] In the area of aid development, market surveys also use the term 'off-grid' to refer to this market segment.

[34] West African Economic and Monetary Union.

[35] See Table 3.1 and its interpretation in Sect. 3.2.

Fig. 3.4 An example of a solar lamp with a lease-to-own scheme (*Note* Users pay for electricity as they can, and eventually become owners of the system [Field Study in Southern Senegal, 2021])

uncommon for equipment suppliers to sell through both channels. The following section will examine this private segment of self-electrification equipment (Figs. 3.4 and 3.5).

The Challenging Development of Off-Grid 'Bottom of the Pyramid' (BoP) Markets in Senegal

In Senegal, as in other West African countries, the uptake of small solar systems has taken longer than in East Africa. The entry of the first 'pico' (lamp) or small (kit) solar systems in Dakar took place in

Fig. 3.5 Branded and generic solar lanterns in a village of Casamance (Field Study in Senegal, 2016)

the mid-2000s, mostly following European SME initiatives (German, Spanish and French) seeking to position themselves in African markets with products sourced from China or Dubai. The director of a French SME, a pioneer in opening up these markets in Senegal, commented:

> I have done a lot of trade fairs, many in Asia, in Honk-Kong in Shanghai, in Canton, etc. It was in these shows that I really learned about all these little systems, these portable solar systems. […] In 2008, I was already importing my first small solar kits, on the plane leaving from Paris, maybe I had sourced them all over the world, but I brought them to Dakar or Ouagadougou to sell them. […] I am telling you about the situation until 2010 because afterwards I no longer recognized my market, because there are so many players who arrived on the market with these small systems, there has been an invasion of products, it's not complicated, an invasion of products and players. (CEO, French SME1, November 2014)

From 2010, these mainly European SMEs were joined by social business actors, which had previously targeted East Africa markets (Kenya, Tanzania, Ethiopia and Uganda). Their objective was to develop so-called 'bottom of the pyramid' (BoP) markets.

Among these, there are pioneering pico-solar start-ups, such as d.light or Greenlight, which are entering West African markets following activities in East Africa; subsidiaries of financial institutions like Baobab+ wishing to enter BoP market; and multinationals like Total operating within their CSR framework. They differ from the above-mentioned European SMEs in their much more intensive 'social impact' marketing. Social business narrative facilitates access to financial levers (responsible finance, donor subsidies), political levers (World Bank support via the Lighting Global programme) and economic levers (strategic partnerships between start-ups, microfinance institutions and major players in the telephone industry). These levers also offer an important institutional base with Lighting Global's marketing expertise, facilitating access to public programmes as well as NGO distribution networks (Trompette & Cholez, forthcoming).

In 2019, ECREEE[36] identified around 30 companies in this 'formal' segment in Senegal, established as importers, distributors or retailers, one-third of which are mature companies. Solar lanterns represent almost 90% of their branded products. Nonetheless, a few years after the launch of this market, sales volatility revealed the challenges of establishing BoP markets with branded products from the formal sector. The selling prices of branded products remain quite high for a basic lamp and phone charge (from €80 in its earliest days to approximately €30 nowadays). Most buyers have become owners of the systems through a lease-to-own scheme, even if the offer includes maintenance and after-sales services. Social businesses have to create their own distribution networks to reach remote and 'poor' customers, which may also result in a chain of indebtedness from the intermediary to the end user. Branded solar product dissemination is still dependent on public programmes and NGOs, which have become the main market intermediaries.

---

[36] ECREEE is the Regional Centre for Renewable Energy and Energy Efficiency of the Economic Community of West African States (ECOWAS).

3.3.2 Competition in Local Markets: When Senegalese Wholesalers Challenge Transnational Companies

At the same time, a more invisible but flourishing market of fairly similar products has developed in Senegalese urban marketplaces, namely non-labelled, low-cost solar products (lamps, kits, SHS), imported from China among the numerous 'chinoiseries' which have entered people's daily life over the last 20 years (Marfaing & Thiel, 2013). In Dakar, as in the major provincial cities such as St Louis, Kaolack and Ziguinchor, longstanding wholesalers in the local marketplaces have supplied solar systems since the early 2000s. They offer a myriad of products providing basic services (e.g., lamps and mobile charging) as well as more elaborate ones (solar kits plugged into appliances such as radios, TVs or fans), right up to SHS.

In Sandaga for example, one of the oldest marketplaces in Senegal providing for the sub-regional markets of Senegal and neighbouring countries, pico systems including a lamp with chargers or mini kits with several bulbs are sold from as little as €15 in hardware stores or specialized electrical shops, alongside solar kits. Prices vary according to quality and size. For SHS, the suppliers systematically connect customers to solar technicians who size and install more powerful systems in their home, leaving them free to combine components of different brands and even different quality/price ranges. In this informal solar market economy, criteria of brands and quality standards have been replaced by those of affordability and easy last-mile transport. Local wholesalers are better able to overcome entry barriers, such as customs taxes and other taxes related to commercial activity, and to control informal resale networks. This ability makes them more competitive than some European wholesalers that have attempted to enter this market.

Unlike SHS installed as part of public programmes, the self-electrification market based on solar kits and SHS was, until recently, unregulated. It was only in 2019 that ASER put the self-electrification market on the agenda. ASER intended to respond to complaints from formal companies regarding 'unfair' competition from the informal sector, which was accused of (at least partial) circumvention of taxes and quality standards, and 'inundating' the market with poor quality products. This common criticism should be considered in the light of the competitive struggle between transnational and local companies. This study of Senegalese suppliers suggest instead that they are defending a broader offer with a low-cost entry level, admittedly of lower quality, while also selling quality products and providing after-sale services. The sellers interviewed reported that buyers tend to prefer low prices to quality (Field Study, 2016). However, according to some empirical works, even low-quality products may offer a more attractive price/performance ratio for the poorest (Bensch et al., 2018; Grimm & Peters, 2016) than solar kits in the formal market.

3.3.3 Villagers Claiming Energy Justice

Following the above description of the plurality of stakeholders and disparity of their services, the study will turn to the population's perception and negotiation of this diversity. A survey carried out in 2016 focuses on a rural commune of about 15,000 inhabitants, located in Basse-Casamance, a geographically isolated region in the south of Senegal. Said year was an interesting period as it revealed issues of energy justice rooted in the accumulation of public and private interventions before the Senegalese government drew up new regulations. As a result of public policies, the rate of rural electrification progressed significantly from 8% in 2000 to 33.2% in 2016 (UFC-MCA, 2017). The electrification of the above-mentioned commune provided the opportunity to empirically explore the complex configuration (Blundo, 2002; Olivier de Sardan, 2004) of public rural electrification services in a single commune.

The commune of Ouonck is composed of 24 small settlements (less than 500 inhabitants each) spanning approximately 30,000 ha, occupied by farmers, mainly from Diola groups. Ouonck is part of the Ziguinchor-Oussouye-Bignona-Sedhiou concession, one of the four that remained unallocated for several years due to their unattractiveness to investors. Faced with a lack of municipal resources and awaiting the implementation of state programmes, the mayor of Ouonck positioned himself as a 'development broker' (Bierschenk et al., 2000) on the market for external donor projects. His objective was to accumulate projects to maximize the electricity coverage of the 24 villages:

> I have been received several times by ASER. The director of ASER knows me. The Minister of Energy knows me. We are even listed in a programme, apparently a programme of the state of Senegal […] I told [the NGO that installed the kits] that you have to compete [with the projects in the village] because if you don‘t, other concessionaires will come, they will propose programmes with much greater economic benefits, and so on. (Mayor of Ouonck, 2016)

Our research on Ouonck in 2016 revealed that five different operators were active in different hamlets of the commune:

- At the entrance to the commune, the main village has benefited from a connection to the grid operated by Senelec, as a result of the first Emergency Rural Electrification Programme (PUER) in 2010. These villagers are thus the only ones benefiting from a continuous service at the lower price, similar to the one applied by Senelec throughout its perimeter.
- Along the central road of the commune, in more remote hamlets, 190 households have benefited from SHS installed by a French NGO, which transferred the fully subsidized equipment to the commune, and its management to a community operator composed of villagers, including several elected municipal officials.
- A mini-grid was installed in a neighbouring hamlet by a Senegalese SME through the ERIL scheme. This SME operates more than ten off-grid photovoltaic electrification projects in the country. The 50 or so households in the village benefit from six hours of electricity per day, with the four levels of service, in line with the conventional ERIL framework.
- A few kilometres further on, a second small village of 230 inhabitants, on the edge of the forest, has had a kiosk solution installed as an ecovillage with an environmental focus. These kiosks have been promoted by the Agence Nationale des Ecovillages (ANEV), a government agency. They allow villagers to collectively access mobile phone

recharging, refrigerated space rental, lamp rental and recharge, along with cinema-video, paying a small fee for each of these services.

- Ten villages in the commune of Ouonck have been equipped with SHS managed by SSER, a subsidiary of Senelec considered a 'transitional delegated manager' (GDT), as part of the government's second emergency programme (PNUER). As SSER has not collected payments, subscribers have used this equipment free of charge but without maintenance (Table 3.2).

One commune has been home to five operators providing very different services (intermittent/continuous, individual/collective, a variable range of power within the S1 to S4 categorization of flat rates, different time slots), and tariffs that can vary by as much as 200% for the same quantity of energy (SSER/NGO). For these villagers, who are neighbours and often relatives, the inequalities are not explainable (Francius et al., 2017). Moreover, they are a source of tension in the interaction with the operators, who constantly face demands from users regarding the price of electricity, the quality of the supply or the power levels. In 2016, the community operator managing the SHS set up by the NGO Fondem, faced a major conflict with users who demanded the same free access as SSER clients in the neighbouring village. The mayor supported the community operator so as to maintain the attractiveness of his village to any future electrification project. Despite the intervention of elected officials, the conflict was settled in court, indicating a major crisis in a Diola society, which usually favours traditional forms of authority. This confrontation between the "sons of the village" (committee) and members of their families is symptomatic of a major political crisis. The tumultuous trajectory of electrification in this small Casamance commune reveals the extent to which this multiplication of service providers in deficient regulatory spaces weakens the social cohesion of a village.

Observing the electrical landscape of 'diffuse urbanization areas',[37] Guillou (2022) describes the same service fragmentation in Kaolack city and its peri-urban and rural periphery. Because they are part of

[37] Fieldwork carried out in 2019.

Table 3.2 Comparative service table (selection of the same range of power for the top three)

Operator	Service	Power (<=>)	Subscription price (FCFA/€)	Operating time	Tariff/month (FCFA/€)
NGO	SHS (S1 to S4)	(S3) 80 Wc/4 bulbs + 12 V outlet	50,000 (€70)	3 h/day	6800 (€10)
ERIL	Solar mini-grid (S1 to S4)	(S2) 50–90 Wc/ 7 bulbs + 12 V outlet	40,000 (€60)	8 h/day	6000 (€9)
SSER	Only service	65 Wc/ 7 bulbs + 12 V outlet	20,000 (€30)	3 h/day	2500 (€3.8)
Senelec	Average price per kWh: 117 FCFA (€0.18)				
Ecovillage	Phone charging: 50 FCFA (€0.076), refrigerated space = 200 FCFA (€0.30)/day, cinema: 50 FCFA (€0.76)				

the perimeter not electrified by Senelec, these areas are classified as 'rural' electrification zones, likely to benefit from limited offers. Certain communities are allocated to Senelec within a zone normally delegated to an inactive concessionaire, which implies a flat-rate payment for the basic services. Within the same area, several ERIL operators (Salensol, NSRESIF, Equip Plus+ and Sud Solar) provide electricity on the basis of mini-grids and SHS (limited-service slots), on a flat-rate payment basis.

Guillou (2022) and Jaglin (2019; Jaglin & Guillou, 2020) stress another aspect, that of hybridization with self-electrification solutions. While the promoters of solar electrification praise the savings made by the 'poor' thanks to the substitution of traditional energy sources, observation of practices shows that limited power, intermittency or power failures lead to the use of complementary solutions, as highlighted in Sect. 3.3 with the example of the Koranic school. As Guillou (2022: 199) explains: 'Hybridization is an adaptive response to the technical limitations of existing electricity supply systems or to a limited ability to pay for efficient services'. Hybridization consists of combining several sources of electricity within the household, with SHSs or generator sets, pooling some energy-consuming applications (community refrigerators), or obtaining electricity from an external source (e.g., recharging phones in neighbouring villages). In line with Jaglin and Guillou's work, other researchers analyzing off-grid electrification in areas both urban (Le Picard & Toulemont, 2022) and rural (Etienne, forthcoming; Cholez & Trompette, 2019; Ulsrud et al., 2018a, 2018b) show that hybridization, more than substitution, has become a common practice. These works also concur on the idea that service inequalities contribute to the perception of decentralized solutions as being downgraded in relation to the grid. The villagers are inclined to self-electrify while waiting for the arrival of the grid.

3.4 Towards Harmonization: The End of the Rural Electrification Patchwork?

Openness to private operators, claimed to be more efficient and able to accelerate electrification, has paved the way for an unequal electricity geography with significant territorial disparities in both service provision and pricing. This has meant, at least temporarily, withdrawing from the model of national tariff uniformity and equal treatment of users (Colombier & Hourcade, 1989), even when addressing the most disadvantaged populations. The variety of electrification stakeholders and delivery patterns is summarized below (Table 3.3).

These inequalities have given rise to social and political controversies, with background confrontations from political and economic elites, regarding the neo-liberal Public–Private Partnerships scheme. On the one hand, critics[38] question the action of ASER (limited competences and means), the non-fulfilment of concessionaires' commitments in infrastructure implementation and their extensive use of minimal electrification solutions to avert financial risk, along with the lack of monitoring leading to many non-functioning installations, like minigrids and kits.[39] On the other hand, ASER officials and private operators denounce the resistance of Senelec and the delays of the CRSE, as well as contracts based on over-optimistic projections, causing critical situations with concessionaires and ERIL exposed to heavy deficits. Nonetheless, all stakeholders concur on the issue of tariff inequalities.

The sensitive issue of electricity tariffs and equity of treatment between urban and rural areas called for a political response. The objective of tariff harmonization for rural areas has been announced in the context of the emergency plans from 2014 but its implementation is effective in 2018.[40] Concessionaires and SMEs in charge of ERIL projects should benefit from financial compensation for losses due to tariffs lower than

[38] The 2016 report by the Court of Auditors, which was motivated by malpractice within ASER (corruption, misappropriation of funds), is emblematic of these arguments.

[39] 'In all the localities visited in the centre, east and south of the country, solar installations over five years old have come to a complete standstill', mentioned the same report.

[40] Avis n°03/2018 concerning the modification of the rural electrification concessionaires' contracts.

Table 3.3 Summary table of electrification stakeholders and delivery patterns

	Senelec	Concessions	ERIL companies	GDT (transitional delegated managers)	Direct solar sellers
Characteristics	Historic national electrification company	Partnerships between international and Senegalese companies	Senegalese SME and one joint venture (Enersa)	Senegalese companies, subsidiaries of Senelec (SSER)	Transnational companies (branded products) or local SME (non-branded)
Names	N/A	ERA-EDF-Matforce Enco-Isofoton /Kolda Energy and EDR ONE-Comasel SCL Energie Solutions-STEG-LCS-Coselec	COSEER, Energie R, Enersa, Faye Energie, NS Resif, Salensol, Sud Solar, Sud Energie	Equip Plus GSERM SS2E SSER (In 2019 only GSERM and SS2E were still operating) (CRSE, 2019 annual report)	Baobab+ , PEG, Oulu Solar, Salensol, Sud Solar, Lagazel SN, among others
Main electrification solutions	* Grid extension * 7 off-grid hybrid centrals	Grid extension SHS	SHS Hybrid mini-grids (solar + diesel)	Grid extension Mini-grid Solar kits	SHS Kits with appliances (solar fridge, solar TV, etc.)

	Senelec	Concessions	ERIL companies	GDT (transitional delegated managers)	Direct solar sellers
Pricing (before tariff harmonization)	According to consumption, with bundles Off-grid and on-grid consumers pay the same tariff	* Low consumers (Services 1, 2 and 3) > Lump sum High consumers (service 4) > According to consumption	Lump sum for all consumers (Services 1, 2, 3, 4)	Low consumers (Services 1, 2 and 3) > Lump sum High consumers (service 4) > According to consumption	Various—not regulated
Subsidies	A 'maximum authorized revenue' is defined by CRSE. In case of deficit, Senelec can increase tariffs or receive state compensation	Benefit from a lower electricity price when buying electricity from Senelec	Most infrastructure costs are covered by cooperation programmes Operating costs are to be covered by tariffs	Infrastructure costs are covered by the state Operating costs are to be covered by tariffs and ASER's compensation	None
Geographical perimeter	Transport: nationwide Distribution: on Senelec perimeter	Concession perimeters	Nationwide, but project dependent	Concession perimeters (temporary solutions before selection of concessionaires)	Nationwide

(continued)

Table 3.3 (continued)

	Senelec	Concessions	ERIL companies	GDT (transitional delegated managers)	Direct solar sellers
Restriction of activities	NA	None: concessionaires can choose their favoured technical option	Capped to 200 consumers until 2021 Return exploitation to concessionaire when requested	Return exploitation to concessionaire when requested	NA

Notes Compilation of authors' observations and interviews, literature review, CRSE website, CRSE decisions and minutes the initial business plan.[41] The ambition is to reduce tariffs by up to 50% of the prices currently paid by rural people. In the same year as tariff harmonization (2018), the government set up a consultation framework to coordinate the actions of stakeholders and organize the sector. Aid organizations (donors and NGOs), public and private operators (Senelec, concessionaires and ERIL projects) as well as transnational and Senegalese equipment companies, the federation of the renewable energy sector (Coperes) and consumer associations are all participating.

The normalization of the relationship between ASER, Senelec and the concessionaires provides a positive environment to sustain the scaling up of rural electrification projects. The UN Sustainable Development Goals are bringing a new impetus to off-grid electrification programmes, with a stronger trend towards renewable energy, while incentives to facilitate the development of ERIL projects have been put on the political agenda. State actors are well aware of the challenges faced by Senegalese SMEs in charge of ERIL. The new Code of Electricity, approved in 2021, has incorporated some of their demands: the limit of 200 clients per village has been removed, as has the mini-grids capacity limit, which was previously capped at 1 MW. These new rules should help companies to access larger villages and ease economies of scale. The harmonization of tariffs should also bring about a fall in client complaints even though, in the short term, it is unsure whether state compensation will improve companies' financial situation since it is known to be delayed. While large companies have enough working capital to wait several months for compensation, it might be more difficult for Senegalese SMEs.

These recent regulations are not only about restoring social justice in access to energy for rural populations. They aim to restore the population's trust in the operators, as well as the operators' trust in the future

[41] The funds come from an Energy Support Fund (FSE—Fonds spécial de soutien au secteur de l'énergie) supplied by the state budget allocation. Part of this fund should normally be collected by Senelec from its urban customers (tariff equalization) (decret n°02019–1884) (Ministère du Pétrole et des Energies, Prospectus d'Investissement, Accès Universel 2025, 2020).

of (off-)grid electrification. They also reflect a form of public–private compromise that reconciles the reform's liberal approach with the ideal of spatial solidarity enshrined in the public service.

3.5 Conclusion

The recent history of rural electrification policies in Senegal has paved the way for a collection of political instruments: a major but incomplete reform, a multitude of ad-hoc aid projects and eventually urgent state plans, each time justified by the electrification emergency. This history reflects a patchwork of projects targeting overlapping rural territories, leading to highly differentiated services in competition or complementarity with one another, or ignorant of each other. The link between a locality—a town, a village or even a hamlet—and a socio-technical system of access to energy has resulted from the political and institutional (micro-)trajectory that led to the inclusion of the place in one of the multiple interventions initiated over the successive strata of public policies, or due to their incompletion or failures. The problem is therefore not so much a territorial fragmentation but rather the lack of any rationale based on legitimate principles of energy justice behind such fragmentation.

Over the course of this story, off-grid solar solutions have become an essential part of energy access for rural Senegalese citizens, whether in the form of mini-grids, SHS, solar kits or lamps. They have been variously embedded in different political economies, as evidenced by a large range of suppliers (Senelec, concessionaires, GDT, SMEs, community operators, (semi-)informal suppliers) coexisting and indirectly competing. While off-grid solutions hold a new political relevance as a technical alternative to the grid, public policies tend to implement them as a 'second-rate' solution addressing remote 'second-class' citizens, deprived of the ideal of the grid (Guillou, 2022). More expensive electricity is provided for an intermittent, low-power service, the sustainability of which depends on the involvement of local actors, such as dynamic SMEs or community representatives (Etienne, forthcoming). As fragile solutions, off-grid systems, on the contrary, need stronger and more coherent public support to increase their legitimacy in the energy landscape. In the meantime, users turn to the self-electrification market, opting for stand-alone equipment. Innovative solar kits, sold by transnational companies, struggle to find their place in competition with low-cost generic products, sold in informal markets with which Senegalese populations are familiar. These are now one of the major paths for stand-alone solar systems and SHS diffusion. They are inclusive markets in the sense that they are driven by local traders and resellers in the value chain. However, the lack of regulation gives way to a range that is variable in quality and includes low-cost degraded products, thus creating uncertainty among the buyers. These markets thus maintain individual solutions (generators, and more recently, lamps and SHS), with differing degrees of cost and efficiency, as an alternative way of accessing off-grid energy.

Annex 1

See Fig. 3.6.

Annex 2

See Fig. 3.7.

The graph shows the estimated costs per kWh considering an estimated average consumption for each service level and comparing them with the tariffs of Senelec and the highest level of service (S4) connected to the grid. The monthly packages can be up to seven times more expensive than the variable tariffs (compared to the kWh). Variable tariffs (per

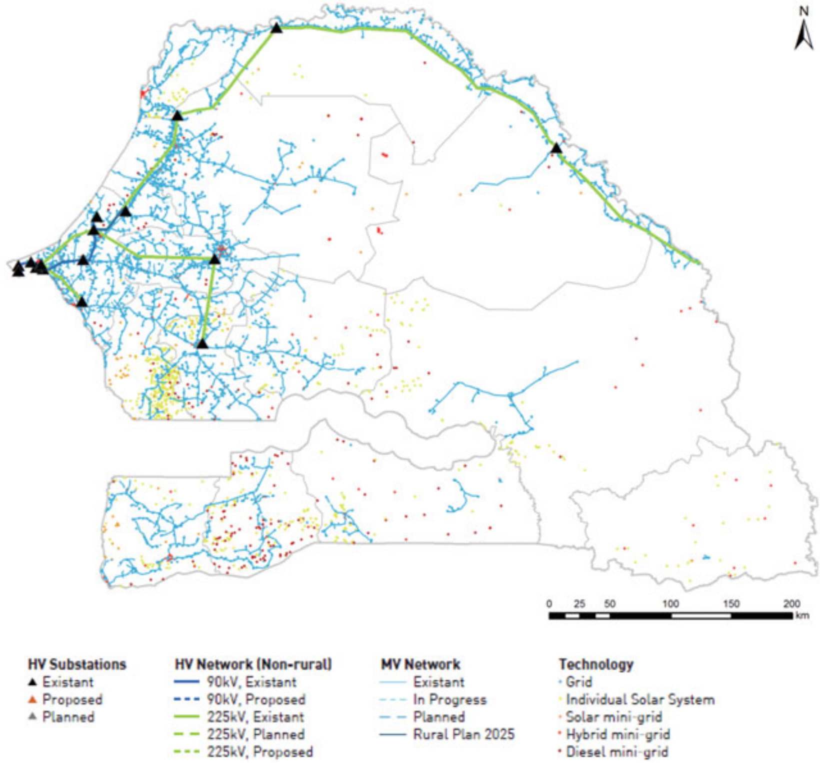

Fig. 3.6 Map of rural electrification options, including off-grid alternatives (diesel, hybrid or solar mini-grids, SHS) (*Source* Authors' GESTO Analysis based on data from ASER)

kWh) are also 20–30% higher in the concessions, however the difference is less significant (Rural Electrification of Senegal SE4All, Gesto Document Analysis, 2018, 51).

References

André-Bataille, C., Livache, N., & Ranzanici, A. (2020). *Publication d'une étude de capitalisation de 16 projets d'électrification rurale à Madagascar*.

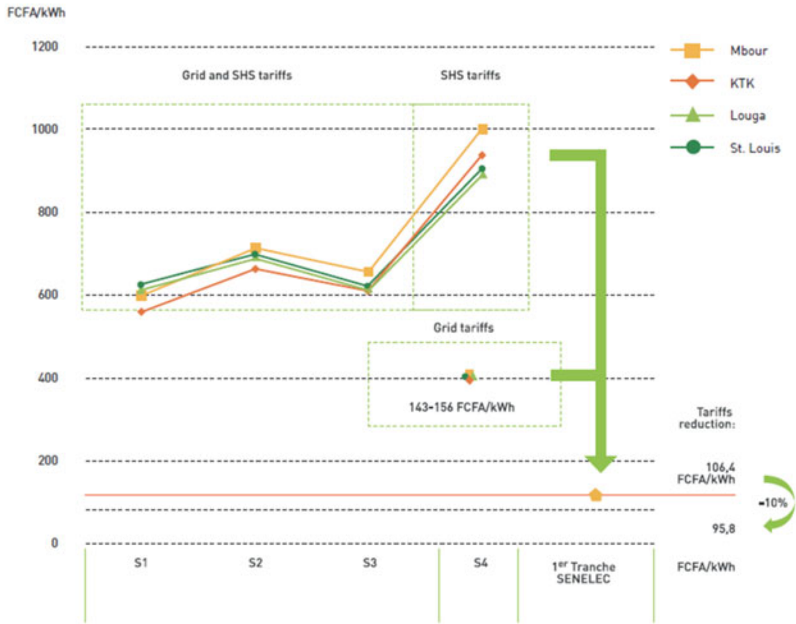

Fig. 3.7 Comparison of different tariffs in Senegal (Concessions and Senelec) (*Source* Authors GESTO analysis based on data from ASER, PLE and Senelec)

Fondation Énergies pour le Monde (FONDEM). Retrieved March 14, 2022, from https://www.pseau.org/outils/ouvrages/fondation_energies_pour_le_monde_etude_de_capitalisation_de_16_projets_d_electrification_rurale_par_mini_reseaux_a_madagascar_2020.pdf

Ardurat, C. (2002). L'électrification du Sénégal de la fin du XIXe siècle à la Seconde Guerre mondiale. *Outre-Mers. Revue D'histoire, 89*(334), 439–457.

ASER (2012). Rapport de passation de service sur le Fonds d'Electrification Rurale. Dakar, Senegal: Internal ASER document.

Bensch, G., Grimm, M., Huppertz, M., Langbein, J., & Peters, J. (2018). Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso. *Renewable and Sustainable Energy Reviews, 90*, 1060–1068.

Berthélemy, J.-C., & Maurel, M. (2021). *A new approach for evaluation of the economic impact of decentralized electrification projects*. Retrieved March 14, 2022, from https://hal.archives-ouvertes.fr/hal-03164719

Bierschenk, T., Chauveau, J., & Olivier de Sardan, J.-P. (2000) (Eds.). *Courtiers en Développement: Les Villages Africains en Quête de Projets*. APAD-KARTHALA.

Blundo, G. (2002). La gouvernance, entre technique de gouvernement et outil d'exploration empirique. *Bulletin de l'APAD*, 23–24. Retrieved March 14, 2022, from http://journals.openedition.org.sid2nomade-1.grenet.fr/apad/129; https://doi-org.sid2nomade-1.grenet.fr/10.4000/apad.129

Caille, F., & Badji, M. (2018). *Du soleil pour tous: L'énergie solaire au Sénégal—un droit, des droits, une histoire*. Éditions science et bien commun, Université Laval. https://openlibrary-repo.ecampusontario.ca/jspui/handle/123456789/784

Cholez, C., & Trompette, P. (2016). *Africa's mundane solar market: Trading routes, globalization and competition*. Interdisciplinary Market Studies Workshop, Edinburgh.

Cholez, C., & Trompette, P. (2019). Designing infrastructure for the poor: Transactions within unstable ecologies. In M. Kornberger, G. C. Bowker, J. Elyachar, A. Mennicken, P. Miller, J. R. Nucho, & N. Pollock (Eds.), *Thinking infrastructures*. Emerald Publishing Limited.

Colombier, M., & Hourcade, J.-C. (1989). Développement des réseaux et modulations spatio-temporelles des tarifs: L'équité territoriale revisitée. *Revue économique*, 649–677.

Commission de Régulation du Secteur de l'Electricité (CRSE)—Annual Report from 2000 to 2018.

Commission de Régulation du Secteur de l'Electricité (CRSE)—Decision 2005–01; Avis 2°18-03, Notice 2018–02.

Commission de Régulation du Secteur de l'Electricité (CRSE)—Document de consultation publique: Révision des conditions tarifaires de ERA (2019–2023) et Comasel (2021–2025).

Coquery-Vidrovitch, C. (2002). La politique de réseaux d'électrification en Afrique. Comparaison Afrique de l'Ouest, Afrique du Sud ou comment faire de l'histoire sociale à partir de sources économiques. *Outre-Mers. Revue d'histoire, 89*(334), 71–84.

Cour des Comptes du Sénégal—Rapport Public 2016—Chapitre 5 _ Agence Sénégalaise d'Electrification Rurale (ASER).

Coutard, O., & Rutherford, J. (2009). Les réseaux transformés par leurs marges: Développement et ambivalence des techniques «décentralisées». *Flux, 76–77*(2), 6–13.

Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. *Energy Research & Social Science, 44*, 100–109.

Dávalos, A., & Herrera, R. de J. G. (2019). A comprehensive solution approach to the sustainability problem of photovoltaic systems: The Bolivian case. *Cogent Engineering, 6*(1), 1691314. https://doi.org/10.1080/23311916.2019.1691314

De Gouvello, C., & Kumar, G. (2007). *OBA in Senegal: Designing technology-neutral concessions for rural electrification*. OBApproaches. Note No. 14. World Bank. Retrieved March 14, 2022, from https://openknowledge.worldbank.org/handle/10986/11034

Diedhiou, S. (2016). *L'énergie électrique au Sénégal de 1887 à 1985. Transfert de technologie, appropriation et enjeu politique d'un patrimoine industriel naissant* (Doctoral dissertation). École Pratique des Hautes Études. Retrieved March 14, 2022, from https://www.researchgate.net/publication/334049397_L'energie_electrique_au_Senegal_de_1887_a_1985_transfert_de_technologie_appropriation_et_enjeu_politique_d'un_patrimoine_industriel_naissant

Diouf, B., & Miezan, E. (2021). The limits of the concession-led model in rural electrification policy: The case study of Senegal. *Renewable Energy, 177*, 626–635. https://doi.org/10.1016/j.renene.2021.05.077

ECREEE. (2019). *Evaluation du marché de l'énergie solaire hors réseau et conception de dispositifs de soutien au secteur privé*.

Etienne, E. (forthcoming). Fiabilité et accountability de l'électricité solaire hors-réseau au Sénégal. *Flux.*

Feron, S., & Cordero, R. R. (2018). Is Peru prepared for large-scale sustainable rural electrification? *Sustainability, 10*(5), 1683.

Francius, R., Trompette, P., & Cholez, C. (2017). Lampes solaires, kit, batteries… Les nouveaux marchés de l'électrification rurale en Afrique. *L'archicube, 22*, 65–72.

Grimm, M., & Peters, J. (2016). Solar off-grid markets in Africa. Recent dynamics and the role of branded products. *Field Actions Science Reports. The Journal of Field Actions, Special Issue, 15*, 160–163.

Guillou, E. (2022). *En réseau—Hors réseau: Configurations électriques émergentes dans les aires d'urbanisation diffuse (Sénégal et Tanzanie)* (Doctoral dissertation). Université Paris Est.

Halpern, C., Lascoumes, P., & Le Galès, P. (2014). *L'instrumentation de l'action publique: Controverses, résistances, effets*. Presses de Sciences Po.

Jaglin, S. (2019). Electricity autonomy and power grids in Africa: From rural experiments to urban hybridizations. *Local Energy Autonomy: Spaces, Scales, Politics, 1*, 291–314.

Jaglin, S., & Guillou, E. (2020). Decentralized electricity solutions: Innovation in essential services is no substitute for policy. *The Field Actions Science Reports. the Journal of Field Actions, Special Issue, 22*, 58–63.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science, 11*, 174–182. https://doi.org/10.1016/j.erss.2015.10.004

Kébé, A. (2013). *Contribution au pré-dimensionnement et au contrôle des unités de production d'énergie électrique en site isolé à partir des énergies renouvelables: Application au cas du Sénégal* (Doctoral dissertation). Université Paris Sud—Faculté des Sciences d'Orsay. Retrieved March 14, 2022, from https://tel.archives-ouvertes.fr/tel-00925530/document

Latour, B., & Venn, C. (2002). Morality and technology. *Theory, Culture & Society, 19*(5–6), 247.

Le Picard, H. & Toulemont, M. (2022, January 18). Booming decentralized solar power in Africa's cities. Satellite imagery and deep learning provide cutting-edge data on electrification. *Briefings de l'IFRI*.

Lettre de Politique de Développement du Secteur de l'Energie, 9 April 2003 (LPDSE), CRSE.

Marfaing, L., & Thiel, A. (2013). The impact of Chinese business on market entry in Ghana and Senegal. *Africa, 83*(4), 646–669.

Mawhood, R. K., & Gross, R. (2014). Institutional barriers to a 'perfect' policy: A case study of the Senegalese Rural Electrification Plan. *Energy Policy, 73*, 480–490. https://doi.org/10.1016/j.enpol.2014.05.047

Ministère du Pétrole et des Energies, Prospectus d'Investissement, Accès Universel 2025, Aout 2020.

Minvielle, J.-P. (1999). *La question énergétique au Sahel*. Karthala Editions.

Mostert, W. (2008). *Review of experiences with rural electrification agencies: Lessons for Africa.* EUEI-PDF. Retrieved March 14, 2022, from https://www.mostert.dk/pdf/Experiences%20with%20Rural%20Electrification%20Agencies.pdf

Ndiaye, A. I. (2017). Les relations professionnelles en Afrique de l'Ouest: Acteurs, conflits, négociations et régulations au Sénégal. *Les relations professionnelles en Afrique de l'Ouest.* L'Harmattan.

Ndiaye, A. S. (2011). *La part des énergies renouvelables dans le projet ERSEN* [Slides from presentation, 18/11/2011]. PERACOD.

Ndour, M., & Boidin, B. (2012). L'accès aux biens et services essentiels: une notion centrale et ambigüe du développement. *L'Homme la Societe*, (3), 223–248.

Niane, I. (2018). *Un aperçu du cadre politique et stratégique pour le développement des mini-réseaux au Sénég*al. Atelier sur les mini-réseaux solaires, Dakar.

Niang, A. (2011). *Programme d'électrification rurale du Sénégal: Opportunités et défis*. Africa Electrification Initiative.

Olivier de Sardan, J.-P. (2004). État, bureaucratie et gouvernance en Afrique de l'Ouest francophone. *Politique Africaine, 4*, 139–162.

Olivier de Sardan, J. -P. (2011). Gouvernance locale. Lasdel Working Paper. Niamey: LASDEL.

Pellegrini-Masini, G., Pirni, A., & Maran, S. (2020). Energy justice revisited: A critical review on the philosophical and political origins of equality. *Energy Research & Social Science, 59*, 101310. https://doi.org/10.1016/j.erss.2019.101310

Rapport de Mission en Afrique Occidentale Française, Électricité de France, Service des Etudes d'Outre-Mer, 1948–1949.

Report of Japanese International Cooperation Agency (JICA by its initials in French), L'Étude du Plan d'Electrification Rurale par voie Photovoltaïque en République du Sénégal, 2001.

Robert, P. (2016). *Une économie politique de la pauvreté énergétique: Le cas du Sénégal* (Doctoral dissertation). Lille 1.

Sareen, S., & Haarstad, H. (2018). Bridging socio-technical and justice aspects of sustainable energy transitions. *Applied Energy, 228*, 624–632. https://doi.org/10.1016/j.apenergy.2018.06.104

Saupique, T. (2002). L'électrification de la ville de Dakar après 1945. *Outre-Mers. Revue D'histoire, 89*(334), 85–104.

Semis. (2020). *Etat des lieux des ERIL et développement de concepts permettant la réhabilitation des mini-réseaux existants; Livrable 2: Rapport d'état des lieux avec les données quantitatives et qualitatives sur l'état de fonctionnement de l'ensemble des ERILs et GDTs*. Ministère du Pétrole et des Energies; GIZ.

Sene, A. (2013). *Les travailleurs de l'électricité du Sénégal face aux PAS*. CADTM. Retrieved March 14, 2022, from https://www.cadtm.org/Les-travailleurs-de-l-electricite

Smith, A. (2016). *The politics of economic activity*. Oxford University Press.

Sous-Commission Cadre Favorable à L'électrification Rurale Hors Réseau. (2021, September 29). *Création d'un Environnement Favorable au*

Déploiement des Mini-Réseaux. Retrieved March 25, 2022, from https://energypedia.info/wiki/Sous-Commission_Cadre_Favorable_%C3%A0_L%E2%80%99%C3%A9lectrification_Rurale_Hors_R%C3%A9seau#R.C3.A9f.C3.A9rences

Sovacool, B. K., Burke, M., Baker, L., Kotikalapudi, C. K., & Wlokas, H. (2017). New frontiers and conceptual frameworks for energy justice. *Energy Policy, 105*, 677–691. https://doi.org/10.1016/j.enpol.2017.03.005

Système d'Information Energétique de l'UEMOA – Rapport de 2013 et 2019.

Thiam Sow, F. (2021, May 12). *Perspective nationale: Du SIE Sénégal au SIE UEMOA*. Publication de statistiques énergétiques dans l'espace UEMOA: du système d'information énergétique à l'atlas de l'énergie. Retrieved March 25, 2022, from https://www.ifdd.francophonie.org/publication-de-statistiques-energetiques-dans-lespace-uemoa-du-systeme-dinformation-energetique-a-latlas-de-lenergie/

Trompette, P., & Cholez, C. (forthcoming). Frugal innovation and the global markets of pico-solar systems. In C. Van Beers, A. Leliveld, P. Knorringa, & B. Saradindu, *Capturing frugal innovation.* Edward Elgar Publishers.

UFC-MCA. (2017). Amélioration de l'accès à l'électricité en milieu rural et périurbain, Unité de Formulation et de Coordination du second programme MCA-Sénégal, UFC Sénégal2.

Ulsrud, K., Muchunku, C., Palit, D., & Kirubi, G. (2018a). *Solar energy, mini-grids and sustainable electricity access: Practical experiences, lessons and solutions from Senegal*. Routledge.

Ulsrud, K., Rohracher, H., Winther, T., Muchunku, C., & Palit, D. (2018b). Pathways to electricity for all: What makes village-scale solar power successful? *Energy Research & Social Science, 44*, 32–40.

Von Schnitzler, A. (2008). Citizenship prepaid: Water, calculability, and techno-politics in South Africa. *Journal of Southern African Studies, 34*(4), 899–917.

Williams, N. J., Jaramillo, P., Taneja, J., & Ustun, T. S. (2015). Enabling private sector investment in microgrid-based rural electrification in developing countries: A review. *Renewable and Sustainable Energy Reviews, 52*, 1268–1281.

4

A Decade of Change: Off-Grid Solar Energy in Rwanda

Iwona Bisaga

4.1 Introduction

Energy access is critical for addressing the most pressing developmental challenges, including poverty reduction, ensuring human wellbeing and addressing climate change. It underpins the achievement of most Sustainable Development Goals (SDGs) (Fuso Nerini et al., 2018). Yet, there were 770 million people without electricity access in 2019 (IEA, 2020). While this represents a substantial decline from 1.2 billion in 2010 (IEA et al., 2019), achieving universal access by 2030 remains out of reach if we continue on a business-as-usual trajectory. Not only more funding, but also more alternative and innovative approaches will be

I. Bisaga (✉)
Loughborough University, Loughborough, UK
e-mail: I.M.Bisaga@lboro.ac.uk

University College London, London, UK

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_4

needed to rapidly scale up access, particularly in the most challenging settings, such as rural, remote areas, informal settlements, displacement contexts and conflict zones. Among the solutions which have been gaining prominence in electricity access, complementing the more traditional and relatively slow extension of national grids, are off-grid solar systems, such as Solar Home Systems (SHSs), pico-solar systems and other solar technologies, including solar mini- and micro-grids. In particular, SHSs have become an integral component of many national electrification strategies across Sub-Saharan African and Asian countries, most notably in Kenya, Uganda, Rwanda, Mozambique, Bangladesh and India, as well as Togo and Benin (World Bank, 2017). Even though it is in the last decade that the numbers of SHS providers have skyrocketed globally, SHSs experienced their first wave of popularity as far back as the 1980s and 1990s, when numerous programmes were deploying them in rural communities, especially in the Central American region. However, being run by Non-Governmental Organizations (NGOs) who often lacked the necessary skillsets and capacities to provide maintenance, and relying mostly on free distribution, compromising the end-user's sense of ownership, many of these programmes failed, leading to SHSs' poor reputation which, along with relatively high prices of PV technologies, put hold on small-scale, decentralized solar solutions for the following couple of decades. Much has changed since early 2000s, due to several important developments, including a significant fall in solar PV prices, improvements in battery technologies, uptick in remote monitoring technologies, and the realization that grid power will likely not reach millions of people for decades to come, leaving them behind and posing important questions around justice and equity. Jointly, those and other factors have paved way for decentralized energy access solutions to be revisited and actively pursued under various electrification scenarios. Unlike the NGO-led efforts of the past, this time it is the private sector who have been the key players growing the market of distributed energy services. This has resulted in millions of solar kits being sold every year across many parts of the world. According to GOGLA (2021), despite the impacts of Covid-19, sales in the second half of 2020 remained high in SSA, being only 4% lower than in that same period in 2019. Total sales of quality-certified solar lighting products reached approx. 3.6

million globally, with SHSs making up about a sixth of those (ibid.). This compares to over 4 million off-grid quality verified solar products sold in the second half of 2015 of which only approx. 290,000 were larger systems, such as SHSs (GOGLA, 2016). This trend demonstrates that larger solar solutions, which can satisfy other energy needs beyond lighting and charging only, have been in growing demand and have become increasingly more available and accessible as more companies have entered the market.

4.2 The Rwandan Context

Rwanda's electrification rate has been growing rapidly over the last decade: from approx. 10% in 2010, to 55% in 2020 (MININFRA, 2021). A combination of factors has enabled this progress, among them: strong governance and policy frameworks, and strategic national level planning, as will be demonstrated in the following section; a favourable environment for private sector's participation in core sectors, such as energy, along with improved ease of doing business over the years (World Bank, 2021b); and geographical factors which include irradiation levels conducive to the use of solar power and a challenging, mountainous terrain which makes the extension of the national grid challenging, particularly for remote, rural areas. Circa 17.8% of Rwandan households are connected through off-grid, predominantly solar systems in 2021 (REG, 2021) which play an important role in the country's electrification strategy and the achievement of ambitious development goals. It has been shown that there exist synergies between 80 targets under the SDGs and off-grid solar systems in Rwanda, spanning all but one goal (Life Below Water) (Bisaga et al., 2020).

However, despite the significant progress made, the numbers are currently not on track to achieve universal access by the Government's deadline of 2024, where 30% of households are expected to have off-grid connections, whether through standalone systems or mini-grids. Issues of affordability and adequacy remain as the off-grid solar sector grapples with models which can allow higher penetration of the bottom of the pyramid (i.e., reaching the poorest unconnected households), and faces questions around the longevity and sufficiency of the offered solutions, which rarely fall above Tier 2 as measured by the World Bank's Multi-Tier Framework (MTF) (Koo et al., 2018). Additionally, the notion of inclusive energy access strategies, while applicable on the surface, calls for a rethinking in the contexts of Rwanda as vulnerable groups, such as women and refugees, do not equally benefit from these solar technologies.

4.3 Outline of the Chapter

This chapter first outlines the energy policy environment in Rwanda and the role it has played in enabling the growth of the off-grid solar sector over the last decade. It then considers some of the key developments in the sector of SHSs, which are the technology on which this chapter will focus, as the off-grid solution which has substantially contributed to Rwanda's electrification to date. Innovation-driven approaches to adapting the energy service offering to the local market and the introduction of quality standards are briefly looked at, followed by a closer examination of persisting questions around the affordability and energy access equity and justice associated with off-grid solar solutions. The chapter concludes with reflections on the last decade and outstanding challenges that remain to be tackled if Rwanda is to facilitate truly just energy transitions, inclusive of off-grid electrification through decentralized, distributed solutions.

4.4 A Decade in the Rwandan Energy Sector: Stakeholders and Policy Milestones

The key stakeholders in the Rwandan energy sector include the commercially operated, state-owned Rwanda Energy Group (REG), which consists of the Energy Development Corporation Limited (EDCL) and the Energy Utility Corporation Limited (EUCL)—the two implementing bodies responsible for energy development and utility service delivery (REG, 2021); the Ministry of Infrastructure (MININFRA) charged with delivering the overall infrastructure development; and the Rwanda Utilities Regulatory Authority (RURA), which regulates the energy sub-sectors, namely electricity, renewable energy, gas and downstream petroleum (RURA, 2020).

A decade ago, when the country's electrification stood at roughly 10%, the key challenges for the energy sector, as defined by those stakeholders, involved energy diversification, boosted supply capacity, increased investment and financial strength of the energy utility, private sector participation, regional integration, and regulatory and institutional capacity (AfDB, 2013). While progress has been made in all these areas, energy diversification, private sector participation, especially through Public–Private Partnerships (PPPs), and regulatory capacity have advanced the most. Foreign Direct Investment (FDI) inflows rose from USD119 million in 2009 to USD420 million in 2019, or 2.2% of GDP and 4.1% of GDP, respectively (World Bank, 2021). The electricity sector has been among the top beneficiaries of these inflows. This is important considering the critical role it plays in supporting Rwanda's socio-economic development, powering both households and businesses, and contributing to the improved collective and individual wellbeing of all Rwandans. The relatively quick advances in connecting households, businesses, as well as public facilities to electricity have shown that the regulatory frameworks put in place have been aiding rather than hindering progress.

Energy access was already considered to be one of the main pillars of Rwanda's development back in 2000 when Vision 2020—a framework to guide Rwanda's development and the achievement of the aim of becoming a middle-income country by 2020, was launched (and subsequently revised in 2012) (Government of Rwanda [GoR], 2012b). It was then that the recognition for the abundant solar resources and the need to engage with the private sector to electrify the growing population was first highlighted. It was also an acknowledgement that the GoR can only achieve its vision and ambition through partnerships as it was faced with numerous barriers to traditional approaches for energy access extension through the national grid, including limited energy sector budgets and lack of internal capacity to support the rollout of decentralized solutions. Additionally, high upfront costs, especially for low-income households, unfavourable topography, scattered and remote rural households, and a combination of low demand and limited affordability, which made the economic feasibility of the grid challenging. Under these conditions, and accompanied by various policy developments, off-grid SHSs and other distributed solutions have started appearing in the energy access solutions mix, and, over the last decade, have demonstrated high potential to serve unelectrified customers (Bisaga, 2019a; Kennedy et al., 2019; Niyonteze et al., 2020). Today, SHSs provide access to electricity to over 2 million people in Rwanda, driven by over 20 private providers who have signed Memoranda of Understanding (MoU) with the GoR. The last 5 years have seen regular GoR-led consultations with the private sector, tax exemptions on solar products, and growing support from international partners. Among them, the Climate Investment Funds (CIF), Energising Development (EnDev) through its results-based financing (RBF) facility, and Power Africa and the World Bank who have provided financial and technical support across the energy sector, both for on- and off-grid access, further propelling the growth of the off-grid solar sector.

Although evidence from some SSA countries, such as Tanzania and Mozambique, was pointing to limited interest from the private sector to invest in the energy access sector, and planning challenges hindering progress (Ahlborg & Hanmar, 2014), Rwanda's experience to date has shown otherwise. Through the development and implementation of short-, medium- and long-term planning strategies, with a strong component of private sector participation, and a demonstrated capacity to build and support PPPs, it has attracted significant investment into the energy sector, even if deficits still persist (Bimenyimana et al., 2018). The Economic Development and Poverty Reduction Strategy (EDPRS) (2008–2012) and the subsequent EDPRS II (2013–2018) have further strengthened the role of infrastructure and energy access on the national priority agenda, explicitly stating that one of the key areas of focus would be to connect rural areas to economic opportunity through improved infrastructure, of which off-grid solar solutions would be a part (GoR, 2012b).

The following Rwanda Rural Electrification Strategy (RES), finalized in 2016, was an important milestone in Rwanda's energy strategy as it set the goal of 100% electrification by 2024 (70% grid and 30% off-grid connections) (REG, 2022). Jointly with the Sustainable Energy for All (SE4All) Action Agenda (2016), the RES has provided a framework for renewable energy-based rural electrification. Additionally, the Energy Sector Strategic Plan (ESSP) 2017/18–2023/24 sets out strategic goals of the wider energy sector to align the national goals and targets with those under the UN 2030 Agenda (GoR, 2018). It highlights the critical role of the private sector in the implementation of off-grid solutions to low-income and low-demand households. Under the Energy Access Rollout Programme (EARP) and through Sector Wide Approaches[1] (SWAp's), led by REG and the World Bank between 2009 and 2017, grid extensions to productive users (such as small businesses or factories) and households within a specified distance from the existing grid have been prioritized (GoR, 2014).

4.5 The Technology Ecosystem, Quality Standards and Focus on the End-User

Off-grid solutions have been promoted as transitionary solutions in locations where grid extensions are not feasible in the short term, for both technical and economic reasons, and as more permanent solutions in areas where the projected energy consumption will remain relatively low and can be satisfied through SHSs and mini-grid connections. This applies mostly to rural households. Quality standards and financing mechanisms have been put in place to support the country's energy access sector which has also benefitted from the growing Information and Communication Technology (ICT) sector. For example, the rise and rapid development of the mobile infrastructure has enabled innovative pay-as-you-go (PAYG) business models to be implemented

[1] According to the World Bank's Energy Sector Management Program (ESMAP) (World Bank, 2013), a SWAp is 'a country-led, results-focused framework that brings together development partners and other stakeholders to coordinate aid within a sector' (p. 1). Rwanda was among the first countries to use a SWAp in the energy sector to increase access to electricity.

by numerous off-grid solar providers operating in the country in the last ten years. A few have also introduced remote monitoring of the sold units. Under PAYG models customers can access financing for the available off-grid solar products, which enables smaller daily, weekly or monthly payments via mobile money (MoMo), rather than upfront cash purchases, which alleviates the affordability barriers. Remote monitoring of systems provides real time energy consumption data which can be utilized to estimate future energy demand in different customer segments, allowing the providers to adapt the design of products and services to better meet the customer needs. In that sense, smart data, as it is called, can also inform investment priorities (Bisaga, 2020; Bisaga et al., 2017). It can also help companies attract investment as the ability to remote switch the systems on and off acts as a de-risking mechanism as non-paying customers can be easily identified and the assets repossessed and reintroduced into the sales channels, so that the initial capital expenditure gets recovered for all systems (or assets). The introduction of MoMo payments has also facilitated greater ease of access and usability for rural households as payments can be made from one's home, instead of having to seek company agents or making long trips to the closest bank branch, which used to be standard payment procedures in the early days of SHSs in Rwanda in 2000s and early 2010s. The service-based PAYG business models, where the provider is expected to have a long-term relationship with the customer (typically with a minimum of 3 years as the system cost is gradually paid off), have been essential in the provision of system maintenance and customer support. This has helped avoid the experiences of SHSs users of 1980s and 1990s in Central America mentioned earlier in this chapter.

There have been known instances of solar energy, including SHSs, having its reputation tarnished due to poor-quality products and no warranty schemes (Friebe et al., 2013; Muok et al., 2015). Those who encounter challenges with their SHSs often lack access to repair services, not least because they are not commonly available in SSA and other regions where off-grid solar solutions have only been around for less than a decade. If such services are not included in the package offered by the provider, households often cannot afford to pay extra for them which can lead to the disuse of systems (Lemaire, 2011) and the loss of trust in the technology, discouraging others from purchasing similar systems in the future (Kizilcec et al. 2021; Laufer & Schäfer, 2011). A decade ago, when the market of off-grid solar solutions was still in its infancy, there were no quality control measures in Rwanda. However, the introduced quality standards for imported solar products have helped minimize the number of counterfeit products in the market. Consequently, there has been a higher availability of quality-certified products than in other countries in the East African region, and other African markets (e.g., Samarakoon, 2021), and an overall low presence of poor-quality counterfeits. The adoption of the Ministerial Guidelines on Minimum Standards Requirement for Solar Home Systems in 2019 (GoR, 2019) further helped establish quality standards and minimum service level requirements for imported solar products. Following their adoption, the global initiative for off-grid solar certification, Lighting Global, have designed a tool to help with the implementation and to assist the GoR, private sector players, and development partners with the identification of off-grid technologies complying with the outlined requirements (World Bank, 2020).

These factors, together with a growing understanding of customer needs in Rwanda, both at a basic (lighting, phone charging, access to information) and aspirational (TV, speakers, productive use appliances such as shavers) level (Bisaga, 2019a, b; World Bank, 2017); the increased proliferation and presence of various providers across the country, allowing customers to compare providers and their offerings, have also had an impact on how households learn about off-grid solar solutions. While initially it was the sales agents and physical outlets that played the most important role in attracting future customers (Scott, 2017), in the last few years, as market penetration of off-grid solar products grew, the trend has shifted. Word-of-mouth has been increasingly seen as the primary way in which households find out about SHSs today (Bisaga, 2019a, b; Kizilcec et al., 2021). It is both a reflection of a relatively high customer satisfaction among off-grid solar adopters, and at the same time an additional motivation for the companies to provide a good quality customer service to be able to drive sales through positive word-of-mouth (Scott, 2017).

4.6 Getting to Grips with Affordability

Availability and affordability are among the eight energy decision-making principles proposed by Sovacool and Dworkin (2015). Over the last decade, availability of off-grid solar solutions across the country has gone up significantly. However, affordability has remained the top barrier to entry for the lowest-income households. Bhattacharyya and Palit (2021: 11) argue that 'a sustainable electrification solution has to be affordable to the users, but the available evidence [in SSA] points to the relatively high cost of decentralized solutions compared to central grid supply', bringing with it issues of fairness, equity and justice. They go on to suggest large-scale renewable energy as an alternative as it can benefit from the economies of scale, thus rapidly reducing costs. However, a study of a large-scale solar PV plant in Rwanda by Brunet et al. (2021) has shown that such large-scale projects do not always result in higher affordability, better electrification and economic development for the local community, which also brings forth justice concerns.

On the back of the product, service and regulatory developments introduced in earlier sections, the off-grid solar sector in Rwanda has benefitted from schemes which have specifically set out to alleviate the affordability barrier. When examining the impacts of pico-solar kits (comprising a light and phone charging) on rural Rwandan households, Grimm et al. (2016) found that future adoption of similar systems would be impeded by affordability and postulated for more direct support to tackle it, such as subsidies or other financing schemes. Here, again, the flexibility of PAYG models has been invaluable in addressing the needs of different customer segments, including those with irregular income streams who would otherwise be unable to make bulk payments (Zollmann et al., 2017). However, there have been more initiatives responding to this need since.

Early programmes promoting off-grid solar solutions predominantly focused on helping households with access to finance and on facilitating access to working capital for the companies. For example, the Development Bank of Rwanda (BRD) has been offering direct support to local companies through local currency credit lines for product financing to minimize the need for foreign currency exchange, and indirectly through financial institutions to promote off-grid solar energy as a viable electrification option (World Bank & BRD, 2020). Yet in line with the findings by Grimm and colleagues (2016), additional sector analysis demonstrated that household-level affordability still remained the biggest challenge to SHSs uptake (Power Africa, 2021). Following that, two notable schemes have been implemented in the country. Between 2014 and 2020, the Energising Development (EnDev) programme supported the development of the solar PV market in Rwanda by providing results-based financing (RBF) incentives to 10 companies, including SHS providers (EnDev, 2021). In the second phase, together with Power Africa, REG and Urwego Bank, EnDev pioneered the pro-poor solar RBF project, using the Ubudehe categories which cluster the Rwandan population according to their socio-economic welfare, with the poorest households being classified as Ubudehe 1 and the wealthiest households falling under Ubudehe 4. The pro-poor RBF focused on subsidizing the costs of SHSs directly for households, where Ubudehe 1 families were eligible for the highest level of subsidy at up to 87% of the sales price (ibid.). According to Power Africa (2021), the project benefitted over 22,000 households, 71% of them in Ubudehe 1, in 5 districts where the scheme was piloted. The pilot informed a country-wide programme with a similar approach which was launched in early 2021. Under the Renewable Energy Fund (REF) and Rwanda Energy Access and Quality Improvement Project (EAQIP), a USD15 million RBF subsidy with an off-grid component (REF Window 5, component 3a) was set to be implemented by the Development Bank of Rwanda (BRD) (Development Bank of Rwanda et al., 2021) with the objective to trigger over 370,000 household connections to off-grid solar solutions (World Bank, 2021). The subsidy allows for price reductions of SHSs for Ubudehe 1, 2 and 3 households at the varying amounts of 90, 70 and 45%, respectively. Only eligible companies that have signed MoUs with EDCL and that meet the Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems of 2019, discussed earlier, can access the subsidy scheme.

4.7 Getting to Grips with Justice and Equity

The off-grid solar sector has come under a lot of scrutiny and, inevitably, criticism over the course of the last decade, which is when it has experienced the most significant growth and hence attracted increased attention. A search of peer-reviewed publications shows an upward trend in the number of publications on both SHSs and solar min-grids since 2010 from single or low double digits to 100+ publications a year. The early literature was heavily focused on techno-economic analyses of the proposed solutions, whether SHSs or mini-grids, in order to determine the least-cost electrification scenarios and assess the levelized cost of electricity (LCOE) across SSA and Asia (e.g., Martin & Susanto, 2014; Ondraczek, 2014; Ondraczek et al., 2015; Ouedraogo et al., 2015; Veldhuis & Reinders, 2015). However, since then the discourse on the appropriateness of decentralized solar technologies has advanced and surpassed the purely technical or techno-economic feasibility studies. For example, Baker et al. (2021) argue that the energy access studies have either been too focused on the engineering and techno-economic modelling aspects, or energy justice frameworks, deeply grounded in social sciences. However, to ensure energy justice, these models should reflect a wide range of stakeholders including, but not limited to, households, communities, public utilities and others. Yet, as Baker et al. further argue, 'moving from a qualitative understanding of preferences to quantitative modelling is challenging' (2021: 1).

The recent discourse on energy access has been based on three dimensions of justice: distributional, relating to resource distribution; procedural, which refers to how policies are formulated; and recognition, which postulates for the recognition of special needs of different groups within a population (Sovacool & Dworkin, 2014). Among those who have expanded the original energy justice framework are Lee and Byrne (2019: 1) who have highlighted additional dimensions worthy of consideration, such as the institutionalized tendencies of dominant energy systems which can also create energy injustices, including the distancing of system designs from local decision-making processes and from the users; and widespread risk-taking by decision-makers as the necessary 'price to pay' for energy innovation and social progress. This can be in terms of the deployed technology (e.g., nuclear power as a high-risk option) or the assumed approach to policy and regulation. While Rwanda has achieved a lot of progress in electrifying a significant proportion of its population in a relatively short period of time, equity and justice issues cannot be ignored. Selected examples of such issues, rather than a comprehensive analysis, are presented below.

4.7.1 Procedures, Distributions and Recognitions

The National Electrification Plan (NEP) and the ongoing REF Window 5 can be seen as the most important milestones to date which have solidified the standing and importance of off-grid energy access in Rwanda's electrification strategy. When the revision of the NEP was published in 2019 (REG, 2019), it presented an updated vision of how the 52–48% split of on- and off-grid electrification was going to be achieved. The country was divided into well-defined areas where access to electricity was to be extended either through the national grid, mini- or micro-grids, or SHSs (p. 33). Although the new plan involved a sophisticated techno-economic modelling exercise, it is unclear whether and to what extent end-users were involved in the process of designing such a strategy, as there is no mentioning of household-level consultations being conducted to inform the design of the proposed policy. The concern expressed by the wider energy access sector, including off-grid solar providers, was that the policy would limit the ability to not only scale up existing and future businesses due to location constraints, but that it would also take away the agency from the end-users for whom the choice would already be made. This was particularly troubling if households in areas designated for grid connections who might not be able to afford access or would like to choose off-grid solutions instead would not be able to do so. On the other hand, those in off-grid demarcated areas were left with no visible prospect of connecting to the national grid, even if they were willing and financially able to. Although in practice the policy does not prohibit households in areas planned for grid electrification from signing up to SHS services, households in off-grid areas, particularly those marked for SHS-led electricity provision, currently have no choice of connecting to the grid or a mini-grid.

Given the nature of those solutions and, in particular, SHSs, which tend to be small-scale (typically ranging between 10Wp and 100Wp, falling under Tier 1 or 2) and generally only able to satisfy basic energy needs, such as lighting, phone charging, access to information through radios and TVs, questions around equality, equity and justice have arisen. As such, distributed systems have their capacity limitations and cannot fully compete with the centralized grid network. This can result in a relatively narrow range of energy services available to those adopting off-grid solutions as compared to those connecting to the grid. Yet, research has shown that this distinction is not so clear cut. Lee et al. (2016) found that in Kenya, despite substantial investments into the grid infrastructure, the demand for grid connections among rural households remained low. For those already on the grid, the adoption of different electrical appliances also remained low (Lee et al., 2017). Affordability challenges, along with other competing priorities at a household level can help explain this trend, hence the need for support to rural households in the form of subsidies and financing mechanisms which can alleviate barriers to entry (to access the connection in the first place and, subsequently, access electric appliances) is needed regardless of which means of electrification is being pursued—grid or off-grid. While grid connections have been subsidized for Rwandan households for a long time, after a decade of growing and testing the market of off-grid solar solutions, a subsidy is now available to households regardless of which electrification pathway they embark on. This addresses the issue of equity at least to the extent where all low-income households can benefit from financial support to access energy services. Whether all households benefit equally from the services they receive remains under question considering how diverse those offerings are: from lighting and phone charging only, to a whole array of services, depending on the type of SHS one is able to afford, even with the subsidy. Although this is meant to be addressed by the flexibility offered by the pay-as-you-go (PAYG) business models, where customers can add on appliances, research has shown that the majority of

SHS users in Rwanda do not upgrade their systems with additional appliances over time (Bisaga, 2019a, b, 2020). Contained here is the problem of distributive justice as despite the GoR's ambition to provide at least Tier 2 energy access to all by 2024; in reality, many households will likely not surpass the very basic services offered at Tier 1. This question of what Moneyi et al. (2018) refer to as 'sufficiency' of electricity has opened up arguments around different energy narratives where voices of the end-users and their understandings of what is needed and what is 'enough' are often marginalized and instead dominated by those in the position of power (Todd et al., 2019). Additionally, as postulated by Groenewoudt and Romijn (2022), there are limits to the corporate-led model of off-grid energy provision. The constant struggle to achieve the 'people, profit and planet triple win' often ends up reproducing and reinforcing both structural and environmental injustices whereby the providers do not reach the poorest and most vulnerable households (linking to the issue of affordability) which goes against the notion of just energy transitions, and at the same time compromise the energy justice principles by producing potentially dangerous solar waste. According to the authors, this is because of the tension between the short-and long-terms goals which require investment of resources in competing directions—a difficult feat for companies operating in challenging, resource-constrained settings (Groenewoudt & Romijn, 2022).

On the one hand, the case of Rwanda's NEP reveals both the procedural justice issue as the policy formulation is exclusive of key stakeholders and the agency is removed from the hands of those whose lives and livelihoods are at stake, and the recognition injustice as specific needs of individuals and communities are not, or not fully, taken into account beyond a high-level, top-down analysis of their current economic standing and the predicted future energy demand. In that, it also demonstrates the applicability of the postulated distancing of system designs from local decision-making processes, such as for example those led by community-based groups and village-level leadership with whom there is little meaningful engagement in policymaking. This has been highlighted by Sovacool et al. (2019) who assert that certain groups, such as the fuel and energy poor (Gillard et al., 2017), are frequently underrepresented in discussions and policymaking. All too often it is the international partners or consultants who are behind the design of strategies that ultimately impact on individuals, households and communities far removed from the circles of decision-makers. Other scholars have also argued that there has to be more policy emphasis on increasing participation and that there has been little focus on reducing power of elites (Lacey-Barnacle et al., 2020). The NEP's approach also reaffirms the continued dominance of techno-economic analyses in policy formulation, as asserted by scholars in recent years (Baker et al., 2021; Cloke et al., 2017; Watson et al., 2012).

On the other hand, Rwanda's energy sector, including off-grid solar as an integral component, is an example of a well-planned, robust energy strategy and regulatory framework, and an adequate enabling environment. These characteristics, along with a regulated market of quality off-grid solar solutions, have been perceived as vital factors for the achievement of universal electrification in SSA and other regions with low electrification rates (Bhattacharyya & Palit, 2021; Samarakoon, 2021). It represents an inclusive approach towards both renewable and decentralized energy, and a clear vision towards bringing energy access to all citizens. However, there are at least two other outstanding issues which demand attention in order to achieve more just energy access transition in Rwanda: financial inclusion and inclusion of marginalized groups, particularly women and refugees. Currently, approx. 61% of adults use MoMo, with 68% of men having MoMo accounts as compared to 56% women. This presents a challenge for the remaining 39% of those who currently have no such access as in order to be able to sign up to off-grid solar services and truly reap their benefits, and to be able to benefit from the available subsidy, households are expected to have the ability to pay with MoMo. A similar gender gap is present in the access and use of formal financial services: only 34% of female adults in Rwanda use banking services, whereas for men that number reaches over 40% (Finscope, 2020). It also persists in electricity access with female-headed households enjoying lower access to both grid and off-grid electricity. In 2017, only 20% of female-headed households had electricity access versus 29% among male-headed households (NISR, 2018). More female-headed households also suffer from poor quality of energy (Tier 0 or 1) than those headed by men, more of whom have access to Tier 2 and above. This leaves some 80% of female-headed households heavily reliant on traditional sources of lighting, such as candles and kerosene lanterns (ibid.). Bisaga (2019a, b) also showed that while majority of SHS adopters as registered by the providers (i.e., customers) in Rwanda are men, it is the women in the households who use and benefit the most from the services offered by the systems. Despite that, in customer surveys and other research on the users of SHSs it is the men who speak on behalf of the household, with women's voices rarely heard. According to Ojong (2021: 1), 'gender intersects with age, geographical location, and other inequalities to shape the adoption of SHSs', which can reproduce certain power structures and local resource allocation, in turn perpetuating distributive injustice and exclusion. This is echoed by Feenstra and Özerol (2021) who further argue that there is a need to better examine the existing injustices by analyzing the representation of energy consumers and going beyond the entity of households to gain a deeper appreciation for the gender gap in access to energy. To create more gender-sensitive and just energy systems, we need to engender energy policy. This, in turn, will optimize energy access outcomes by 'enable[ing] a fair energy distribution between women and men, recogniz[ing] gendered energy needs, and contribut[ing] to equal participation of women and men in the energy sector' (Feenstra & Özerol, 2021: 2).

Finally, the subsidy mechanism which is meant to bring off-grid solar energy to thousands of households across Rwanda, currently does not include refugees residing in the country, meaning they are not eligible to benefit from the financial support offered to the citizens. While there are humanitarian agencies working on addressing the challenges of energy access among the displaced, and especially in refugee camps, of which there are six in Rwanda hosting close to 140,000 people, the exclusion of this vulnerable group from national level planning contributes to the reproduction of inequalities and inequities that have existed between different groups for decades. In a study of three refugee camps in Rwanda, Thomas et al. (2021a) found that even though SHSs can be advantageous in comparison to other existing energy access solutions, without subsidies and adaptations to payment models, SHSs will be unlikely to provide access to a large number of refugee households.

In another study of the same refugee camps, Thomas et al. (2021b) demonstrated the need for improved maintenance of decentralized, off-grid solar solutions to extend their longevity, as well as the alignment of energy programmes in humanitarian contexts with national policies to galvanize political support. This is particularly critical given the long-standing exclusion of humanitarian energy access from national policymaking (Rosenberg-Jansen et al., 2019). It also reflects all three tenets of energy injustice and calls for a rethinking of what just and equitable energy transitions and strategies should look like in the future, and how decisions on who is worthy of inclusion are made.

4.8 Where to From Here?

Rwanda has made great strides in developing and implementing its electrification strategy which is inclusive of off-grid, distributed solutions such as SHSs and mini-grids. This chapter has presented an overview of Rwanda's journey with the off-grid solar sector over the last decade, demonstrating the many developments which have contributed to its achievements to date. It has also highlighted the most significant issues which have been addressed along the way, as well as those which still have to be tackled in order to facilitate more just energy transitions in Rwanda.

In the years since solutions such as SHSs started gaining momentum, with the private sector leading efforts on increasing both awareness and availability of such products, it became clear that affordability would be among the most prohibitive factors hindering access. The policies and regulations, along with the piloting and introduction of various financing mechanisms, have informed the design of a subsidy scheme which many national and international stakeholders have a lot of hope for, as it directly tackles the affordability barrier. However, while the achievements are laudable, there remain significant justice, equality and inclusion challenges, as argued in this chapter. According to the International Energy Agency (IEA) et al. (2021: 5), "[r]eaching the last-mile households, who are mostly poor, vulnerable and remote, while accelerating electrification in low-income countries, […] and countries housing refugee camps occupied by millions of displaced people is the formidable challenge governments and the international community must overcome." Although not an easy feat, energy planning and policymaking should be more 'justice-aware', as Sovacool et al. (2017) well put it. This applies to Rwanda as well as other countries striving for just energy transitions. It should also be more inclusive and capable of recognizing that different groups have different needs, and that simply availing distributed electrification options to the unconnected and addressing the affordability issue might not be enough. There is a need for a more concerted targeting of the marginalized and historically excluded, as well as the need for extending complementary services, such as financial ones, to everyone; and women in particular. Engendering energy policy will also be critical going forward to ensure redistributive justice and improved energy equity. Decentralized and renewable energy-based electricity generation mixes have been shown to come with higher costs, and efforts, but also potential greater social benefits (Gladkykh et al., 2021), of which Rwanda has been a witness. However, in order to ensure that everyone can benefit from adequate, sustainable and affordable electrification, more remains to be done. The decade of off-grid solar is a valuable lesson for the future calling for more deliberate steps towards just energy transitions for Rwandans, and as a result, a more just society at large.

References

African Development Bank. (2013). *Rwanda energy sector review and action plan*. Retrieved September 20, 2021, from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-andOperations/Rwanda_-_Energy_Sector_Review_and_Action_Plan.pdf

Ahlborg, H., & Hanmar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique—Grid-extension, off-grid, and renewable energy technologies. *Renewable Energy, 61*, 117–124.

Baker, E., Nock, D., Levin, T., Atarah, S.A., Afful-Dadzie, A., Dodoo-Arhin, D., Ndikumana, L., Shittu, E., Muchapondwa, E., & Van-Hein Sackey, C.

(2021, March). Who is marginalized in energy justice? Amplifying community leader perspectives of energy transitions in Ghana. *Energy Research & Social Science, 73*, 101933.

Bhattacharyya, S. C., & Palit, D. (2021). A critical review of literature on the nexus between central grid and off-grid solutions for expanding access to electricity in Sub-Saharan Africa and South Asia. *Renewable and Sustainable Energy Reviews, 141*, 110792.

Bimenyimana, S., Asemota, G. N. O., & Li, L. (2018). The state of the power sector in Rwanda: A progressive sector with ambitious targets. *Frontiers of Energy Research*.

Bisaga, I. (2019a). *Scaling up off-grid solar energy access through improved understanding of customers' needs, aspirations and energy use of decentralised (SMART) Solar Home Systems—A case study of BBOXX customers in Rwanda* [Dissertation, University College London]. http://discovery.ucl.ac.uk/10069395/. Accessed 20 Sept 2021.

Bisaga, I. (2019b, September). *Bboxx research brief*. Issue 03. Retrieved September 20, 2021, from https://www.bboxx.com/news/research-brief-issue-03/

Bisaga, I. (2020). Innovation for off-grid solar rural electrification. In W. Leal Filho, A. Azul, L. Brandli, A. Lange Salvia, & T. Wall (Eds.), *Affordable and clean energy: Encyclopedia of the UN sustainable development goals*. Cham: Springer.

Bisaga, I., Parikh, P., Tomei, J., & To, L.S. (2020, November). Mapping synergies and trade-offs between energy and the sustainable development goals: A case study of off-grid solar energy in Rwanda. *Energy Policy*, 112028.

Bisaga, I., Puzniak-Holford, N., Grealish, A., Baker-Brian, C., & Parikh, P. (2017). Scalable off-grid energy services enabled by IoT: A case study of BBOXX SMART solar. *Energy Policy, 109*, 199–207.

Brunet, C., Savadogo, O., Baptiste, P., Bouchard, M. A., Cholez, C., Gendron, C., & Merveille, N. (2021, March). The three paradoxes of the energy transition: Assessing sustainability of large-scale solar photovoltaic through multi-level and multi-scalar perspective in Rwanda. *Journal of Cleaner Production, 288*, 125519.

Cloke, J., Mohr, A., & Brown, E. (2017). Imagining renewable energy: Towards a Social Energy Systems approach to community renewable energy projects in the Global South. *Energy Research & Social Science, 31*, 263–272.

Development Bank of Rwanda (BRD), Energy Development Corporation Limited (EDCL), & World Bank. (2021). *Window 5 operations manual.*

Version 04/23.06.2021. Retrieved September 20, 2021, from https://www.brd.rw/brd/wp-content/uploads/2021/06/REF_Window_5_Operations_Manual.pdf

Energising Development (EnDev). (2021). *Transforming energy access markets with results-based financing: Lessons from 7 years of implementation under EnDev's RBF facility financed by UK aid*. Retrieved September 20, 2021, from https://endev.info/wp-content/uploads/2021/08/EnDev_RBF-Lessons-Learnt-Report_2021.pdf

Feenstra, M., & Özerol, G. (2021). Energy justice as a search light for gender-energy nexus: Towards a conceptual framework. *Renewable and Sustainable Energy Reviews*, 138(March 2021), 110668.

FinScope. (2020). *Financial inclusion.* Kigali: Access to Finance Rwanda.

Friebe, C. A., von Flotow, P., & Täube, F. A. (2013). Exploring the link between products and services in low-income markets—Evidence from solar home systems. *Energy Policy, 52*, 760–769.

Fuso Nerini, F., Tomei, J., To, L. S., Bisaga, I., Parikh, P., Black, M., Borrion, A., Spataru, C., Castan Broto, V., Anandarajah, G., Milligan, B., & Mulugetta, Y. (2018). Mapping synergies and trade-offs between energy and the Sustainable Development Goals. *Nature Energy, 3*, 10–15.

Gillard, R., Snell, C., & Bevan, M. (2017, July). Advancing an energy justice perspective of fuel poverty: Household vulnerability and domestic retrofit policy in the United Kingdom. *Energy Research & Social Science, 29*, 53–61.

Gladkykh, G., Davíðsdóttir, B., & Diemer, A. (2021, September). When justice narratives meet energy system models: Exploring energy sufficiency, sustainability, and universal access in Sub-Saharan Africa. *Energy Research & Social Science, 79*, 102075.

Global Off-Grid Lighting Association (GOGLA). (2016). *Global solar off-grid semi-annual market report*. Retrieved September 20, 2021, from https://www.gogla.org/sites/default/files/recource_docs/glb_solar_og_market_report_h22015_public_web.pdf

GOGLA. (2021). *Global off-grid solar market report semi-annual sales and impact data*. Retrieved September 20, 2021, from https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h2_2020.pdf

Government of Rwanda (GoR). (2012a). *Economic development and poverty reduction strategy 2013–2018 shaping our development*. Kigali: Republic of Rwanda.

GoR. (2012b). *Rwanda vision 2020: Revised 2012*. Retrieved September 20, 2021, from https://kigalicity.gov.rw/fileadmin/templates/Documents/policies/Rwanda_Vision_2020__revised_2012_.pdf

GoR. (2014). *Sustainable energy for all rapid assessment and gap analysis*. Ministry of Infrastructure (MININFRA), Kigali.

GoR. (2016a). *Sustainable energy for all action agenda 2016a update—Draft*. Ministry of Infrastructure (MININFRA) Resource and Sustainable Energy for All Resource. Retrieved September 20, 2021, from https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_AAs/Rwanda_Action_Agenda.pdf

GoR. (2016b). *Rural electrification strategy*. Ministry of Infrastructure (MININFRA) Resource. Retrieved September 20, 2021, from http://www.mininfra.gov.rw/fileadmin/user_upload/aircraft/Rural_Electrification_Strategy.pdf

GoR. (2018). *Energy sector strategic plan 2018/19–2023/24*. Ministry of Infrastructure (MININFRA) Resource. Retrieved September 20, 2021, from http://www.mininfra.gov.rw/fileadmin/user_upload/infos/Final_ESSP.pdf

GoR. (2019). *Ministerial guidelines on minimum standards requirements for solar home systems*. Ministry of Infrastructure (MININFRA) Resource. Retrieved September 20, 2021, from https://www.mininfra.gov.rw/fileadmin/user_upload/Mininfra/Documents/Energy_Docs/Ministerial_Guidelines_on_minimum_requirements_for_solar_home_systems.pdf

GoR. (2020). *Vision 2050: Ministry of finance and economic planning resource*. Retrieved September 20, 2021, from https://www.nirda.gov.rw/uploads/tx_dce/Vision_English_Version_2050_-31_Dec_2020.pdf

Grimm, M., Lenz, L., Peters, J., & Sievert, M. (2016). *Demand for Off-Grid Solar Electricity: Experimental Evidence from Rwanda* (IZA Institute of Labor Economics Discussion Paper Series, IZA DP No. 10427, 1–33).

Groenewoudt, A. C., & Romijn, H. A. (2022). Limits of the corporate-led market approach to off-grid energy access: A review. *Environmental Innovation and Societal Transitions, 42*, 27–43.

International Energy Agency (IEA). (2020). *Access to electricity: Covid-19 reverses electricity access progress*. Retrieved September 20, 2021, from https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Statistics Division (UNSD), World Bank (WB), & World Health Organization (WHO). (2019). *Tracking SDG7: The energy progress report 2019*. Washington, DC.

International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Statistics Division (UNSD), World Bank (WB), & World Health Organization (WHO). (2021). *Tracking SDG7: The energy progress report 2021*. Washington, DC.

Kennedy, R., Numminen, S., Sutherland, J., & Urpeleinen, J. (2019, November). Multilevel customer segmentation for off-grid solar in developing countries: Evidence from solar home systems in Rwanda and Kenya. *Energy, 186*, 115728.

Kizilcec, V., Parikh, P., & Bisaga, I. (2021). Examining the journey of a pay-as-you-go solar home system customer: A case study of Rwanda. *Energies, 14*(2), 330.

Koo, B. B., Rysankova, D., Portale, E., Angelou, N., Keller, S., & Padam, G. (2018). *Rwanda: Beyond connections*. World Bank Resources. Retrieved September 20, 2021, from https://openknowledge.worldbank.org/bitstream/handle/10986/30101/129101-ESM-P156666-PUBLIC-MTF-Energy-Access-Country-Diagnostic-Report-Rwanda-6-2018.pdf?sequence=1&isAllowed=y

Lacey-Barnacle, M., Robison, R., & Foulds, C. (2020, April). Energy justice in the developing world: A review of theoretical frameworks, key research themes and policy implications. *Energy for Sustainable Development, 55*, 122–138.

Laufer, D., & Schäfer, M. (2011). The implementation of Solar Home Systems as a poverty reduction strategy—A case study in Sri Lanka. *Energy for Sustainable Development, 15*(3), 330–336.

Lee, J., & Byrne, J. (2019). Expanding the conceptual and analytical basis of energy justice: Beyond the three-tenet framework. *Frontier of Energy Research*. https://doi.org/10.3389/fenrg.2019.00099

Lee, K., Miguel, E., & Wolfram, C. (2016). *Appliance ownership and aspirations among electric grid and home solar households in rural Kenya* (Energy Institute @ Haas Working Paper 266). Berkeley, CA.

Lee, K., Miguel, E., & Wolfram, C. (2017). *The economics of rural electrification: Evidence from Kenya* (Policy Brief 89339). London: International Growth Centre.

Lemaire, X. (2011). Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. *Energy for Sustainable Development, 15*(3), 277–283.

Martin, S., & Susanto, J. (2014). Supplying power to remote villages in Lao PDR.—The role of off-grid decentralised energy options. *Energy for Sustainable Development, 19*(April 2019), 111–121. https://doi.org/10.1016/j.esd.2013.12.012

MININFRA. (2020). *Government launches US$35 million solar project for rural households*. Retrieved September 20, 2021, from https://www.mininfra.gov.rw/updates/news-details/government-launches-us35-million-solar-project-for-rural-households

Ministry of Infrastructure (MININFRA) of Rwanda. (2021). *Energy division*. Retrieved September 20, 2021, from https://www.mininfra.gov.rw/digital-transformation-1-1

Moneyi, C. G., Jenkins, K., Serestina, V., & Adewumi, A. O. (2018, August). Examining energy sufficiency and energy mobility in the global south through the energy justice framework. *Energy Policy, 119*, 68–76. https://doi.org/10.1016/j.enpol.2018.04.026

Muok, B. O., Makokha, W., & Palit, D., (2015). Solar PV for enhancing electricity access in Kenya: What policies are required? (*Policy Brief July 2015*). New Delhi: The Energy and Resources Institute (TERI).

National Institute of Statistics of Rwanda (NISR). (2018). *EICV5: Rwanda poverty profile report*. Kigali: National Institute of Statistics of Rwanda.

Niyonteze, J. D. D., Zou, F., Asemota, G. N. O., Bimenyimana, S., & Shyiambere, G. (2020, January). Key technology development needs and applicability analysis of renewable energy hybrid technologies in off-grid areas for the Rwanda power sector. *Heliyon, 6*(1), e03300.

Ojong, N. (2021, May). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.

Ondraczek, J. (2014, February). Are we there yet? Improving solar PV economics and power planning in developing countries: The case of Kenya. *Renewable and Sustainable Energy Reviews, 30*, 604–615.

Ondraczek, J., Komendantova, K., & Patt, A. (2015, March). WACC the dog: The effect of financing costs on the levelized cost of solar PV power. *Renewable Energy, 75*, 888–898.

Ouedraogo, B. I., Kouame, S., Azoumah, Y., & Yamegueu, D. (2015, July). Incentives for rural off-grid electrification in Burkina Faso using LCOE. *Renewable Energy, 78*, 573–582.

Power Africa. (2021). *Pro-poor results-based financing: Increasing off-grid access to electricity in Rwanda*. Retrieved September 20, 2021,

from https://www.usaid.gov/sites/default/files/documents/Power-Africa-Rwanda-Pro-Poor-Report.pdf
Rwanda Energy Group (REG). (2019). *Review assessment of current electrification programs prepared by REG/EDCL and confirmation on institutional, technical and financial aspects*. Retrieved September 20, 2021, from http://www.reg.rw/fileadmin/user_upload/Task_Design_of_the_National_Electrification_Plan_in%20Rwanda_Report.pdf
REG. (2021a). *Electricity access*. Retrieved September 20, 2021, from https://www.reg.rw/what-we-do/access/
REG. (2021b). *Rwanda Energy Group*. Retrieved September 20, 2021, from https://www.reg.rw/index.php?id=2
Rwanda Energy Group (REG) (2022). *Electricity access*. Retrieved September 30, 2023 from https://www.reg.rw/what-we-do/access/news/the-updated-electrification-plan-increases-targeted-on-grid-connections-to-70-by-the-year-2024/?tx_news_pi1%5BoverwriteDemand%5D%5Bcategories%5D%20=%2035%2C32%2C24%2C25%2C27%2C17&cHash=179c088340fc22fedc2b3a69de0f1629
Rosenberg-Jansen, S., Tunge, T., & Kayumba, T. (2019). Inclusive energy solutions in refugee camps. *Nature Energy, 4*, 990–992.
Rwanda Utilities Regulatory Authorities (RURA). (2020). *Overview—Energy*. Retrieved September 20, 2021, from https://rura.rw/index.php?id=137
Samarakoon, S. (2021). The troubled path to ending darkness: Energy injustice encounters in Malawi's off-grid solar market. *Energy Research & Social Science, 69*(November 2020).
Scott, I. (2017, April). A business model for success: Enterprises serving the base of the pyramid with off-grid solar lighting. *Renewable and Sustainable Energy Reviews, 70*, 50–55.
Sovacool, B. K., & Dworkin, M. H. (2014). *Global energy justice: Problems, principles, and practices*. Cambridge University Press.
Sovacool, B. K., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. *Applied Energy, 142*, 435–444.
Sovacool, B. K., Burke, M., Baker, L., Kotikalapudi, C. K., & Wlokas, H. (2017, June). New frontiers and conceptual frameworks for energy justice. *Energy Policy, 105*, 677–691.
Sovacool, B. K., Lipson, M. M., & Chard, R. (2019, May). Temporality, vulnerability, and energy justice in household low carbon innovations. *Energy Policy, 128*, 495–504.

Thomas, P., Williamson, S. J., & Harper, P. W. (2021a). The diffusion of solar home systems in Rwandan refugee camps. *Energy for Sustainable Development, 63*(9), 119–132.

Thomas, P., Sandwell, P., Williamson, S. J., & Harper, P.W. (2021b, June). A PESTLE analysis of solar home systems in refugee camps in Rwanda. *Renewable and Sustainable Energy Reviews, 143*. https://doi.org/10.1016/j.rser.2021.110872

Todd, I., De Groot, J., Mose, T., McCauley, D., & Heffron, R. J. (2019). Response to 'Monyei, Jenkins, Serestina and Adewumi examining energy sufficiency and energy mobility in the global south through the energy justice framework.' *Energy Policy*. https://doi.org/10.1016/j.enpol.2019.05.012

Veldhuis, A. J., & Reinders, A. H. M. E. (2015, December). Reviewing the potential and cost-effectiveness of off-grid PV systems in Indonesia on a provincial level. *Renewable and Sustainable Energy Reviews, 52*, 757–769.

Watson, J., Byrne, R., Morgan Jones, M., Tsang, F., Opazo, J., & Fry, C. (2012). *What are the major barriers to increased use of modern energy services among the world's poorest people and are interventions to overcome these effective* (Systematic Review, Collaboration for Environmental Evidence, CEE Review No. 11–004).

World Bank. (2013). *Rwanda | Extending access to energy*. Energy Sector Management Assistance Program, Knowledge Series 013/12. Retrieved September 20, 2021, from https://www.esmap.org/sites/default/files/esmap-files/ESMAP_Energy_Access_RwandaSWAp_KS013-12_Optimized.pdf#:~:text=The%20sector%2Dwide%20approach%20(SWAp,coordinate%20aid%20within%20a%20sector.&text=Rwanda%20is%20one%20of%20the,to%20increase%20access%20to%20electricity

World Bank. (2017). The state of electricity access report 2017. Resource Document: World Bank Group, ESMAP, Sustainable Energy for All & SEAR. Retrieved September 20, 2021, from http://documents.worldbank.org/curated/en/364571494517675149/pdf/114841-REVISED-JUNE12-FINAL-SEAR-web-REV-optimized.pdf

World Bank. (2020). *International development association project appraisal document* (Report No: PAD4005). Retrieved September 20, 2021, from https://documents1.worldbank.org/curated/en/819241600653622828/pdf/Rwanda-Energy-Access-and-Quality-Improvement-Project.pdf

World Bank. (2021a, June). *Rwanda economic update: The role of the private sector in closing the infrastructure gap* (Edition No. 17). Retrieved September

20, 2021a, from https://documents1.worldbank.org/curated/en/992631626808031540/pdf/Rwanda-Economic-Update-The-Role-of-the-Private-Sector-in-Closing-the-Infrastructure-Gap.pdf

World Bank (2021b). *Ease of doing business in Rwanda*. Retrieved September 20, 2021b, from https://www.doingbusiness.org/en/data/exploreeconomies/rwanda

World Bank and Development Bank of Rwanda (BRD). (2020). Renewable energy fund project. Retrieved September 20, 2021, from https://www.brd.rw/brd/wp-content/uploads/2021/01/REF_OM_MGDs_Window3.pdf

Zollmann, J., Waldron, D., Sotiriou, A., & Gachoka, A. (2017). *Escaping darkness understanding consumer value in PAYGo solar*. Access to Finance Forum Reports, CGAP, No. 13, Washington, DC.

Part II

Manifestations of Energy Injustices

5

The Dark Side of the Sun: Solar Home Systems and Their Injustices in Africa

Nathanael Ojong

5.1 Introduction

Renewable energy technologies are increasingly used in various countries in Africa, and decentralized energy generation is regarded as a viable option to providing energy to the millions of people on the continent without access (Menghwani et al., 2020; Osunmuyiwa & Kalfagianni, 2017; Winkler et al., 2017). Off-grid solar photovoltaic systems, especially solar home systems (SHSs), is one of several decentralized renewable energy technologies that is increasingly being used to meet the energy needs of people on the continent of Africa (Bhamidipati et al., 2019; Monyei et al., 2018; Ojong, 2021a; Ulsrud, 2020). According to estimates, 70% of SHSs are sold in SSA (GOGLA, 2019). Around 342,000 SHSs were sold in East Africa and about 102,000

N. Ojong (✉)
York University, Toronto, ON, Canada
e-mail: nojong@yorku.ca

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_5

SHSs were sold in West Africa in the first half of 2020 (GOGLA, 2020). SHSs consist of one or more solar panels connected to a battery, inverter and charge controller, which supply energy for household appliances, including lighting (Sovacool & Griffiths, 2020). Full-service SHSs can power larger electrical devices such as refrigerators (Groenewoudt et al., 2020).

Several factors account for the popularity and increasing uptake of SHSs in Africa. First, there is an abundance of solar energy (Anugwom et al., 2020; Kebede & Mitsufuji, 2014; Lemaire, 2009), and second, arguably, SHSs play a role in eliminating indoor air pollution, which affects respiratory and eye health (Diallo & Moussa, 2020; Lemaire, 2011). According to estimates, each year there are 4 million premature deaths from illness linked to household air pollution from inefficient cooking practices, and about half of under-five deaths due to pneumonia are caused by soot inhaled from household air pollution (WHO, 2018). Third, the decreasing prices of solar PV modules have made SHSs a viable economic alternative for a segment of the population in Africa (IRENA, 2016); for example, since 2012, installation costs have decreased by 61% (IRENA, 2016). Fourth, the availability of consumer financing models, especially the pay-as-you-go model, has been vital in the uptake of SHSs in Africa (REN21, 2020). Between January and June 2020, about 84% of all SHSs were sold via pay-as-you-go financing (GOGLA, 2020). However, just households with relatively higher incomes are more likely to purchase pay-as-you-go SHSs due to high upfront down payment and regular monthly payment requirement (Guta, 2018; Jacobson, 2007; Smith & Urpelainen, 2014). Fifth, in several communities, people with electricity grid connections face regular outages, and hence adopt SHSs to deal with power uncertainties (Boamah & Rothfuß, 2020; Wassie & Adaramola, 2021). Sixth, SHSs are often adapted to recharge mobile phones (Kizilcec et al., 2021; Lemaire, 2011; Steel et al., 2016; Wagner et al., 2021), and therefore are highly useful to owners of such devices, including those in remote areas.

That said, impressive statistics regarding the uptake of SHSs on the continent as well as upbeat stories regarding their virtues often obscure the multiple injustices that are manifested in different spheres and scales with respect to access and use of these technologies. Scholars have highlighted the flaws of market-based diffusion of solar products (Cross & Neumark, 2021; Groenewoud & Romijn, 2022; Samarakoon, 2020). Access to energy through SHSs can bring social net benefits, but it can also enhance vulnerabilities. This chapter, based on a critical review of the scholarly literature on SHSs in Africa, maps out injustices along multiple dimensions. Drawing on the energy justice framework, I examine multiple illustrators of distributional, recognition and procedural injustices with regards to energy access using SHSs.

The rest of the chapter is structured as follows. The next section describes the method used to review the extant scholarship on SHSs in Africa. Section 5.3 focuses on the manifestations of injustices across multiple dimensions. Lastly, Sect. 5.4 provides concluding remarks.

5.2 Methodology

Systematic literature reviews are frequently used to evaluate the success of interventions designed to address societal problems (Petticrew & Roberts, 2006; Sorrell, 2007). A systematic review attempts to gather the relevant literature while minimizing bias 'in the identification, selection, synthesis, and summary of studies' (Shamseer et al., 2015: 3), and scholars are increasingly conducting systematic reviews in energy social science (Groenewoud & Romijn, 2022; Ojong, 2021a, 2021b; Sovacool et al., 2017). This systematic literature review draws from core principles offered by Sovacool et al. (2018) and Petticrew and Roberts (2006), and consists of the steps outlined below.

5.2.1 Search Parameters

I conducted a search of academic literature in September 2021. As a result of time constraints, I limited the search to three major databases (Scopus, ScienceDirect and Web of Science). These databases consist of a wide range of literature in various disciplines.

To search published research in these databases, I developed a search string which combined the following synonyms and wildcard search terms: 'solar home system', 'solar pv', 'home solar*', 'solar photovoltaic panels', 'solar photovoltaic system' and 'solar system' (Table 5.1). The qualifier 'Africa' was added to locate literature specifically pertaining to that continent. Also, a search was also conducted that included the name of each of the 54 countries in Africa with the aim of capturing literature that omitted a specific mention of the keyword 'Africa'. I conducted searches on 13 September 2021 (Scopus), 15 September 2021 (Web of Science), and 17 September 2021 (ScienceDirect).

Table 5.1 Search string based on search terms

Database	Date	String
Scopus	13 September 2021	(TITLE-ABS-KEY ('solar home system' OR 'solaire domestique' OR 'home solar' OR 'système solaire domestique' OR 'système solaire' OR 'panneaux solaires photovoltaïques' OR 'solar photovoltaic panels' OR 'solar pv' OR 'stand-alone systems' OR 'solar system') AND TITLE-ABS-KEY (Africa))
Web of Science	15 September 2021	Topic: ('solar pv' OR 'solar home system' OR 'solaire domestique' OR 'système solaire domestique' OR 'panneaux solaires photovoltaïques' OR 'stand-alone systems' OR 'solar photovoltaic panels' OR 'home solar' AND 'Africa')
Science Direct	17 September 2021	Title-, author-, or abstract-specific keywords: 'solaire domestique' OR 'home solar' OR 'système solaire domestique' OR 'solar home system' OR 'panneaux solaires photovoltaïques' OR 'solar photovoltaic panels' OR 'solar pv' OR 'stand-alone systems' AND 'Africa'

5.2.2 Inclusion and Exclusion Criteria

The aim of the inclusion and exclusion criteria was to eliminate irrelevant papers. I included peer-reviewed academic papers published up to September 2021, and papers not published in English and French were excluded. Following Ojong et al. (2021), conference proceedings, books, book reviews, book chapters, working papers and reports were excluded. I also excluded papers where the SHSs component was deemed to be an insignificant aspect or by-product of the research, including those which focused on engineering dimensions of SHSs. I also included comparative studies which covered any of the African countries and countries which were beyond the scope of our review.

I used a multi-step process to decide whether to include a paper in the review. I read the abstract of all papers generated from the three databases searches, and those which seemed relevant were included in the next stage. This was followed by retrieving the full-text articles and assessing them for eligibility. Moreover, due to the nature of the research, only empirical studies were included in the review. This screening process, depicted in Fig. 5.1, identified a total of 60 papers, which I examined in order to understand the manifestations of injustices with respect to access and use of SHSs.

5.2.3 Data Extraction and Analysis

In order to review the 60 papers selected, I first created an Excel workbook (Petticrew & Roberts, 2006) to document aspects of each paper, such as geographical location, journal title, paper title and year of publication, and subsequently uploaded all 60 papers to Nvivo. Sections from the selected studies was coded into thematic categories.

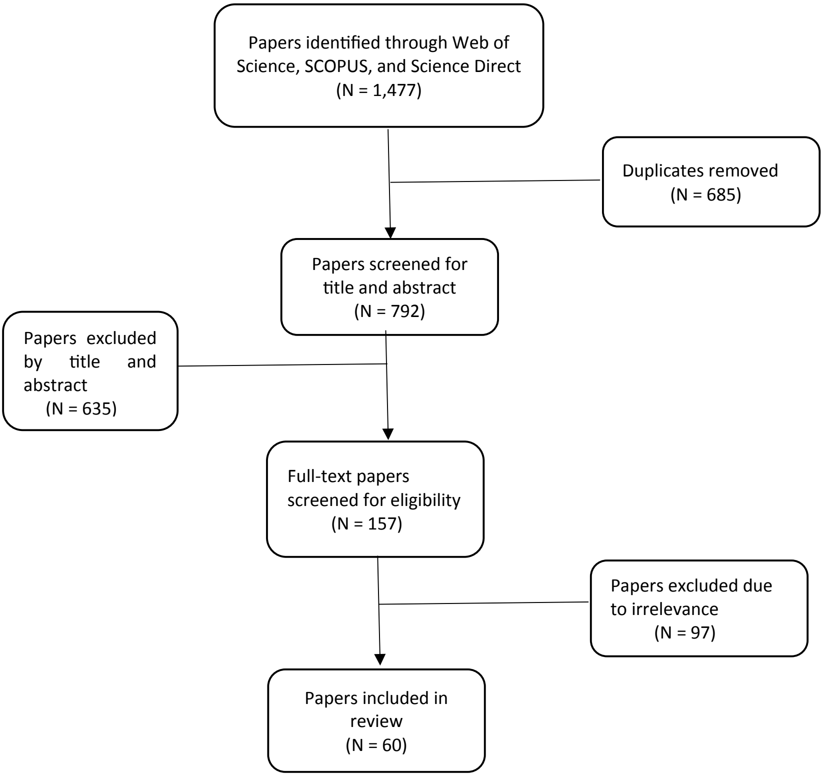

Fig. 5.1 Systematic review process flowchart

5.3 Manifestations of Injustices

5.3.1 Affordability, Limited Capacity of Solar Home Systems, and Intra-Household Dynamics

As mentioned in Chapter 1, affordability is one of the key principles of energy justice (Sovacool et al., 2017), and in this case, affordability relates to the price of SHSs. SHSs are often portrayed as well-suited to address the problem of energy poverty especially in rural areas, but a significant percentage of the population in these communities find high-quality systems unaffordable. In Kenya, the affordability of a small SHS was the principal factor influencing decisions to install them (Opiyo, 2016), while in Burkina Faso, only relatively wealthy households were able to acquire brand-name SHSs (Bensch et al., 2018). Although the price of SHSs has decreased significantly in the past decade, many poor households still find them unaffordable (Kebede & Mitsufuji, 2014; Kizilcec et al., 2021; Ondraczek, 2013; Ulsrud, 2020). Generally, only the smallest SHSs (10–25W) seem to be affordable for lower-income households (Jacobson, 2007; van der Vleuten et al., 2007).

However, having the smallest SHSs means that households may not really get much from these systems due to limited energy generated. For school-age children in homes with small SHSs, they may have to continue using other traditional sources of fuel to study at night such as candles and kerosene lamps. For instance, a study conducted in rural Kenya found that of the 80% of households with SHSs that had school-age children, just 47% used the system to study, and the author linked this to several factors, including the size and performance of the SHS (Jacobson, 2007).

Similarly, with respect to entertainment, households with a small SHS may not be able to spend relatively long periods watching television, for example, as watching a favourite TV show may come at the expense of preventing children to study at night by turning off light bulbs.

Discontents related to the capacity of SHSs are well documented. A frustrated adopter of a solar system in Ghana said: 'The thing [solar PV panel] is hanging on our rooftop but we cannot use it to power our electric iron [...]. The charcoal can easily destroy a white shirt when ironing with the box-iron but light [grid-based electricity] would not' (Boamah & Rothfuß, 2020: 8).

Moreover, discontents related to limited capacity of solar systems are not restricted to people who installed smaller systems, as people with larger ones were equally frustrated. A 500W solar PV adopter in Ghana was disappointed because they could not use a 350W deep freezer they had purchased, prompting them to say that 'the electrical grid is free from these restrictions even if tariffs are too high [...]' (Boamah & Rothfuß, 2020: 9). The point I am emphasizing here is that installing low-capacity SHSs have implications. Household seemingly have access to energy but very little can be done with energy generated by the system. The limited energy generation capacity of solar systems has also been noted in studies conducted in other countries such as Ethiopia (Wassie & Adaramola, 2021), South Africa (Green & Erskine, 1999), Rwanda (Thomas et al., 2021), Zambia (Gustavsson & Ellegard, 2004), and Malawi (Samarakoon, 2020). The limited capacity of these solar systems calls into question the triumphalist narrative often used by donor organizations and solar companies regarding their ability to tackle the problem of energy poverty, hence contributing to achieving SDG 7 which relates to energy access.

Notably, it is important to move beyond the number of people who have energy access through SHSs to taking a deeper look at access to energy services, as this facilitates a better understanding of certain injustices. Energy services as used here refers to '[…] those functions performed using energy which are means to obtain or facilitate desired end services or states' (Fell, 2017: 137). This definition of energy services establishes a clear distinction between 'energy services' and 'end services or states'. Based on sampled literature, there are four core energy services associated with SHSs: charging of mobile phones; powering televisions, electric fans and radios; powering light bulbs; and powering kitchen appliances. In turn, these energy services generate desired end services or states. For instance, as illustrated in Fig. 5.2, the charging of a mobile phone is considered as an energy service which leads to three desired end services, that is, communication, entertainment, and information/news. Similarly, the powering of a light bulb is an energy service, while income generation, social status, education, security, cooking, cleaner indoor environment, and social connection are desired end services and states. This distinction contributes to understanding the discontents of solar adopters and brings to the fore the need to go beyond statistics on energy access. The capacity of an SHS determines the degree to which users could benefit from various energy services. For example, people with relatively low-capacity SHSs must prioritize energy services, which means that different household members cannot simultaneously use some energy services, e.g., some households cannot charge mobile phones and power light bulbs at the same time. In a similar vein, a significant proportion of rural households get small SHSs, and such systems are unlikely to power TVs for a significant amount of time as well as power an outside security light throughout the night.

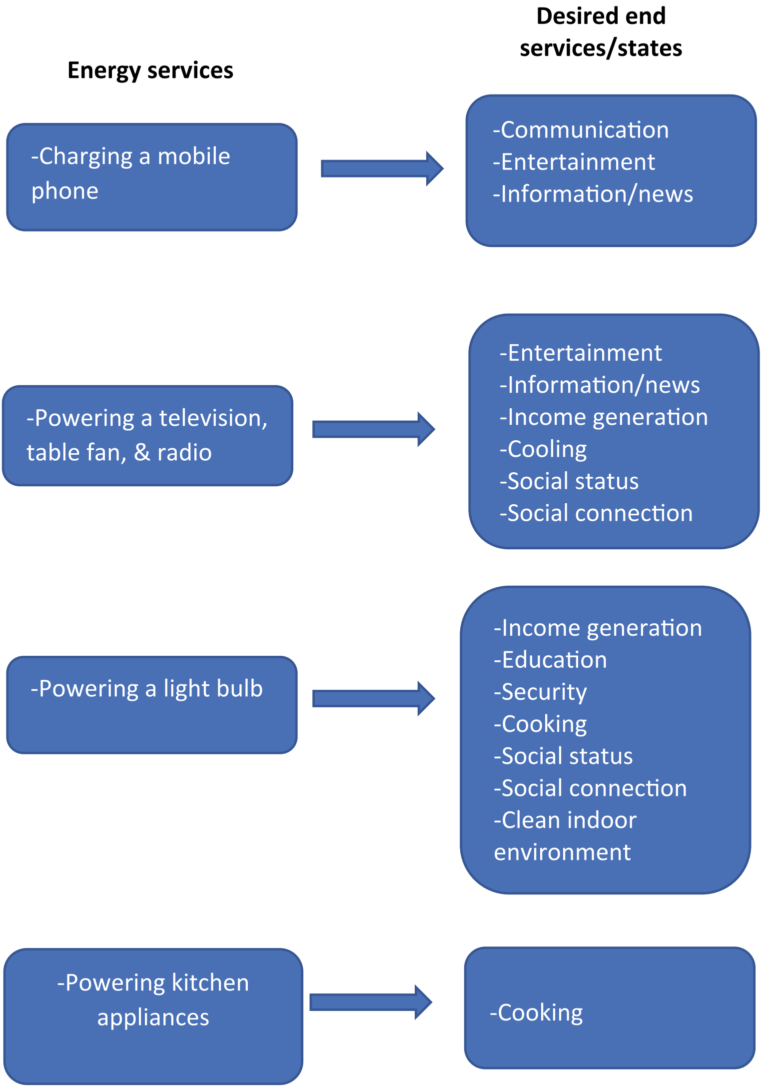

Fig. 5.2 Distinction between energy services and desired end services or states

Arguably, the adoption of low-capacity SHSs means that certain deprivations are not addressed either partially or fully, and this affects the wellbeing of owners of these systems. O'Neill (2011) argued that a loss in the level of satisfaction with one need cannot be compensated for by greater satisfaction of other needs. For example, the loss in the level of satisfaction with the need to power light bulbs for educational purposes cannot be satisfied by a gain in entertainment from watching TV. Additionally, for households with low-capacity SHSs, a gain in the level of satisfaction with a particular need can also prevent the satisfaction with others. For instance, satisfaction with the need for communication via a mobile phone can hinder the satisfaction with a security need due to the inability to power a light bulb.

The discontent here has also got a gender dimension. Notably, the inability to benefit from some energy services is particularly detrimental to women. When small SHSs are installed, women often suffer because they cannot use various appliances such as electric spice-grinders, rice cookers, kettles and irons, since the power generated is used for charging mobile phones and powering TVs and light bulbs. It is time-consuming to prepare meals without the use of these kitchen appliances, and it is also time-consuming to use a non-electric iron for ironing. Injustices related to women are linked to various factors, including gendered divisions of labour, decision-making power, and gendered domestic spaces (Ojong, 2021a). The point highlighted here is the manifestation of distributional injustice regarding access to the benefits of energy within the household. As discussed in Chapter 1, distributional justice calls for the even distribution of the energy benefits and ills on all members of society regardless of forms of social difference such as gender, race, etc. (Jenkins et al., 2016). The inability of women to have access to certain energy services, indicates that even within households, the benefits of energy access are not evenly distributed. Clearly, in multiple contexts, SHS adoption (re)produces distributional inequalities with respect to energy access within households. Within households, vulnerability is manifested as inequitable access to energy generated by solar home systems.

From another lens, the inability for women to have access to some energy services go against the *Ubuntu* philosophy. As noted in Chapter 1, *Ubuntu* is grounded in the sayings, 'I am a person because you are, I am because I share and participate' and 'I am because of others' (Chigangaidze et al., 2022: 320). It reflects the human characteristics of caring and consideration towards others (Broodryk, 2008; Mabvurira, 2020). Thus, when women cannot use various appliances such as electric spice-grinders, rice cookers, kettles and irons because their use is regarded as marginal, it indicates a lack of consideration towards them. *Ubuntu* shuns selfishness and promotes consideration of other people's needs (Mugumbate & Nyanguru, 2013).

Arguably, the absence or limited involvement of women and children in decisions related to the use of energy generated by the systems may be framed as procedural injustice. As noted in Chapter 1, procedural justice centres on access to decision-making processes that govern the distribution of energy benefits and ills (Heffron & McCauley, 2017; Jenkins et al., 2016; Sovacool, 2014). In several communities in the continent, men make decisions regarding which kitchen appliances can be powered by solar energy, including where light bulbs can be located, and often neglecting spaces used by women (Boamah & Rothfuß, 2020; Winther et al., 2018). In a study conducted in Ghana, the male household-heads and other male members of households enforced decisions not to use energy-intensive appliances such as electric blenders, kettles, irons and microwaves, even though women disapproved of these decisions, as the use of some of these appliances would enable them to prepare meals by using modern methods (Boamah & Rothfuß, 2020), hence saving time as well as reducing the drudgery associated with cooking. Failure to involve women in the decision-making process regarding energy use in the household contributes to an uneven distribution of the energy benefits of SHS adoption within households.

The exclusion of women in the decision-making process regarding the use of energy generated by the SHSs is antagonistic to the *Ubuntu* philosophy. As Ntibagirirwa (1999: 104) puts it, *Ubuntu* promotes 'normative principles for responsible decision-making and action, for oneself and for the good of the whole community'. Within households, responsible decision-making should take into account not just the interest of men but also those of women and children. Responsible and inclusive decision-making is crucial to the notion of 'oneness' espoused by Ubuntu philosophy.

From another angle, the intra-household dynamics discussed above may be framed as recognition injustice. As discussed earlier (Chapter 1), recognition justice is also about recognizing the particular needs of specific social groups (Sovacool & Dworkin, 2014; Walker & Day, 2012). Arguably, when decisions are made by men regarding the location of light bulbs and how power generated by SHSs is to be used, which works to the disadvantage of women, such decisions can be read as a lack of recognition of the needs of the latter. Paying attention to the specific energy needs of women by using a recognition rationale renders visible certain forms of injustice that they experience. Walker and Day (2012: 71) argue that 'lack of recognition is seen as foundational to distributional inequalities', and I contend that the distribution and recognition injustices manifested in households are intimately connected, and addressing the former begins by addressing the latter.

In some contexts, subsidies have been used to address the problem of cost, but these have been ineffective in practice. In Malawi, distributor-end subsidies were provided to encourage market-entry into the country's SHS market, but consumer-end subsidies were not provided to tackle the problem of affordability (Samarakoon, 2020). In Uganda, the subsidy programme was not totally effective, as several SHS providers did not pass on the benefits to consumers (Bhamidipati et al., 2019). The point here regarding subsidies is another illustration of distributional injustice. The uneven spread of the benefits of the subsidies meant that owners of SHSs did not benefit from a reduction in prices. Producers of SHSs and other parties benefited from the subsidies while SHSs adopters continued to pay relatively high prices for these systems.

The discussion regarding the distribution of subsidies goes against some core principles of *Ubuntu*. *Ubuntu* revolves around fairness (Kgatla, 2016) and equality and equity (Chigangaidze et al., 2022). There is no fairness or equity when distributors of SHSs receive subsidies but low-income households (i.e., consumers) do not also receive subsidies to enable them gain access to these solar systems. *Ubuntu* also entails caring for marginalized segments of society by meeting their needs. In this case, the subsidies policy did not meet the needs of low-income households which found SHSs unaffordable.

To address liquidity constraints, SHS providers have developed various business models. Regarding the fee-for-service model, SHSs are owned by the service provider, for instance the Office National de l'Electricité (ONE) in Morocco, and consumers pay a monthly fee for power (Nygaard et al., 2017). Consumers also have the possibility of getting loans from microfinance institutions (Lemaire, 2011; Tillmans & Schweizer-Ries, 2011). Other SHS financing options are rent-to-own and hire-purchase, whereby people purchase SHSs on credit and pay on a monthly basis (Opiyo, 2016; Rolffs et al., 2015). The pay-as-you-go business model is also available for the low-income population (Barrie & Cruickshank, 2017; Ockwell et al., 2019; Rolffs et al., 2015). Although these business models and payment modalities aim to alleviate liquidity constraints, their success is not guaranteed. For example, in rural Kenya, SHS end-users were provided options to pay in daily, weekly or monthly instalments, based on their payment capabilities; however, some low-income households could not afford daily payments (Adwek et al., 2020). Still in Kenya, high interest rates of about 40% charged by a hire-purchase company led to increases in the price of SHSs by 80–150% (Rolffs et al., 2015). In Ghana, a bank designed a Solar Loan Facility, but interest rates were between 32 and 33% and potential borrowers were required to hold an account with the bank for a minimum of three months, which pushed away many individuals (Boamah & Rothfuß, 2018). Similarly, in southern Ethiopia, owners of solar pv systems noted that the interest rate of 15–18% imposed by microfinance institutions rendered the loan repayment very challenging (Wassie & Adaramola, 2021).

The examples mentioned earlier regarding affordability of solar systems are good illustrators of distributional injustice. The financial burden of solar energy access weighs heavily on low-income households, as they have to use a relatively higher share of their household income, and this has consequences. In Botswana, several SHSs were repossessed by the providers because households could not make regular payments (Ketlogetswe & Mothudi, 2009). In other words, some low-income households could no longer bear the financial burden of accessing energy by using this solar technology. In Rwanda, some SHS adopters in refugee camps had to reduce expenditures on food to make SHS payments on time (Thomas et al., 2021). Put differently, because of the relatively higher share of energy costs on total income, some SHSs adopters in refugee camps in Rwanda had to reduce expenditure on a core element—food—that is essential for their survival and wellbeing. Relatively wealthy SHSs adopters do not have to make such sacrifices. For these relatively wealthy households, their discontent is not about affordability of this decentralized off-grid solar technology, but their inability to use certain household appliances such as a 350W deep freezer (see, for example, Boamah & Rothfuß, 2020: 9).

This uneven spread of the burden with respect to affordable access to energy services also brings to the fore the interaction between the price of SHSs/payment plans and other factors such as income or wealth. It is as a result of this interaction that some end-users purchase small SHSs while others get larger SHSs that can power larger household appliances such as a 60W freezer. Additionally, unlike relatively wealthy households, a significant percentage of low-income households do not have energy-efficient appliances, which therefore increases the amount of energy that needs to be consumed.

5.3.2 Product Design and Post-Acquisition Support

Beyond issues related to affordability, injustices were manifested in various spheres, including failure to design products which meet household energy needs, failure to train consumers regarding how SHSs work, providing low-quality products and services, and not providing maintenance services.

With respect to SHSs product design, household requirements are rarely met in a one-size-fits all model. In rural Kenya and Uganda, kitchens were separate from the main house, so cables which connect the light bulbs to the battery could not reach the kitchens (Stojanovski et al., 2017). In other words, some SHS designs do not take into consideration the specific needs of users in this region, who tend to prepare meals in structures which are separate from the main house. The technical limitations of SHSs can be read as a lack of recognition of the needs of certain groups. Arguably, recognition justice on the part of producers of SHSs entails taking into consideration the structure of houses in particular regions and designing appropriate systems. As Castán Broto et al. (2018: 647) put it, the principle of recognition is 'a celebration of the particular' and 'a condition for the incorporation of excluded groups into an otherwise hegemonic regime'.

Arguably, the fact that SHSs models did not take into consideration contextual issues with regards to housing structure is another example of procedural injustice. Procedural justice also entails the mobilization of local knowledge (Jenkins et al., 2016). In this case, it is clear that local knowledge was not mobilized by manufacturers of SHSs. If the local people were consulted and their knowledge taken into consideration, the solar systems would have been suitable to the local context. Failure to mobilise local knowledge was detrimental to SHSs adopters in these areas, as it negatively affected their access to energy services.

Even if SHSs are well-designed to meet household needs, their use will decline if durability is poor, and repairs have to be performed on a frequent basis. In Malawi, some households purchased SHSs with the promise of a three-year warranty, but the sub-standard systems failed within days (Samarakoon, 2020). In several countries, including Kenya, Senegal, Nigeria, Ghana and Uganda, although high-quality SHSs exist, the increasing share of low-quality or outright fake products may have adverse effects on their overall use and hinder consumers from deriving the benefits they had hoped to get of their use (Groenewoudt et al., 2020; Nygaard et al., 2017; Steel et al., 2016; Ugulu, 2019). In a study conducted in Uganda, vendors noted that batteries degraded rapidly that they were unusable before they could be sold (Groenewoudt et al., 2020).

Additionally, poor-quality SHSs may also increase maintenance costs, as seen in Ethiopia, where some SHS adopters have complained about the high cost of maintenance (Gebreslassie, 2020). In Malawi, households were replacing batteries almost every two years at a cost of between US$20–100 (Samarakoon, 2020). The cost of replacing solar batteries was also a major issue in South Africa (Lemaire, 2009).

Regardless of the business model or payment modality, SHSs must be installed at the end-users' homes. In some cases, SHS providers are responsible for the installation of the systems (Bhamidipati et al., 2019; Gustavsson & Ellegard, 2004; Lemaire, 2011; Nygaard & Dafrallah, 2016; Tillmans & Schweizer-Ries, 2011), while in other cases, it is the responsibility of the end-user to install them. In the latter, some retailers (for example, shopkeepers) without formal training take it upon themselves to install SHSs for their customers (Samarakoon, 2020).

Training of end-users on how to use them efficiently is crucial for their long-term use (Azimoh et al., 2015; Bisaga & Parikh, 2018; Gebreslassie, 2020). A few SHS providers train end-users in the use of SHSs (Carrasco et al., 2016), but in most cases, end-users do not receive training and relevant knowledge about how the systems work (Samarakoon, 2020; Tillmans & Schweizer-Ries, 2011). Lack of understanding of how these systems work can lead to draining the battery during the day and having no lights in the evening (Barrie & Cruickshank, 2017; Gustavsson & Ellegard, 2004) and led to premature breakdown of the systems (Tillmans & Schweizer-Ries, 2011). The point that I am driving here is that failure to educate users of SHSs regarding how the systems work is another form of injustice.

Offering maintenance services and addressing customer concerns post-sale is important to the long-term use of SHSs. Some SHS providers provide maintenance services for a period after installation (Bensch et al., 2018; Carrasco et al., 2016; Gustavsson & Ellegard, 2004; Groenewoudt et al., 2020; Lemaire, 2011); for example, in Morocco, an SHS provider offered maintenance services for ten years after installation (Carrasco et al., 2016). However, not all SHSs adopters have access to maintenance services (Kebede & Mitsufuji, 2014). Some end-users repair their SHSs through experimentation (Samarakoon, 2020), while others take them to an individual in the community who repairs appliances but is not licensed to perform such repairs (Cross & Murray, 2018). Lack of or inadequate customer support and after-sale services are key injustices, and the low-income population more often suffer the most. Drawing on the case of Kenya, Harrington and Wambugu (2021: 4) note: 'burden of failed solar products may be heaviest on rural households that may spend up to 50% of their daily income of Ksh. 100 on solar services with the hope that once the system is paid off, they will benefit from free electricity'. This is another example of distributional injustice. Again, the financial burden of regular repairs weighs heavily on lower income households, as they have to use a relatively higher percentage of their income.

The prevalence of failed SHSs or the need for frequent repairs is disadvantageous to end-users in the medium and long-term. Some researchers have argued that SHS adoption may lead to household budgetary improvements, as households reduce their consumption of kerosene and candles (Chen et al., 2017). As the argument goes, households are expected to cover the cost of purchasing these systems in the medium and long-term as a result of a decrease in consumption of traditional fuels such as candles and kerosene. However, this argument holds only if the systems do not fail or do not require regular repairs. Since a significant percentage of SHSs often break down after a couple of days, months, or years (Cross & Murray, 2018; Harrington & Wambugu, 2021; Samarakoon, 2020), hence requiring frequent repairs or the purchase of a new one, a significant proportion of low-income SHS adopters may not experience any household budgetary improvement. SHS adopters in this category may be worst off in the medium and long-term due to a significant increase in energy expenditure.

Closely related to the problem of repairs is the problem of waste generated from the mass consumption of solar products. There is an emerging body of work on the disposal of solar products that have ceased to function (Cross & Murray, 2018; Hansen et al., 2021; Samarakoon et al., 2021). In 2016, a report commissioned by the UK's Department for International Development (DFID) stated that the off-grid solar sector across 14 SSA countries would generate 3600t of electronic waste in 2017 (Magalini et al., 2016), which researchers familiar with the sector in Africa consider as a fraction of e-waste produced by the sector (Cross & Murray, 2018). The environmental impact of solar waste is contrary to the philosophy of *Ubuntu*. Beyond human-to-human relations, Ubuntu is also associated with human-environment relations (Chibvongodze, 2016). As Chigangaidze et al. (2022: 326) frame it: 'Ubuntu emphasizes ecological justice and environmental friendliness, as these also ensure the sustainable survival of humanity on earth'. Often, the manner in which solar waste is disposed of in Africa does not respect mother earth, and this disruption in the human-environment relationship has negative consequences. The negative consequences are due to the reciprocal relationship between humans and the environment. Parties engaged in a reciprocal relationship have obligations (Ojong, 2020). When humans meet their obligations towards the environment (e.g., by not polluting or destroying the natural environment), the latter reciprocates by meeting its obligation towards humans. The contribution of the off-grid solar sector to the alienation of people from nature is often obscured in the celebratory narratives of off-grid solar electrification.

5.3.3 Regulatory and Enforcement Issues

Standards and their enforcement are important for the solar industry. Weak regulatory frameworks or the absence of regulations and consumer protections are injustices (Ugulu, 2019), since this leaves consumers with the burden of navigating technical complexities and figuring out the difference between high-quality and sub-standard systems (Bawakyillenuo, 2009; Samarakoon, 2020). In countries where regulations for renewable energy and SHS standards exists, enforcement remains a key challenge (Muchunku et al., 2018; Samarakoon, 2020), and where laxity with respect to enforcement is pervasive, accredited companies can import uncertified products (Samarakoon, 2020), which is detrimental to consumers. Evidence of such practices is not difficult to find. In Ethiopia, licensed providers of SHSs sold low-quality products (Wassie & Adaramola, 2021). The point emphasized here is that energy justice in the off-grid solar energy space is 'not just the distribution of access to energy' (Cross & Murray, 2018: 108), it is also about broader questions in several domains.

5.4 Conclusion

The environmental credentials of off-grid technologies such as SHSs have been used to justify their place in Africa's energy landscape. Beyond the celebrating tone with regards to their virtues, there are numerous injustices. The aim of this chapter was to bring to the fore these multiple injustices as well as highlight their complex manifestations. Drawing on the energy justice framework as discussed in Chapter 1, I have shown manifestations of distributional, recognition and procedural injustices at various levels and in various spaces. Energy injustices were manifested at intra-households, household-SHSs providers and household-government levels. In the SHS space, energy justice goes beyond access to solar energy technology, as it encompasses issues related to the presence of weak regulations and enforcement measures, limited or no SHS post-acquisition services, and no training of end-users on how SHSs work, which contribute to inequities in the distribution of benefits and responsibilities. If Africa's renewable energy transitions are to be sustainable, then these issues must be at the centre of discussions in order to ensure that 'system transitions are not only more sustainable, but also more just' (Williams & Doyon, 2019: 144).

Furthermore, promoting the adoption and long-term use of SHSs in Africa is also about addressing recognition injustice, which manifests at various levels. The differential needs of marginalized segments of the population are not often taken into consideration, and at times this is reflected in the design of SHSs and their component parts, as well as the design of payment options. Moreover, recognition injustice, I argue, is manifested in households. In some households, the energy needs of women are not often taken into consideration, and so 'sustainable energy for all' will remain just a slogan if recognition injustices are not made visible and addressed. On this point, I widen the application of core principles of *Ubuntu* and conceptualization of recognition justice in renewable energy transition studies to include intra-household dynamics.

References

Adwek, G., et al. (2020). The solar energy access in Kenya: A review focusing on Pay-As-You-Go solar home system. *Environment, Development and Sustainability, 22*, 3897–3938.

Anugwom, E., Anugwom, K., & Eya, O. (2020). Clean energy transition in a developing society: Perspectives on the socioeconomic determinants of Solar Home Systems adoption among urban households in southeastern Nigeria. *African Journal of Science, Technology, Innovation and Development, 12*(5), 653–661.

Azimoh, C., Klintenberg, P., Wallin, F., & Karlsson, B. (2015). Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa. *Applied Energy, 155*, 354–364.

Barrie, J., & Cruickshank, H. (2017). Shedding light on the last mile: A study on the diffusion of Pay As You Go Solar Home Systems in Central East Africa. *Energy Policy, 107*, 425–436.

Bawakyillenuo, S. (2009). Policy and institutional failures: photovoltaic solar household system (PV/SHS) dissemination in Ghana. *Energy & Environment, 20(6),* 927–947.

Bensch, G., et al. (2018). Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso. *Renewable and Sustainable Energy Reviews, 90*, 1060–1068.

Bhamidipati, P., Hansen, U., & Haselip, J. (2019). Agency in transition: The role of transnational actors in the development of the off-grid solar PV regime in Uganda. *Environmental Innovation and Societal Transitions, 33*, 30–44.

Bisaga, I., & Parikh, P. (2018). To climb or not to climb? Investigating energy use behaviour among Solar Home System adopters through energy ladder and social practice lens. *Energy Research & Social Science, 44*, 293–303.

Boamah, F., & Rothfuß, E. (2018). From technical innovations towards social practices and socio-technical transition? Re-thinking the transition to decentralizsed solar PV electrification in Africa. *Energy Research & Social Science, 42*, 1–10.

Boamah, F., & Rothfuß, E. (2020). 'Practical recognition' as a suitable pathway for researching just energy futures: Seeing like a 'modern' electricity user in Ghana. *Energy Research & Social Science, 60*, 101324.

Broodryk, J. (2008). *Understanding South Africa: The Ubuntu way of living*. Ubuntu School of Philosophy.

Carrasco, L., Martin-Campo, F., Narvarte, L., Ortuno, M., & Vitoriano, B. (2016). Design of maintenance structures for rural electrification with solar home systems: The case of the Moroccan program. *Energy, 117*, 47–57.

Castán Broto, V., Baptista, I., Kirshner, J., Smith, S., & Alves, S. (2018). Energy justice and sustainability transitions in Mozambique. *Applied Energy, 228*, 645–655.

Chen, A., et al. (2017). Welfare impacts of an entry-level solar home system in Uganda. *Journal of Development Effectiveness, 9*(2), 277–294.

Chibvongodze, D. T. (2016). Ubuntu is not only about the Human! An analysis of role of African philosophy and ethics in environment management. *Journal of Human Ecology, 53*(2), 157–166.

Chigangaidze, R. K., Matanga, A. A., & Katsuro, T. R. (2022). Ubuntu philosophy as a humanistic–existential framework for the fight against the COVID-19 pandemic. *Journal of Humanistic Psychology, 62*(3), 319–333.

Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. *Energy Research & Social Science, 44*, 100–109.

Cross, J., & Neumark, T. (2021). Solar power and its discontents: Critiquing off-grid infrastructures of inclusion in East Africa. *Development & Change, 52*(4), 902–926.

Diallo, A., & Moussa, R. (2020). The effects of solar home system on welfare in off-grid areas: Evidence from Cote d'Ivoire. *Energy, 194*, 116835.

Fell, M. J. (2017). Energy services: A conceptual review. *Energy Research & Social Science, 27*, 129–140.

Gebreslassie, M. (2020). Solar home systems in Ethiopia: Sustainability challenges and policy directions. *Sustainable Energy Technologies and Assessments, 42*, 100880.

GOGLA. (2019). *Global off-grid solar market report semi-annual sales and impact data*. Utrecht. https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h1_2019.pdf. Accessed 8 Feb 2022.

GOGLA. (2020). *Global off-grid solar market report semi-annual sales and impact data*. Utrecht. https://www.gogla.org/sites/default/files/resource_docs/global_off_grid_solar_market_report_h1_2020.pdf. Accessed 8 Feb 2022.

Green, G., & Erskine, S. (1999). Solar (photovoltaic) systems, energy use and business activities in Maphephethe, KwaZulu-Natal. *Development Southern Africa, 16*(2), 221–237.

Groenewoudt, A., & Romijn, H. (2022). Limits of the corporate-led market approach to off-grid energy access: A review. *Environmental Innovation and Societal Transitions, 42*, 27–43.

Groenewoudt, A., Romijn, H., & Alkemade, F. (2020). From fake solar to full service: An empirical analysis of the solar home systems market in Uganda. *Energy for Sustainable Development, 58*, 100–111.

Gustavsson, M., & Ellegard, A. (2004). The impact of solar home systems on rural livelihoods. Experiences from the Nyimba Energy Service Company in Zambia. *Renewable Energy, 29*, 1059–1072.

Guta, D. (2018). Determinants of household adoption of solar energy technology in rural Ethiopia. *Journal of Cleaner Production, 204*, 193–204.

Hansen, U. E., Nygaard, I., & Dal Maso, M. (2021). The dark side of the sun: Solar e-waste and environmental upgrading in the off-grid solar PV value chain. *Industry and Innovation, 28*(1), 58–78.

Harrington, E., & Wambugu, A. W. (2021). Beyond technical standards: Creating an ecosystem for quality and repair in Kenya's off-grid solar sector. *Energy Research & Social Science, 77,* 102101.

Heffron, R. J., & McCauley, D. (2017). The concept of energy justice across disciplines. *Energy Policy, 105*, 658–667.

IRENA. (2016). *Solar PV in Africa: Costs and markets*. IRENA. https://www.irena.org/publications/2016/Sep/Solar-PV-in-Africa-Costs-and-Markets#:~:text=Stand%2Dalone%20solar%20PV%20mini,for%20poor%20quality%20energy%20services. Accessed 8 Feb 2022.

Jacobson, A. (2007). Connective power: Solar electrification and social change in Kenya. *World Development, 35*, 144–162.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science, 11*, 174–182.

Kebede, K., & Mitsufuji, T. (2014). Diffusion of solar innovations in Ethiopia: Exploring systemic problems. *International Journal of Technology Management & Sustainable Development, 13*(1), 53–72.

Ketlogetswe, C., & Mothudi, T. (2009). Solar home systems in Botswana—Opportunities and constraints. *Renewable and Sustainable Energy Reviews, 13*, 1675–1678.

Kgatla, S. T. (2016). Relationships are building blocks to social justice: Cases of biblical justice and African Ubuntu. *HTS Telogiese Studies/Theological Studies, 72*(1), 1–6.

Kizilcec, V., Parikh, P., & Bisaga, I. (2021). Examining the journey of a pay-as-you-go solar home system customer: A case study of Rwanda. *Energies, 14*, 330.

Lemaire, X. (2009). Fee-for-service companies for rural electrification with photovoltaic systems: The case of Zambia. *Energy for Sustainable Development, 13*, 18–23.

Lemaire, X. (2011). Off-grid electrification with solar home systems: The experience of a fee-for-service concession in South Africa. *Energy for Sustainable Development, 15*, 277–283.

Mabvurira, V. (2020). Hunhu/Ubuntu philosophy as a guide for ethical decision-making in social work. *African Journal of Social Work, 10*(1), 73–77.

Magalini, F., Sinha-Khetriwal, D., Rochat, D., Huismann, J., Munyambu, S., Oliech, J., Chidiabsu, I., & Oliver Mbera, O. (2016). Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector. *Evidence on Demand*. http://www.evidenceondemand.info/electronic-waste-impacts-and-mitigation-options-in-the-off-grid-renewable-energysector

Menghwani, V., Zerriffi, H., Korkovelos, A., Khavari, B., Sahlberg, A., Howells, M., & Mentis, D. (2020). Planning with justice: using spatial modelling to incorporate justice in electricity pricing—The case of Tanzania. *Applied Energy, 264*, 114749.

Monyei, C., Adewumi, A., & Jenkins, K. (2018). Energy (in)justice in off-grid rural electrification policy: South Africa in focus. *Energy Research & Social Science, 44*, 152–171.

Muchunku, C., Ulsrud, K., Palit, D., & Jonker-Klunne, W. (2018). Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? *WIREs Energy and Environment, 7*, 1–15.

Mugumbate, J., & Nyanguru, A. (2013). Exploring African philosophy: The value of Ubuntu in social work. *African Journal of Social Work, 3*(1), 82–100.

Ntibagirirwa, S. (1999). *A retrieval of Aristotelian virtue ethics in African social and political humanism: A communitarian perspective* [Master's thesis, University of Natal]. https://researchspace.ukzn.ac.za/bitstream/handle/10413/5714/Jennings_Ian_1999.pdf?sequence=1&isAllowed=y

Nygaard, I., & Dafrallah, T. (2016). Utility led rural electrification in Morocco: Combining grid extension, mini-grids, and solar home systems. *Wires Energy Environment, 5*, 155–168.

Nygaard, I., Hansen, U., Mackenzie, G., & Pedersen, M. (2017). Measures for diffusion of solar PV in selected African countries. *International Journal of Sustainable Energy, 36*(7), 707–721.

Ockwell, D., Atela, J., Mbeva, K., Chengo, V., et al. (2019). Can pay-as-you-go, digitally enabled business models support sustainability transformations in developing countries? Outstanding questions and a theoretical basis for future research. *Sustainability, 11*, 2105.

Ojong, N. (2020). *The everyday life of the poor in Cameroon: The role of social networks in meeting needs*. Routledge.

Ojong, N. (2021a). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.

Ojong, N. (2021b). Solar home systems in South Asia: Examining adoption, energy consumption, and social practices. *Sustainability, 13*(14), 7754.

Ojong, N., Simba, A., & Dana, L.-P. (2021). Female entrepreneurship in Africa: A review, trends, and future research directions. *Journal of Business Research, 132*, 233–248.

Ondraczek, J. (2013). The sun rises in the east (of Africa): A comparison of the development and status of solar energy markets in Kenya and Tanzania. *Energy Policy, 56,* 407–417.

O'Neill, J. (2011). The overshadowing of needs. In F. Rauschmayer, I. Omann, & J. Fruhmann (Eds.), *Sustainable development: Capabilities, needs, and well-being* (pp. 25–42). Routledge Studies in Ecological Economics.

Opiyo, N. (2016). A survey informed PV-based cost-effective electrification options for rural sub-Saharan Africa. *Energy Policy, 91*, 1–11.

Osunmuyiwa, O., & Kalfagianni, A. (2017). Transitions in unlikely places: Exploring the conditions for renewable energy adoption in Nigeria. *Environmental Innovation and Societal Transitions, 22*, 26–40.

Petticrew, M., & Roberts, H. (2006). *Systematic reviews in the social sciences: A practical guide*. Wiley-Blackwell.

REN21. (2020). *Global status report*. REN21, France, Paris. https://www.ren21.net/wp-content/uploads/2019/05/gsr_2020_full_report_en.pdf. Accessed 8 Feb 2022.

Rolffs, P., Ockwell, D., & Byrne, R. (2015). Beyond technology and finance: Pay-as-you-go sustainable energy access and theories of social change. *Environment and Planning A, 47*, 2609–2627.

Samarakoon, S. (2020). The troubled path to ending darkness: Energy injustice encounters in Malawi's off-grid solar market. *Energy Research & Social Science, 69*, 101712.

Samarakoon, S., Bartlett, A., & Munro, P. (2021). Somewhat original: Energy ethics in Malawi's off-grid solar market. *Environmental Sociology, 7*(3), 164–175.
Shamseer, L., Moher, D., Clarke, M., et al. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P): Elaboration and explanation. *BMJ, 349*, g7647.
Smith, M. G., & Urpelainen, J. (2014). Early adopters of solar panels in developing countries: Evidence from Tanzania. *Review of Policy Research, 31*, 17–37.
Sorrell, S. (2007). Improving the evidence base for energy policy: the role of systematic reviews. *Energy Policy, 35,* 1858–1871.
Sovacool, B. (2014). Energy studies need social science. *Nature, 511*, 529–530.
Sovacool, B., & Dworkin, M. H. (2014). *Global energy justice: Principles, problems, and practices*. Cambridge University Press.
Sovacool, B., & Griffiths, S. (2020). The cultural barriers to a low-carbon future: A review of six mobility and energy transitions across 28 countries. *Renewable and Sustainable Energy Reviews, 119*, 109569.
Sovacool, B., Axsen, J., and Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. *Energy Research & Social Science, 45*, 12–42.
Sovacool, B., Kivima, P., Hielscher, S., & Jenkins, K. (2017). Vulnerability and resistance in the United Kingdom's smart meter transition. *Energy Policy, 109*, 767–781.
Steel, W., Anyidoho, N., Dadzie, F., & Hosier, R. (2016). Developing rural markets for solar products: Lessons from Ghana. *Energy for Sustainable Development, 31*, 178–184.
Stojanovski, O., Thurber, M., & Wolak, F. (2017). Rural energy access through solar home systems: Use patterns and opportunities for improvement. *Energy for Sustainable Development, 37*, 33–50.
Thomas, P., Williamson, S., & Harper, P. (2021). The diffusion of solar home systems in Rwandan refugee camps. *Energy for Sustainable Development, 63*, 119–132.
Tillmans, A & Schweizer-Ries, P. (2011). Knowledge communication regarding solar home systems in Uganda: The consumers' perspective. *Energy for Sustainable Development, 15*, 337–346.
Ugulu, A. (2019). Barriers and motivations for solar photovoltaic (PV) adoption in urban Nigeria. *International Journal of Sustainable Energy Planning and Management, 21*, 19–34.

Ulsrud, K. (2020). Access to electricity for all and the role of decentralized solar power in sub-Saharan Africa. *Norsk Geografisk Tidsskrift–Norwegian Journal of Geography, 74*(1), 54–63.

van der Vleuten, F., Stam, N., & van der Plas, R. (2007). Putting solar home system programmes into perspective: What lessons are relevant? *Energy Policy, 35(3),* 1439–1451.

Wagner, N., Rieger, M., Bedi, A., et al. (2021). The impact of off-grid solar home systems in Kenya on energy consumption and expenditures. *Energy Economics, 99*, 105314.

Walker, G., & Day, R. (2012). Fuel poverty as injustice. Integrating distribution, recognition and procedure in the struggle for affordable warmth. *Energy Policy, 49*, 69–75.

Wassie, Y., & Adaramola, M. (2021). Socio-economic and environmental impacts of rural electrification with Solar Photovoltaic systems: Evidence from southern Ethiopia. *Energy for Sustainable Development, 60*, 52–66.

Williams, S., & Doyon, A. (2019). Justice in energy transitions. *Environmental Innovation and Societal Transitions, 31*, 144–153.

Winkler, B., Lemke, S., Ritter, J., & Lewandowski, I. (2017). Integrated assessment of renewable energy potential: Approach and application in rural South Africa. *Environmental Innovation and Societal Transitions, 24*, 17–31.

Winther, T., Ulsrud, K., & Saini, A. (2018). Solar powered electricity access: Implications for women's empowerment in rural Kenya. *Energy Research & Social Science, 44*, 61–74.

World Health Organization [WHO]. (2018). *Household air pollution and health*. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. Accessed 8 Feb 2022.

6

Framing Energy Justice: Perspectives from Malawi's Off-Grid Solar Market

Shanil Samarakoon and Collen Zalengera

6.1 Introduction

Bright stepped off the bus and made his way past the bustling stalls on Mzuzu's main thoroughfare before heading into an adjacent alleyway. It didn't take long for him to notice the large shop sign that his neighbour had suggested when Bright expressed interest in purchasing a solar system. It was hard to miss. A salesperson at the entrance was loudly announcing the latest promotions through a PA system. Amidst the cacophony of music and announcements, his ears caught mention of 'ending darkness by buying solar'

S. Samarakoon (✉)
The University of New South Wales, Sydney, NSW, Australia
e-mail: s.samarakoon@unsw.edu.au

C. Zalengera
Mzuzu University, Mzuzu, Malawi

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_6

as he walked in. The glass cabinets at the front of the store were filled with a wide range of electronic gadgets, ranging from torches and smartphones to sound systems and televisions.

Venturing further into the store, he noticed a large array of solar panels on display, positioned upright and ordered by size. He felt the gaze of the shop owner lift from the CCTV monitor and fix on him as he ventured towards the panels. He then heard him motion to his salesperson in Gujarati, commonly spoken in Indian-owned businesses, to assist him. Bright indicated in Chichewa that he wished to purchase a solar system that could power some lights and a television. After a brief exchange, the salesperson pointed to one of the panels in the middle, drawing attention to the thick sticker on the front that indicated that it was 'Made in Germany'. 'This is a good quality one, German. It is 100 watts, and we sell many of them,' the sales assistant remarked, and then proceeded to showcase a solar battery, charge controller and an inverter that could accompany the panel. Bright was eager, but quickly realised that he didn't have the funds to purchase all these additional components. After outlining his budgetary constraints, he finally settled on purchasing the solar panel, a few LED bulbs and a cheaper car battery instead of a lithium-ion solar battery.

'How about installation? Can you help me with this?' Bright asked as he paid for his goods at the counter and watched the assistant string his purchases in a box for him to carry home. 'No, we don't do that. You will need an installer to do that for you. Where are you coming from?' the salesperson inquired. When Bright replied that he had come from rural Rumphi, the salesperson said that he didn't know anyone who did installations that far away. Bright thanked the salesperson and carried his newly purchased system with him back towards the bus depot. He wondered if he should ask a local technician to help him wire the system, or if he should venture to do it himself. Above all, he was excited by the prospect of being able to finally use the television his son had sent him for Christmas and have lights in all rooms of the house.

This vignette from Malawi highlights several dimensions of how Malawians experience the nation's off-grid solar market. Such encounters occur in a context, like much of sub-Saharan Africa, in which the Malawian State is placing significant reliance on the off-grid solar market as a policy tool to address acute issues of energy poverty. In this chapter we critically examine the energy justice implications of this reliance on a market-based mechanism to address energy poverty in Malawi, giving particular attention to the impacts of certified and uncertified solar products. This involves attending to inequities in the distribution of benefits and burdens associated with off-grid solar technologies, as well as issues of recognition and procedural justice that Malawians experience in the off-grid solar market. Our analysis also considers a broad array of issues across the supply chain for off-grid solar products, considering flows of solar products, the roles of various actors, the implications of upstream design decisions, as well as the afterlives of these products. While acknowledging the limitations of a market-based approach, we conclude by offering several recommendations that could improve justice and sustainability outcomes in Malawi's off-grid solar market.

6.2 Malawi's Energy Landscape—The Growing Role of Off-Grid Solar Products

Malawi is a landlocked nation bordered by Tanzania (North and East), Zambia (West) and Mozambique (West, South and East). It is one of the least electrified nations in the world, with only an estimated 11.4% of its 17.5 million population having access to grid-based electricity (NSO, 2019). This lack of access to grid-based electricity is especially acute among the nation's majority rural population (approximately 83%), where it is estimated that only 3–5% have access to grid-based electricity despite the ongoing efforts of the *Malawi Rural Electrification Program* (MAREP) (USAID, 2019; Zalengera et al., 2014, 2021). The predominantly urban populations that have access to grid-based electricity, experience a lack of reliability due to persistent load-shedding (USAID, 2019; Zalengera et al., 2014); although the load-shedding reduced between 2020 and 2021. As such, both urban and rural households in Malawi rely on purchasing a range of energy technologies to address basic energy service needs such as lighting, cooking and powering small appliances. This is reflected in the last national census, which indicates that 75% of Malawian households rely on battery-powered LED torches for lighting, while the vast majority rely on biomass such as firewood (77%) and charcoal (18%) for cooking (NSO, 2019). It is within this context that off-grid solar products become an increasingly popular option among Malawian households seeking access to basic energy services, particularly as more cost-effective products have become available in trading centres over the last decade. While there is limited data on the extent of adoption in Malawi, it is estimated that between 6 and 13% of households are using some form of off-grid solar device for lighting (Business Innovation Facility, 2016; NSO, 2019).

Malawi's installed grid capacity has a significant contribution from hydro schemes, which was over 90% in 2017 (GoM, 2017a), and stands at about 80% in 2021 following the commissioning of 80 MW of solar power plants in 2021 and 2022. However, despite significant hydro, solar and wind power potential, and an attempt to introduce feed-in tariffs for renewable electricity generation technologies in 2012, investment in large-scale renewable energy projects has been very limited in Malawi (Gamula et al., 2013; Zalengera et al., 2014). The first grid-connected solar power plant of 60 MW in installed capacity was commissioned towards the end of 2021, and another 20 MW mid 2022 relative to an installed generation capacity of about 540 MW: 75% of hydro, 10% diesel generators for peaking and 15% solar photovoltaic. In recent years, the nation's power sector has been the subject of neoliberal reforms, for example, by the Millennium Challenge Corporation (MCC) to increase private sector participation (USAID, 2019). The MCC programme supported power sector infrastructure development including transmission lines and substations, tools for system monitoring and supported reforms towards financial sustainability of the power sector in Malawi.

The composition of the 2030 aspirational connection mix outlined in both the Malawi Renewable Energy Strategy (MRES) and the Malawi Sustainable Energy for ALL Action Agenda (SE4ALL) speak to the significant reliance the Malawian State is placing on market-based off-grid solar products as a solution to acute energy poverty (GoM, 2017a, 2017b). The country targets 30–40% for household connections to be achieved through the grid (2.3 million) while apportioning 50% of Malawi's household connections (2.8 million) to personal or home-scale solar products (GoM, 2017b; USAID, 2019). This vision of Malawi's energy mix in 2030, developed in service to Sustainable Development

Goal 7 (United Nations, 2018), would see over half of Malawi's households having to source electricity through the purchase of solar lanterns or solar household systems (GoM, 2017a, 2017b; USAID, 2019).

This vision bears a striking resemblance to neighbouring Tanzania's energy trajectory, where solar home systems have been promoted as a key means of electrification for over a decade, particularly for rural households where energy poverty is most acute (Ferrall et al., 2021). This is illustrative of a broader paradigmatic shift in the responsibility for provisioning electricity in sub-Saharan Africa, from the traditional domain of the state as a driver of the broader socio-economic development via centralized grid infrastructure, to the private concern of householders through the purchase of home-scale off-grid solar products (Samarakoon, 2020). This growing shift from electricity being a public service to a private commodity poses several energy justice concerns that will be discussed across this chapter. As Ferrall et al. (2021) illustrate through the case of Tanzania, reliance on market-based mechanisms tends to result in uneven outcomes–spatially and in terms of household income. While solar home systems are often rationalized as a solution to issues of acute rural energy poverty, their adoption tends to be concentrated in urban centres in practice—they are more profitable locations for private firms to operate from due to lower distribution costs and greater access to customers that can actually afford their products (Bensch et al., 2018; Ferrall et al., 2021; Grimm et al., 2020; Yadav et al., 2019). Allied to this are concerns in terms of equity in access, as a market-based approach relegates households to the products they can best afford. This can result in highly compromised levels of access to electricity when compared to the capabilities offered by grid-based electricity (e.g., a pico solar lantern or entry-level solar home system capable of charging a few lights and a mobile phone). We see these issues highlighted in this chapter's opening vignette, where Bright's capacity to purchase a quality solar home system was constrained by income; with him having to compromise on the use of a car battery instead of a more capable lithium-ion solar battery.

Delving deeper into this vision of Malawi's energy future, the MRES and SE4All Action Agenda outlines two broad phases that will accelerate the household adoption of home-scale solar products for electricity by 2030. The first involves NGOs and social enterprises developing supply chains and 'subsidizing' adoption up to 2020 and wider scale adoption due to falling prices and better finance models for the low-income by 2025 (GoM, 2017a, 2017b). Thus far, there is limited evidence to suggest that this has transpired at the intended scale or pace. The MRES states that the home-scale solar products would eventually be displaced by more capable mini-grids and grid-scale power post-2030. Thus, while there is an admission that these home-scale solar products are not a long-term solution to energy poverty, there is limited attention to what the transition to more sustainable energy infrastructures and services would entail.

The Malawian State has sought to facilitate the achievement of MRES and the aligned SE4ALL Action Agenda by facilitating market-based adoption of off-grid solar products. However, apart from the Government's project financed by UNDP that intended to remove barriers to renewable energy in Malawi[1]; the foundations of Malawi's off-grid solar market were laid by the efforts of NGOs that recognized the role of energy access in addressing issues of poverty (GoM, 2017a). SolarAid's trading arm, 'SunnyMoney', a social enterprise that sells solar lanterns through a nationwide network of local entrepreneurs (SunnyMoney 2021), is often cited as the largest seller of quality-certified solar products in Malawi (USAID, 2019). In recent years, both local and international market entrants have been distributing larger and more expensive solar household systems using pay-as-you-go models that were popularized in East Africa. These entities tend to position themselves as 'social enterprises' that are using business models, often backed by philanthropic and venture capital from the Global North, to address acute energy poverty in Malawi.

The Malawian State has also instituted policy measures to attract investment and additional market entrances, as well as improve affordability for the urban and rural poor. Most significant among these measures has been the removal of import duties on solar panels and

[1] From 1999 to 2007, the Malawi Government implemented a project called 'Barrier Removal to Renewable Energy in Malawi (BaRREM)'. The project was intended to address technical, economic, and institutional barriers to renewable energy in Malawi. Among other outcomes, through project, duties were waived to registered importers that complied with technical standards for solar products.

batteries, and the subsequent removal of value-added tax (VAT) on clean energy household products (GoM, 2017a, 2017b; MRA, 2019; USAID, 2019). Furthermore, USAID launched a 'Solar Home System Kick-Starter Program for Malawi' in 2019, a grant programme that seeks to enable solar businesses to sell subsidized pay-as-you-go solar systems to low-income households (USAID, 2019). Therefore, there is an acknowledgement that driving the adoption of off-grid solar products through the market hinges on significant support in the form of tax exemptions and subsidy programmes, at least in the early phase of market development.

In terms of the regulation of Malawi's off-grid solar market, the Malawi Energy Regulatory Authority (MERA) and the Malawi Bureau of Standards (MBS) are key institutions. MERA's mandate is to issue licences for importation and installation while also promoting consumer education about solar products (MERA, 2016), whereas MBS's role is to work in concert with MERA to test the quality of solar products against national standards and issue import certificates for compliant products (MBS, 2017). Notably, the country has adopted the 'Lighting Global' quality standard (subsequently renamed 'Verisol') into its national standards for solar products, a strong recommendation within the MRES and SE4All Action Agenda (GoM, 2017a, 2017b). There are also industry peak bodies such as the Solar Trade Association and the Renewable Energy Association of Malawi (REIAMA). However, there are questions about the effectiveness of existing regulatory arrangements, particularly as the market has been characterized as being overrun with counterfeit and uncertified products (Malawi Nation, 2019; Samarakoon et al., 2021).

In summary, Malawi's renewable energy vision broadly aligns with the trajectories outlined by neighbouring states such as Tanzania—particularly with regard to the growing role of market-based home-scale solar products in addressing rural energy poverty (Ferrall et al., 2021; Samarakoon, 2020). The MRES outlines a vision that places strong emphasis on the market-based adoption of these products by Malawian households and has sought to remove barriers such as duties and taxes to facilitate this. However, in practice, the adoption of these products has been driven by NGOs on flexible terms, thus the financial and logistical viability of a purely market-based approach to adoption by low-income rural households is unclear. Insights from more affluent nations in the region suggest that most rural households cannot afford solar home systems and that consumer subsidies would be necessary to drive wider adoption (Cross & Neumark, 2021; Grimm et al., 2020; Sievert & Steinbuks, 2020). The situation in Malawi's off-grid solar market is further complicated by regulatory laxity. This has led to the influx of uncertified solar products that are widely available at significantly lower prices than their certified counterparts. In the next section, we critically examine the issues of justice entangled in how Malawian households experience this two-tiered market.

6.3 A Tale of Two Tiers: Sub-Saharan Africa's Off-Grid Solar Markets

Off-grid solar products sold across sub-Saharan Africa, and the Global South more generally, can broadly be categorized into two tiers—certified and uncertified products. To be clear, these market tiers we refer to should not be confused with ESMAP's multi-tier framework (MTF, 2022) for assessing the quality of access to electricity offered by decentralized solutions at various scales, such as pico solar lanterns, solar home systems and solar mini-grids, as well as centralized solutions such as grid-based electricity (Alstone et al., 2015). Rather, in this chapter, our tiers refer to broad market dynamics which involve the sale of both certified and uncertified solar products across the Sub-Saharan African region. Table 6.1 provides a summary of the general distinctions between certified and uncertified off-grid solar products. As the name suggests, certified tier products have passed national and international quality certifications such as Verasol. The manufacturers and distributors of these products also tend to be members of the global industry peak body, GOGLA. In contrast, the *uncertified* tier tends to comprise products that are referred to in pejorative terms as being 'generic', 'copycat' and 'fake' solar products. These terms are largely in reference to issues of intellectual property, as these products can often be derived from the designs of more expensive certified products.

Table 6.1 A summary of the certified and uncertified tiers of the off-grid solar market in Africa for Pico Solar and SHS

	Certified	Uncertified
Country of manufacture	Primarily China	Primarily China
Distributors	Social businesses	A wide range of formal and informal businesses
Quality certification	Lighting Global certified	Tend to have no quality certification
Industry affiliation	Affiliated with GOGLA and local industry bodies	Unaffiliated with GOGLA and local industry bodies
Product differentiation	Quality certification, flexible payment plans, customer service	Emphasis on low price, some claim to be 'Made in Germany' to signal quality
Type of system	Complete system out of the box	Each component is sold separately e.g., panel, inverter, battery
Interoperability	– USB ports are common – Increased use of proprietary plugs and digital handshakes to restrict use of appliances	– Use of standard inverters allows for use with a vast array of AC appliances
Payment	Upfront or via pay-as-you-go financing	Sold upfront, layby arrangements are rare
Installation	Plug and play systems, an installer is optional	An installer is necessary for SHS
Warranty	Minimum 12-month warranty	Typically, no warranty, at the discretion of the seller
Repair	Highly integrated black-boxed technologies and proprietary screws	Discrete components. Some components are repairable by informal repair technicians
After-sales service	Local agents for after-sales service	Tend to have no local service presence

Another key point of differentiation is that uncertified solar products tend to be sold as discrete components instead of a complete solar system e.g., solar panels, inverters, batteries and charge controllers. These products are seldom sold with warranties, and if they are, they tend to be at the discretion of the distributor. While the complexity of trading networks making it hard to estimate precise sales numbers, it is generally accepted that the uncertified tier of the market constitutes most off-grid solar products that are sold in sub-Saharan Africa (Cross, 2019). Even key industry institutions such as GOGLA and Lighting Global (2020) estimate that uncertified products ('unaffiliated' in their report) constitute as much as 73% of all off-grid solar products sold to date. As we will illustrate through the case of Malawi, the ethics of the uncertified tier are complex. There is a growing body of research that challenges the dominant narrative that uncertified products are inherently inferior and undesirable in off-grid solar markets. Indeed, it is even argued that some of these products are more 'pro-poor' as they can offer comparable performance at significantly lower price points than their counterparts (Bensch et al., 2018; Grimm & Peters, 2016; Samarakoon et al., 2021).

6.4 Energy Injustice in Malawi's Off-Grid Solar Market

We now turn to the justice implications of this two-tiered off-grid solar market in a Malawian setting, especially as the State places significant reliance on it as a mechanism to address energy poverty. To this end, we draw upon an energy justice framework to examine rich ethnographic insights from Malawi's off-grid solar market. The use of ethnography is particularly salient contribution of this chapter as there is a paucity of research that examines the lived experiences of key stakeholders in off-grid solar markets in the Sub-Saharan African region. Our use of an interdisciplinary energy justice framework offers both a normative and evaluative lens through which we can examine multiple dimensions of justice (Heffron & McCauley, 2017; Jenkins et al., 2016; McCauley, 2018) that relate to Malawi's off-grid solar market. This involves examinations of how burdens and benefits of off-grid solar products are spatially distributed (distributive justice), whose needs are recognized or ignored (recognition justice), and how users can meaningfully inform and participate in decision-making (procedural justice). In this chapter we have categorized our insights into subsections based on three thematic areas: (1) quality and affordability; (2) consumer literacy and protections; and (3) off-grid solar repair and e-waste.

6.4.1 Quality and Affordability

Over the last decade, solar panels, various types of batteries and inverters have become a common sight in both urban and rural markets, purchased by energy-poor households to handle daily lighting and charging needs beyond the limited reach of the grid electricity. Similar to trends observed across the Sub-Saharan African region, the Malawian off-grid solar market is dominated by the uncertified tier of solar products. While there are no credible estimates of the extent of adoption, even Malawian standards officials publicly admit that Malawi's solar market is 'flooded with counterfeit products' (Malawi Nation, 2019). Recent ethnographic research suggests that 'fake' and sub-standard products are popular in Malawi's solar market as they are often more readily available and much more affordable than certified products (Samarakoon, 2020; Samarakoon et al., 2021). In this way, we can see how the two-tiered nature of Malawi's off-grid solar market presents a clear issue of maldistribution as access to quality-certified solar products tends to be circumscribed by household income and inequities in access to reliable information, resulting in the urban and rural poor being relegated to a murky spectrum of cheaper uncertified products.

A growing body of research on issues of affordability in off-grid solar markets in the Global South suggests that certified products are not necessarily within the reach of low-income households, even with the reduced cost of production and the advent of pay-as-you-go technologies (Bensch et al., 2018; Grimm & Peters, 2016; Grimm et al., 2020; Ojong, 2021; Yadav et al., 2019; Zalengera et al., 2015). The relatively small and urban focus of current distributors of certified solar home systems in Malawi suggests that there are similar dynamics in Malawi, with only less expensive solar lanterns enjoying more widespread adoption among the rural poor (Samarakoon, 2020). There is growing recognition of these structural inequities among organizations that promote the certified tier of off-grid solar products, evidenced in growing calls for both supply and demand-side subsidies as a mechanism to improve the inclusion of low-income households through improved affordability. An example being USAID's 'Solar Home Kick-Starter Program for Malawi', which has provided distributor-end subsidies and operational support to improve product affordability, as well as industry peak body GOGLA mounting the case for consumer-end subsidies (GOGLA, 2021a, 2021b). These efforts are still at their very early stages, and it is yet unclear whether they will adequately address the issue of affordability among Malawi's rural poor.

The supply chain for most off-grid solar products imported into Malawi is characterized by a distinct ethno-geographic hierarchy. The nation's largest importers tend to be affluent traders of South Asian and (more recently) Chinese origin that reside in the nation's commercial capitals, Lilongwe, and Blantyre (Englund, 2002; Samarakoon et al., 2021). These dynamics echo those broadly observed across the Eastern and Southern African regions, where affluent Asian migrants in urban centres tap into powerful global networks of capital, logistics, and access to manufacturers that few local traders can match (Englund, 2002). In Malawi, this translates to an inflow of solar products, typically from China via Tanzania or South Africa, that is steered by the determinations of Asian producers and traders (Samarakoon, 2020). This involves notions of which solar products cater to discerning and influential urban elites, and which are better suited to the needs of the nation's urban and rural low-income. This can be understood as an issue of recognition justice as these inflows of solar products are framed by the profit motives of manufacturers and distributors, rather than the needs of energy-poor populations. The asymmetries in power and influence between these market actors yield clear conflicts between the pursuit of profit, often hinged on prolonging circuits of consumption, and the desire for a 'permanent' solution to a lack of electricity.

One of the ways in which market actors in the uncertified tier respond to these trade-offs between quality and affordability is through the sale of what Malawians colloquially refer to as 'somewhat original' off-grid solar products (Samarakoon et al., 2021). Observed across a range of markets for commodities in the Global South, these products can utilize 'made in' production labels to give authenticity to consumers' hopes of purchasing a quality product. 'Somewhat original' products bring together a particular constellation of parts, ideas, place labels and forms of positional marketing. This class of products are not demonstrably counterfeit or faulty, but may lack the features, certifications and warranties that their more expensive competitors offer. One notable practice involves the use of positional labelling on solar panels to signal quality to the consumer through reference to a favourable country of origin; e.g., Germany or South Africa. Another involves reference to vague 'guarantee' periods (not to be confused with warrantees) spanning decades. In effect, there can be uncertified products that pretend to be certified products through their use of branding and labelling.

The example in Fig. 6.1 illustrates how positional labelling on a solar panel can be used. As we saw in this chapter's opening vignette, it is an effort to forge a connection to Germany, which is commonly perceived to be a source of high-quality products. These practices may be adopted by both manufacturers and distributors of off-grid solar products. Suffice to say, the claims made through these forms of labelling and packaging can be misleading and deceptive but tend to proliferate in a market defined by regulatory laxity. As we see through the example of Bright, most customers place strong reliance on the guidance of shop assistants and product labelling to inform their decisions. As we'll go on to examine, the confluence of poverty, low levels of solar literacy and weak consumer protections shape an environment where these products are widely adopted.

Another complicating factor in the inflow of solar products into Malawi involves Malawian diaspora networks in South Africa (Samarakoon, 2020). This is particularly acute in Malawi's northern region, where high unemployment continues to drive migration to urban centres in South African such as Johannesburg. This connection brings inflows of a wide range of electrical appliances, and solar systems to power them. These systems are brought in person during annual visits or through hired transporters that negotiate border crossings and bring goods to their relatives in Malawi on their behalf (Samarakoon, 2020). In Mzimba, one of north's most prominent trading centres, there has been evidence of second-hand solar products from South Africa being

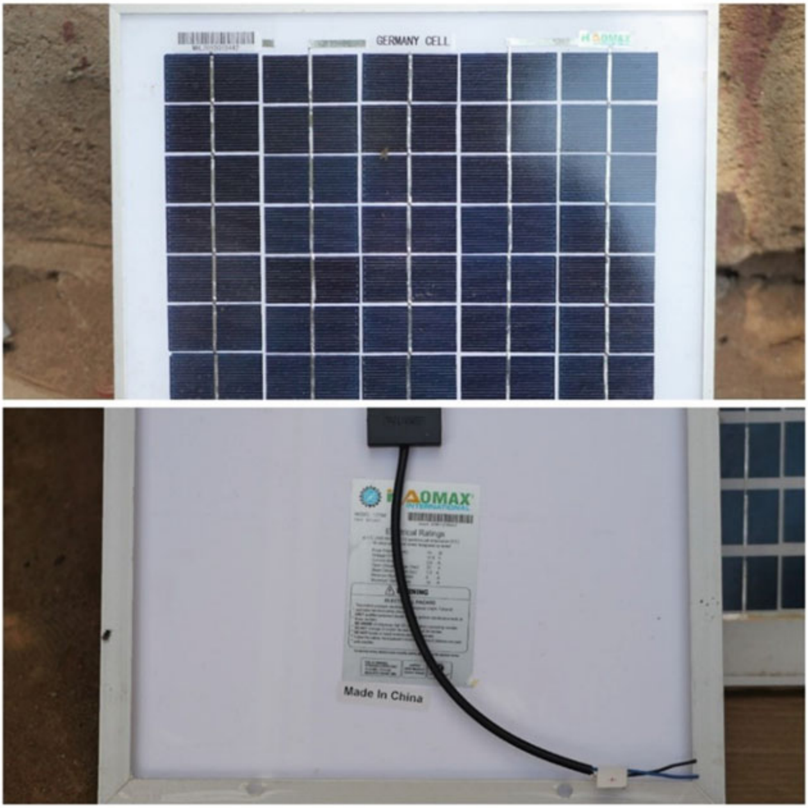

Fig. 6.1 A typical uncertified product in Malawi. The front of the panel (top) refers to 'Germany Cell' whereas the back (bottom) refers to being 'Made in China' (*Source* Authors' fieldwork)

sold as brand new to unsuspecting customers (Samarakoon, 2020). These diaspora-led inflows of solar products circumvent the regulatory mechanisms embedded into formal importation channels in the form of licences, product certification and customs checks. As such, this exacerbates issues of distributive injustice in the off-grid solar market as it tends to increase the number of uncertified goods available in the market, particularly among rural households who may find these products more readily available and affordable (Samarakoon et al., 2021).

Such inflows could also be framed as an exercise in agency, an opportunity for Malawian households with relatives or friends in South Africa to bypass the vagaries of the local supply chain. Solar products, thus, enter the Malawian energy landscape through a combination of formal importation channels *and* informal diaspora networks. While there is a paucity of research in this area, the preponderance of uncertified products in Malawi's energy scape is not just a function of informal cross-border inflows through diaspora networks. Indeed, the firm-level certification of enterprises selling solar, and lax oversight of imported goods mean that even 'certified' firms can import the aforementioned 'somewhat original' products, with relative impunity. Thus, Malawi's off-grid solar market is highly complex, filled with an ever-increasing diversity of off-grid solar products, ranging in functionality, price and quality. Given the extent of low-income households in Malawi, it is unsurprising that households favour products that they perceive as representing the best value for money—a calculation that overwhelmingly leads to the adoption of uncertified products. Thus, in effect, low-income households tend to be cut off from typical quality-affordability trade-offs; they are often relegated to choices between battery-powered LED torches and uncertified off-grid solar products for basic energy service needs, representing forms of both recognition and distributive injustice (Samarakoon, 2020).

6.4.2 Consumer Literacy and Protections

While solar panels, batteries and inverters have become ubiquitous across Malawian landscapes and entered the lexicon of even the most rural households, the extent of consumer literacy remains an issue of considerable concern. As described earlier, the Malawian State's energy trajectory places significant reliance on the adoption of off-grid solar products to address energy poverty. We contend that this represents a paradigmatic shift in responsibility for energy provision, from the shoulders of the State via grid infrastructure, to those of households through private home-scale generation (Samarakoon, 2020). Thus, a core focus in terms of energy justice involves attending to whether this shift in responsibility is accompanied by a commensurate level of care and protection by the

State via its policies and institutions, not just employing the principle of *caveat emptor*—the notion of 'buyer beware' (Cieslik, 2016; Sayer, 2000). In this regard, the degree to which Malawian households can make well-informed decisions, and have meaningful access to remedies through consumer protections, are critical issues of procedural justice.

Recent research in Malawi suggests that most households in Malawi have a limited capacity to make well-informed purchase decisions in the nation's off-grid solar market (Samarakoon, 2020; Samarakoon et al., 2021). Indeed, this may not be relegated to end-users as the distributors of off-grid solar products, who sell a wide range of electronic goods, tend to lack specialized training or experience with solar products. While MERA, as per its mandate, has made efforts to engage in consumer education through printed literature, radio and television programming, these efforts appear to be more concentrated in urban centres and thus may not be reaching the nation's largely rural population. The same could be said of its network of certified installers, who tend to be situated in urban centres, where a greater volume of customers are willing and able to pay for their services (Samarakoon, 2020). Overall, there is little evidence to suggest that there is meaningful engagement between the state and households with respect to navigating the complexities of the off-grid solar market. This poses salient issues of both recognition and procedural injustice as it reflects a lack of recognition of the informational needs of consumers, resulting in informational deficiencies and inequities that constrain their agency in the marketplace.

As with issues of affordability, here too we see how systemic inequalities are replicated in market-based interactions. More specifically, we can observe how levels of education and access to information, often across an urban–rural divide, can constrain the ability of households to make well-informed decisions in the off-grid solar market. Recent ethnographic research in Malawi suggests that while 'solar electricity' is widely understood as the process of converting sunlight to electricity, it is largely associated with the solar panel, not the associated components that are vital to a well-functioning and sustainable solar systems such as charge controllers, batteries, and inverters (Samarakoon, 2020). Thus, there is a tendency for households to prioritize purchasing solar panels and adding in the requisite components once they learn of their importance, if or when they can afford to. We see this in the opening vignette in this chapter, where Bright's budget limits his ability to purchase a charge controller and a lithium-ion solar battery in line with best practice. Instead, he opts for a low-cost car battery and even ponders installing the whole system by himself. This is commonplace in rural Malawi where installers are in short supply and their services are deemed unaffordable.

There is also the common perception that solar electricity is 'permanent' and thus maintenance-free; a view that grates against the need for maintenance, repair and the eventual replacement of various components in a solar system. The limited research on off-grid solar adoption in Malawi suggests that there are fundamental knowledge gaps regarding the functioning of solar systems, what the markers of good quality products are, maintenance practices, and consumer protections (Samarakoon et al., 2021). The perception that solar power is maintenance-free can even be observed in government institutions, particularly in hospitals with solar PV systems. These hospitals are typically not provided with any financing for the ongoing maintenance of the solar PV systems; while if they were connected to the grid, they are financed for payment of bills. This again represents a distributive injustice that affects reliable and equitable access to health services, particularly in underserved rural regions where solar systems are more likely to be used.

Given these knowledge gaps, 'copycat' approaches to off-grid solar adoption, whereby households seek to emulate the adoption decisions of those in their village, are commonplace across Malawi (Samarakoon, 2020). This is often sparked by curiosity—the glow of a house from lights late at night or the audible spectacle of a game of football on television. However, these decisions to adopt aren't necessarily guided by detailed discussions about specifications, brands, installation practices or user experiences. This might be explained by cultural mores, where being inquisitive might be construed as a form of temerity that is frowned upon within a community (Samarakoon, 2020). Ultimately, households tend to emulate what they have observed in their community or place deep reliance on the distributor's advice—a context in which the aforementioned 'somewhat original' products often appear attractive. In place of clear checklists to purchase good quality solar products, households often tend to rely on physical attributes such as weight, size and colour, as well as product labels to inform their decision-making (Samarakoon, 2020).

These dynamics of adoption can yield a wide range of solar system configurations with components that may be poorly matched, such as a solar panel being matched with an improper battery or inverter. Coupled with the tendency to engage in DIY installations to save on cost, these dynamics can result in systems that perform sub-optimally and are prone to breaking down (Samarakoon, 2020). Indeed, given the extent of solar illiteracy and the lack of expert guidance through the installation process, it can be hard to discern whether a 'broken' system is the result of a poorly configured system or product failure through the purchase of 'somewhat original' products. Thus, these technical issues require expert support, support that seldom accompanies the uncertified products that most Malawians purchase (Samarakoon, 2020).

Alongside these issues of consumer literacy, consumer protection in the form of warranties and meaningful redress from unfair trade practices, are also issues of concern in Malawi's off-grid solar market. While the legal minimum warranty period for off-grid solar products in Malawi is 12 months, a market that is dominated by the uncertified tier means that this tends to be the exception, rather than the norm. Recent research in Malawi suggests that most uncertified off-grid solar products are sold without any form of warranty, and given the prevailing levels of consumer illiteracy, are seldom insisted on by the end-user (Samarakoon et al., 2021). This practice is not just a phenomenon relegated to remote rural locations far beyond the regulatory gaze, they are commonplace in urban centres such as Mzuzu and Lilongwe, punctuating the extent to which enforcement is lacking (Samarakoon, 2020).

There tend to be two main reasons articulated by distributors for not offering warranties with their products. One is that the high rate of user error through DIY installations means that genuine product failure is hard to discern. As such, there are concerns that high return rates threaten the viability of their businesses (Samarakoon, 2020). The other is that while these solar products often flow through multi-layered distribution networks to reach Malawian marketplaces, manufacturer warranties seldom accompany them to the point of sale. As such, the provision of warranties and aftersales service is typically relegated to the smaller certified tier of the market and emphasized as a key point of difference. These dynamics concerning consumer protection, coupled with high consumer illiteracy, shape a context in which Malawian populations, particularly low-income rural households, bear undue risks and burdens while provisioning the electricity they have been made responsible for.

6.4.3 Off-Grid Solar Repair and E-Waste

While rapid adoption of off-grid solar products across sub-Saharan Africa is widely discussed in the context of facilitating universal access to electricity, there is limited discussion about afterlives of the millions of household-scale solar devices and appliances consumed in the pursuit of greater access to energy services (Cross & Murray, 2018; Hansen et al., 2020). An emerging body of research grapples with the intergenerational social and ecological consequences of these fast-paced circuits of consumption, with households moving from solar lanterns to various forms of solar home systems in their quests to provision electricity in the absence of grid infrastructure (Cross & Neumark, 2021; Hansen et al., 2020). The dynamics of repair and e-waste associated off-grid solar products have important implications in contexts like Malawi, which currently lacks both the policy settings and the infrastructure to effectively manage e-waste (ITU, 2018). This represents a significant issue of distributive justice as the growing consumption of off-grid solar devices, as promoted in the MRES, pose long-term health and ecological risks to Malawian households. Solar e-waste could also be characterized as largely invisible as its highly dispersed, often languishing in homes and front yards of accumulating in sprawling waste sites such as those seen in Agbogbloshie in Accra, Ghana (Kumar & Turner, 2020). Given that Malawian's low-income rural majority are more inclined to purchase uncertified products, there are concerns with respect to the waste implications of the products themselves and the lack of any accountable entity and mechanism to collect and safely dispose of these products. This is also a significant issue for the distributors of certified solar products, given the significant cost of incentives and logistics to collect their products at the end of life from rural areas—at present these schemes are entirely voluntary (Samarakoon et al., 2021) (Fig. 6.2).

While solar e-waste looms large as a systemic issue linked to the mass consumption of home-scale solar products, there are also significant efforts to extend the productive lifespans of these products through acts of repair. In a Malawian context dominated by an uncertified tier of off-grid solar products, informal repair technicians are an important part of this endeavour. These repair technicians are often self-taught or draw on knowledge and acumen passed on from reputed mentors. In the case of products such as inverters and lead-acid batteries, these technicians draw on repertoires of expertise that stretch beyond the off-grid solar market. These sole traders or small-scale centres tend to be in peri-urban and rural areas and are thus more proximate to a large base of solar users

Fig. 6.2 An informal repair technician at work in peri-urban Mzuzu (*Source* Authors' fieldwork)

across Malawi (Samarakoon et al., 2021). Though often lacking in formal training, they may be the only layer of support that purchasers of off-grid solar products can rely on in lieu of warranties and aftersales service. In a context characterized by poor consumer protection and regulatory laxity, these repair centres tend to offer the only possibility of extending the productive lives of these valuable investments made by households. Through their encounters with end-users encountering problems, they may also serve as an important source of guidance on how end-users could make better-informed decisions.

Beyond local technicians, there are significant distinctions that can be drawn between the certified and uncertified tiers regarding repair. While the uncertified off-grid solar products are traded through ethereal trading networks that do not tend to offer warranties and aftersales service, it could be argued that they do have some advantages over their affiliated counterparts when it comes to issues of interoperability, repair, and replacement (Samarakoon, 2020; Samarakoon et al., 2021). We see this through upstream design decisions associated with affiliated products such as the use of proprietary screws, black-boxed technologies and closed product ecosystems. While these measures are often rationalized in terms of durability, safety and preserving the pay-as-you-go systems that make them financially viable, they can have the effect of constraining repairability and consumer choice. For instance, affiliated products are often very difficult for informal technicians to repair due to their highly integrated nature, the use of proprietary screws, and limited access to spare parts. Even end-users covered by a warranty (typically up to two years) may have to endure long wait times if they are situated in rural areas as most affiliated distributors have repair centres based in urban centres such as Lilongwe, Mzuzu or Blantyre. However, it is worth noting that there are novel approaches to repair that are emerging from the affiliated sector in response to these dynamics. In 2021, Malawi's largest distributor of off-grid solar products, Sunny Money, has made strides to decentralize its repair network by forging working relationships with informal repair technicians across both Malawi and Zambia.

Connected to matters of solar repair and e-waste is the issue of interoperability—the ability of a solar system to work with other parts or appliances. Here too, we see notable distinctions between the affiliated and uncertified tiers of products. For example, the common use of standard inverters with uncertified systems offers the advantage of being compatible with a vast array of existing AC appliances, unlike affiliated products which typically requires the use of proprietary DC accessories. To harken back to the vignette in our introduction, it is likely that Bright would not be able to use the television his son purchased for him—he'd have had to purchase a system with a proprietary DC television had he opted for a pay-as-you-go system from the affiliated tier. Thus, we can see how the latter's limited interoperability can have the effect of creating both additional expenditures for end-users and additional flows of e-waste (Fig. 6.3).

Use of automotive lead-acid batteries with solar home systems is widespread, and some households prefer these over lithium-ion-based solar batteries because they are cheaper and can be refilled with battery acid. This could be a result of poor solar literacy, as solar batteries are typically a more efficient, durable, and ecologically safe choice for a solar home system (Balasubramanian et al., 2018). Nonetheless, this occurrence also blurs the distinction between solar e-waste and more general streams of e-waste, particularly as automotive lead-acid batteries and inverters are not products that are exclusive to the off-grid solar market. The implications of these dynamics are wide-ranging. For instance, while

Fig. 6.3 A collection of batteries in a household in Karonga North—depleted solar batteries (foreground) accompanied by a motorcycle battery (background) (*Source* Authors' fieldwork)

there is limited knowledge of the health and environmental impacts associated with improperly handling and disposing of these products, as well as a lack of infrastructure to facilitate it, the afterlives of products such as batteries and inverters, are entangled in livelihoods centred on repair, recycling, and reuse (Samarakoon et al., 2022).

As households spend a significant amount of their limited finances on solar products, there is a general reluctance to discard them, even if they cannot be repaired (Balasubramanian et al., 2018). Selling these objects to others that viewed them as a resource, e.g., repair centres, recyclers, upcycles tends to be the preferred course of action for households if the price is right. As such Malawian households tended to view 'solar e-waste' through an economic rather than an environmental lens, as non-working objects that they are unable to recover significant monetary value from (Samarakoon et al., 2022). Indeed, the prices offered for solar products such as batteries and inverters at the end of life tends to be modest, their value often approximated by weight. There is some evidence to suggest repair centres harvest spare parts from these products at end-of-life, and that scrap dealers are using metals and plastics associated with these products are to create products such as pots, chairs, and storage containers (Samarakoon et al., 2021). While there is limited evidence on the specific practices adopted in Malawi, evidence across Africa suggests that it is unlikely that the toxic metals associated with off-grid solar systems, including the widespread use of lead-acid batteries, are being safely managed (Balasubramanian et al., 2018; UNEP, 2017).

Though relatively small in the context of broader flows of e-waste, we can see how the afterlives of off-grid solar products pose a range of justice and sustainability challenges; from upstream design decisions that impede repair and interoperability to the mounting health and environmental implications of solar e-waste (Hansen et al., 2020; Samarakoon et al., 2021, 2022). Given the varied and diffuse networks through which uncertified solar products enter Malawi, there are often no clear lines of responsibility for the afterlives of these products after the point of sale. Meanwhile, the affiliated tier is still grappling with the upstream design decisions of manufacturers, and the unfavourable economics of trying to collect highly dispersed solar e-waste for recycling. This endeavour is further complicated by the lack of recycling facilities in Malawi, meaning that the only recourse that a firm has is to stockpile e-waste and send it to regional centres in Kenya or South Africa for recycling. Thus, while peak industry body GOGLA is increasingly mobilizing the language of circularity in relation to improving the sustainability of its supply chain (GOGLA, 2021a, 2021b), the ground realities in contexts like Malawi would suggest that there are several systemic challenges that need to be overcome.

6.5 Advancing Energy Justice in Malawi's Off-Grid Solar Market

This chapter has illustrated how Malawi's off-grid solar market is presently generating several forms of energy injustice for low-income households. Thus, while off-grid solar products are delivering salient positive benefits to populations that are excluded from grid-based access to electricity, we contend that significant market reforms and initiatives are necessary to address important issues of justice and sustainability.

Energy undertakings are a regulated business in Malawi. This includes both the electricity and liquid and gas fuels whose pricing, though market-based, is regulated using a pricing methodology set up by the Malawi Energy Regulatory Authority. However, the sale of 'somewhat original' solar products and the lack of access to qualified installers by the underprivileged are key foundations of the distributive, recognition and procedural injustice perpetrated by off-grid energy provisioning in absence of regulatory and consumer association focus on the same. The other driver of the injustices detailed in the previous section is the current configuration of the off-grid solar market, which emphasizes volumes of product sales instead of ongoing access to reliable energy services. Given the current tax waivers enjoyed by the off-grid market, we argue that it is both fair and essential that the market is properly regulated to ensure that these incentives maximize benefits to end-users; and therefore, enhance equitable access to modern energy services. In this vein, in concluding this chapter, we offer a wide range of avenues for market reform that could yield more just and sustainable outcomes in Malawi's off-grid solar market if coupled with a subsidy programme for the off-grid space (Table 6.2).

Table 6.2 Avenues for market reform in Malawi's off-grid solar sector

Regulatory and policy measures	• The Malawi Energy Regulatory Authority (MERA), Malawi Bureau of Standards (MBS), and Malawi Revenue Authority (MRA) should ensure that only products that have passed quality tests in light of established standards should be eligible for tax waivers • MERA and the Ministry responsible for Energy should facilitate regular training and certification of installers in remote areas, at the Village Development Committee (VDC) level to ensure broader access • Every importer or distributor of an off-grid solar product should have a list of qualified installers recognized by the MERA, who they can link up to install their products for qualification of issuance of an aftersales warranty • MERA should set up and regularly update maximum prices for home-scale solar products by applying the pricing/tariff methodologies that are applied in grid-based systems and mini-grids systems
Incentives and social safety nets measures	• In recognition of the role of home-scale off-grid systems on pre-grid rural electrification; the Ministry of Energy and MERA should set up a subsidy system using the rural electrification fund and carbon tax for off-grid systems. The system should pay the service provider the cost difference above grid-based energy costs until price-regulated off-grid systems reach grid parity

(continued)

Table 6.2 (continued)

Consumer awareness	• Trade associations such as the Renewable Energy Industry Association should take a leading role in promoting voluntary regulation compliance among its members as a means to differentiate themselves from non-compliant traders. This should include consumer awareness of fair-trade practices in the off-grid solar systems market • The Renewable Energy Industry Association of Malawi (REIAMA) and the Consumer Association of Malawi should set up a complaint receiving and redress system that rural populations can easily access • MERA and MBS should establish a mechanism (including an audit function) that ensures that all regulated purveyors of off-grid solar systems implement a warranty system
Repair and e-waste management	• MERA and REIAMA's member businesses should include informal repair technicians in their strategies to facilitate the repair of off-grid solar systems, particularly in rural regions. This would include initiatives to upskill technicians on repairing a wider range of products, providing health and safety resources, and improving access to spare parts • Malawi Energy Regulatory Authority, Councils, and the Environment Protection Authority should set up a system for the collection of solar products at the end of useful life

References

Alstone, P., Gershenson, D., & Kammen, D. (2015). Decentralized energy systems for clean electricity access. *Nature Climate Change, 5*, 305–314. https://doi.org/10.1038/nclimate2512

Balasubramanian, S., Clare, D., & Ko, S. (2018). *Off-grid solar e-waste: Impacts & solutions in East Africa*. Retrieved February 15, 2021, from https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/18419/Balasubramanian_Clare_Ko-SolarEWaste.pdf?sequence=1&isAllowed=y

Bensch, G., Grimm, M., Huppertz, M., Langbein, J., & Peters, J. (2018). Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso. *Renewable and Sustainable Energy Reviews, 90*, 1060–1068.

Business Innovation Facility. (2016). *Off-grid lighting and phone charging study*. Accessed January 4, 2022, from https://www.bifprogramme.org/sites/default/files/attachments/malawi_off_grid_and_phone_charging_survey.pdf

Cieslik, C. (2016). Moral economy meets social enterprise community-based green energy project in rural Burundi. *World Development, 83*, 12–26.

Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. *Energy Research and Social Science, 44*, 100–109.

Cross, J. (2019). The solar good: Energy ethics in poor markets. 47–66. https://doi.org/10.1111/1467-9655.13014

Cross, J., & Neumark, T. (2021). Solar power and its discontents: Critiquing off-grid infrastructures of inclusion in East Africa. *Development and Change*. Early online https://doi.org/10.1111/dech.12668

Englund, H. (2002). Ethnography after globalism: Migration and emplacement in Malawi. *American Ethnologist, 29*(2), 261–286.

Ferrall, I., Heinemann, G., von Hirschhausen, C., & Kammen, D. M. (2021). The role of political economy in energy access: Public and private off-grid electrification in Tanzania. *Energies, MDPI 14*(11), 1–23.

Gamula, G. E. T., Hui, L., & Peng, W. (2013). Development of renewable energy technologies in Malawi. *International Journal of Renewable Energy Technology Research, 2*(2), 44–52.

GOGLA. (2021a). *What is an end-user subsidy?* Retrieved January 10, 2022, from https://www.gogla.org/off-grid-solar-smart-subsidies/end-user-subsidies

GOGLA. (2021b). *Beyond e-waste: A circular approach to reducing the footprint of the off-grid solar industry*. Retrieved January 10, 2022, from https://www.gogla.org/about-us/blogs/beyond-e-waste-a-circular-approach-to-reducing-the-footprint-of-the-off-grid-solar

Government of Malawi. (2017a). *Malawi renewable energy strategy*. Retrieved January 24, 2022, from https://www.meramalawi.mw/index.php/resource-center/other-regulatory-tools/send/20-other-regulatory-tools/61-malawi-renewable-energy-strategy

Government of Malawi. (2017b, June). *Malawi SEforALL action agenda*.

Grimm, M., & Peters, J. (2016). Solar off-grid markets in Africa: Recent dynamics and the role of branded products. Field actions science reports. *The Journal of Field Actions* (Special Issue 15), 160–163.

Grimm, M., Peters, J., & Sievert, M. (2020). Demand for off-grid solar electricity: Experimental evidence from Rwanda. *Journal of the Association of Environmental and Resource Economists, 7*(3), 417–454.

Hansen, U. E., Nygaard, I., & Dal Maso, M. (2020). The dark side of the sun: Solar e-waste and environmental upgrading in the off-grid solar PV value chain. *Industry and Innovation, 28*(1), 58–78. https://doi.org/10.1080/13662716.2020.1753019

Heffron, R. J., & McCauley, D. (2017). The concept of energy justice across disciplines. *Energy Policy, 105*, 658–667.

ITU. (2018). *Developing an e-waste national policy and regulatory framework for Malawi*. Retrieved January 25, 2022, from https://www.itu.int/en/ITU-D/Climate-Change/Documents/2018/Developing_e-waste_national_policy_and_regulatory_framework_Malawi.pdf

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research and Social Science, 11*, 174–182.

Kumar, A., & Turner, B. (2020). Sociomaterial solar waste: Afterlives and lives after of small solar. In G. Bombaerts, K. Jenkins, Y. Sanusi, & W. Guoyu (Eds.), *Energy justice across borders* (pp. 155–173). Springer.

Malawi Nation. (2019). *Counterfeit solar products flood the market—MBS*. Accessed January 15, 2022, from https://mwnation.com/counterfeit-solar-products-flood-the-market-mbs/

Malawi Revenue Authority (MRA). (2019). *Amendments to the customs and excise (tariffs) order*. Accessed January 14, 2022, from https://www.mra.mw/press-releases/amendments-to-the-customs-and-excise-tariffs-order

MBS. (2017). Catalogue of Malawi Standards, [Online], Available at: http://www.mbsmw.org/wp-content/uploads/2017/10/2017-Malawi-Standards-Catalogue.pdf, Accessed on 7th June 2021.
McCauley, D. (2018). *Energy justice: Re-balancing the trilemma of security*. Palgrave Macmillan.
MERA. (2016). MERA Mandates, [Online], Available at: https://www.meramalawi.mw/index.php/about-us/mera-mandates, Accessed on 6th November 2021.
Multi-Tier Framework. (2022). *Electricity*. Retrieved January 14, 2022, from https://mtfenergyaccess.esmap.org/methodology/electricity
NSO. (2019, May). *2018 Malawi population and housing: Census main report*. National Statistics Office. Retrieved August 20, 2021, from http://www.nsomalawi.mw/images/stories/data_on_line/demography/census_2018/2018%20Malawi%20Population%20and%20Housing%20Census%20Main%20Report.pdf
Ojong, N. (2021). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.
Samarakoon, S. (2020). The troubled path to ending darkness: Energy injustice encounters in Malawi's off-grid solar market. *Energy Research & Social Science, 69*, 101712.
Samarakoon, S., Bartlett, A., & Munro, P. G. (2021). Somewhat original: Energy ethics in Malawi's off-grid solar market. *Environmental Sociology, 7*(3), 164–175.
Samarakoon, S., Munro, P. G., Kearnes, M., & Zalengera, C. (2022). The afterlives of off-grid solar: The dynamics of repair and e-waste in Malawi. *Environmental Innovation and Societal Transitions, 42*, 317–330.
Sayer, A. (2000). Moral economy and political economy. *Studies in Political Economy, 61*(1), 79–103.
Sievert, M., & Steinbuks, J. (2020). Willingness to pay for electricity access in extreme poverty: Evidence from sub-Saharan Africa. *World Development, 128*, 104859.
SunnyMoney. (2021). *Solar aid*. Retrieved January 5, 2022, from https://sunnymoney.org/solaraid/
United Nations. (2018). *Advancing SDG 7 implementation in support of the 2030 agenda*. Retrieved January 5, 2022, from https://sustainabledevelopment.un.org/content/documents/17462PB1.pdf

United Nations Environmental Program. (2017). *Turning tragedy into opportunities: Overcoming Africa's lead challenge*. Retrieved August 7, 2021, from https://www.unep.org/news-and-stories/story/turning-tragedies-opportunities-overcoming-africas-lead-challenge

USAID. (2019, January). *Southern Africa Energy Program (SAEP): Market entry information pack*.

Yadav, P., Heynen, A. P., & Palit, D. (2019). Pay-As-You-Go financing: A model for viable and widespread deployment of solar home systems in rural India. *Energy for Sustainable Development, International Energy Initiative, 48*, 139–153.

Zalengera, C., Blanchard, R. E., & Eames, P. C. (2015). Putting the end-user first: Towards addressing the contesting values in renewable energy systems deployment for low-income households—A case of Likoma Island in Malawi. In S. Hostettler, A. Gadgil, & E. Hazboun (Eds.), *Sustainable access to energy in the global south* (pp. 101–112). Springer.

Zalengera, C., Blanchard, R. E., Eames, P. C., Juma, A. L., Chitawo, M., & Gondwe, K. T. (2014). Overview of the Malawi energy situation and A PESTLE analysis for sustainable development of renewable energy. *Renewable and Sustainable Energy Reviews, 38*, 335–347.

Zalengera, C., Chitawo, M. L., Chitedze, I., To, L. S., Mwale, V., Gondwe, K. T., & Maroyi, T. (2021) Unbending the Winding Path of a Low-Income Country's Energy Sector amid the COVID-19 Pandemic: Perspectives from Malawi. *Energies 14*, 21:7184. https://doi.org/10.3390/en14217184

7

Gender Differentiation, Equality and Equity in Off-Grid Solar Usage in Rural Tanzania: A Fraying Thread?

Annelise Gill-Wiehl, Isa Ferrall, and Daniel Kammen

7.1 Introduction

The United Nation's Sustainable Development Goal 7 (SDG7) calls for 'universal access to affordable, reliable, sustainable, and modern energy services' (IEA, 2021: 1). Women and the lowest income groups carry a

A. Gill-Wiehl (✉) · I. Ferrall · D. Kammen
Energy and Resources Group, University of California, Berkeley, CA, USA
e-mail: agillwiehl@berkeley.edu

I. Ferrall
e-mail: isa.ferrall@berkeley.edu

D. Kammen
e-mail: kammen@berkeley.edu

D. Kammen
Goldman School of Public Policy, University of California, Berkeley, Berkeley, CA, USA

Department of Nuclear Engineering, University of California, Berkeley, Berkeley, CA, USA

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_7

disproportionate burden of energy poverty and a disproportionate lack of service until SDG7 is achieved. This disproportionate burden is a core motivating factor for the theoretical and practical pursuit of universal energy access. This effort is at the core of the United Nations efforts to pursue energy access and its description as the 'golden thread' linking and enabling at least nine of the SDGs including eradication of poverty, gender equality, and increased work and economic growth (Jeuland et al., 2021).

Although providing the level of service currently only provided by high-quality grids is the ultimate goal, decentralized systems such as mini-grids, solar home systems (SHS), and intra-household 'pico-solar' products represent a vital interim level of access. The International Energy Agency (IEA) projects that 55% of the population lacking access will gain electricity access through mini-grids (30%) or stand-alone systems (25%) (Bouckaert et al., 2021). Decentralized energy systems, particularly off-grid solar systems, have played a prominent role in providing access, particularly in East Africa (IEA, 2021).

Despite this, quantifying the prioritization, use, and impact of off-grid and/or mini-grid solar requires further research (Jeuland et al., 2021). Furthermore, many plans to provide access appear to proceed in a gender-blind fashion (Govindan et al., 2019) and scholarship of off-grid solar's access, usage, and impact is rarely differentiated by gender (Alstone et al., 2015; Casillas & Kammen, 2010; Govindan et al., 2019; Ojong, 2021a, 2021b). As off-grid solar plays an increasing role in rural electricity access worldwide, studies evaluating the energy justice implications of solar will become more important.

Therefore, in this chapter, we draw on a case study from rural Tanzania to investigate the energy justice implications of off-grid solar in relation to gender and low-income households. We ask: How do categories of gender and social class shape the use of energy generated from off-grid solar technologies at the household level?

Roundtable on Climate & Environmental Justice, Rausser College of Natural Resources, University of California, Berkeley, Berkeley, CA, USA

In Tanzania, 77% of the population lacks direct access to electricity,[1] placing it among the top 20 access-deficit countries. The provision of electricity access in Tanzania is keeping pace with population growth (IEA, 2021), but rapid improvement is needed in order to meet SDG7's goal of universal access by 2030. Striving to meet SDG7 during 2012–2016, Tanzania's former president, John Magufuli, and the former Minister of Energy and Minerals, Sospeter Muhongo, prioritized expanding the national grid, particularly in rural areas with their establishment of the Rural Energy Agency. Despite this, investment in solar continued to rise, particularly between 2014 and 2017 during drought-related power outages (Phillips, 2020). Overall, the 2017–2018 Tanzanian Household Budget Survey found that 29% of the population utilizes the national grid for lighting, while 26.5% of the population relies on solar as their main source of lighting. This leaves 55.5% of the population relying on torches or rechargeable lamps, kerosene, candles, paraffin, etc.[2] (Tanzania National Bureau of Statistics, 2018). Specifically, our chapter focuses on a rural town, Shirati, located in the Mara Region, where in 2017–2018, 20.7% of the population utilized the national grid as their main source of lighting and 26.6% rely on solar (Tanzania National Bureau of Statistics, 2018).

Despite the prevalence of off-grid solar in Tanzania, recent literature from Tanzania focuses primarily on urban settings and national grid electricity (Jacome & Ray, 2018; Koepke et al., 2021; Luo et al., 2021). These works offer great insight into the dynamic nature of energy access in cities. However, there have been a few key ethnographic pieces on the gender and off-grid energy in Tanzania. Phillips's (2020) article is one of the few recent works that focuses on rural settings in Tanzania, exposing the gendered nature of rural energy access before the grid arrives (Phillips, 2020). Specifically focusing on the Singida region of

[1] To track progress towards SDG7, the International Energy Agency (IEA) access to electricity, as 'a household having access to sufficient electricity to power a basic bundle of energy serves—at a minimum, several lightbulbs, phone charging, a radio and potentially a fan or television—with a level of service capable of growing over time' (pg. 1), but practically measure it as a connection to an electricity gird or stand-alone system that can provide that basic energy bundle (IEA, 2020).

[2] We acknowledge that the Household Budget Survey did not categorize diesel generators. However, the 'other' category was only 1% of the population.

Tanzania, Phillips offers a deep ethnographic account of energy use and finds energy in rural Tanzania to be a 'relational and gendered configuration of people, nature, labour, and sociality that makes and sustains human and natural life' (Phillips, 2020: 71). Cross and Neumark (2021) document the tumultuous relationship between customers and the solar energy companies in East Africa's prominent off-grid market (and specifically Tanzania), and the injustice in exploiting and ultimately excluding rural, low-income households. These have been critical additions to the literature upon which our chapter builds. Therefore, this chapter adds to the growing body of energy justice literature on off-grid solar, specifically adding to the body of literature regarding gendered access in Tanzania.

7.2 Conceptualizing and Operationalizing Energy Justice

Energy justice is a body of academic scholarship that is concerned with the achievement of equity in both the social and economic participation in the energy system, while also remediating social, economic, and health burdens on marginalized communities (Baker et al., 2019). Theories of energy justice have organized the concept into three core tenets: distributional justice, procedural justice, and finally recognition justice (Heffron et al., 2013). Distributional energy justice covers the uneven allocation of the benefits and burdens of energy. Procedural energy justice is the equitable engagement of all stakeholders in decision-making surrounding energy. Procedural justice also requires 'participation, impartiality and full information disclosure' (Heffron et al., 2013: 2). And finally, recognition energy justice calls for the fair representation and the offering of complete and equal political rights to all individuals. This may appear as insults, degradation, and devaluation of individuals surrounding energy policy (Heffron et al., 2013). Samarakoon (2019) argues that the literature must address distributive, recognition and procedural injustices in energy services. While Sovacool et al. use energy poverty as their key example of a violation of distributive justice (Sovacool et al., 2016). Therefore, we focus on distributional effects of energy justice in this work.

According to Sovacool et al.:

> [D]istributive justice deals with three aspects: what goods, such as wealth, power, respect, food or clothing, are to be distributed? Between what entities are they to be distributed (for example, living or future generations, members of a political community or all humankind)? And what is the proper mode of distribution— is it based on need, merit, utility, entitlement, property rights or something else? (Sovacool et al., 2016)

For the purposes of this paper, we evaluate what goods from solar are distributed and between what entities are they to be distributed. The rest of this article focuses on two modes of distribution to operationalize our concept of justice.

i. A primary goods approach in which every individual has a minimum level of said good (Rawls, 1971). This is to say to each in equal parts—which we will refer to as *equal*; or
ii. a capability approach in which every individual receives according to the level needed to enable the individual to achieve equivalent capability (Sen, 1979, 1992). This is to say to each according to need—which we will refer to as *equitable.*

As an example, while an energy justice approach prioritizing equality may value equal access to, usage, and impact of off-grid solar, an equity approach would account for the disproportionate burden felt by electricity's absence. Women and the lowest-income groups feel disproportionate burdens of energy poverty; therefore, they stand to gain the most from access.

In addition to the three tenets of distributive, recognition and procedural justice, energy justice has been defined by eight core principles: availability, affordability, due process, transparency and accountability, sustainability, *intra-* and *inter*-generational equity and responsibility (Sovacool et al., 2016). We focus on three of these principles: availability, affordability and intragenerational equity. Availability is defined as 'people deserve sufficient energy resources of high quality' (Sovacool et al., 2016: 5). Affordability within energy justice is 'the provision of energy services should not become a financial burden for consumers, especially the poor' (Sovacool et al., 2016: 5). Finally, intragenerational equity is defined as 'all people have a right to fairly access energy services' (Sovacool et al., 2016: 5).

We acknowledge the rich feminist and gender studies literature that theorizes how gender mediates access across society, specifically within the context of development (Chua et al., 2000; Jackson, 1996; Kabeer, 1994; Ojong, 2020). We also acknowledge the powerful theory derived from the lived experiences of the Sangtin Writers in India which demonstrates how gender and feminism can never truly be extricated from caste or class in development work (Sangtin Writers Collective & Nagar, 2006). We recognize the difference between sex and gender, and the problem with equating the two, specifically in energy policy (Fathallah & Pyakurel, 2020; Listo, 2018). However, rural Tanzanian society generally equates the two due to the strong culturally and socially prescribed roles. Finally, we draw upon the theory of 'gender myths' often found in development literature which often assumes women are the poorest of the poor without evidence (Chant, 2004; Listo, 2018). This work builds from their theory, providing evidence through an in-depth case study and serving to open the space for future gender-differentiated dialogues within the off-grid solar literature.

7.3 Off-Grid Solar

The off-grid solar market has rapidly expanded in the last ten years to provide lighting to millions across the developing world, particularly in sub-Saharan Africa. In 2019, the market served 420 million users, and it is expected to expand to 823 million users by 2030 (Rysankova et al., 2020). Solar products on the market range from pico products such as portable lanterns to high-capacity SHS. Despite this growth in the off-grid solar market, it is important to note that 83% of sales were for pico products such as portable solar lanterns (Rysankova et al., 2020).

The World Bank's Energy Sector Management Assistance Program (ESMAP) developed a multi-tiered framework (Tiers 0 to 5) to reflect the differing levels of energy access between no connection and high-quality grid connection (Angelou & Bhatia, 2015). Portable solar lanterns only enable Tier 0, while a multi-light system or a SHS is necessary to reach Tier 1 or 2 (Angelou & Bhatia, 2015). These tiers are based on capacity, duration, reliability, quality, affordability, legality, health and safety, and annual or daily consumption. Tier 4 corresponds to the IEA's definition of access to electricity as 1250 kWh annually (Angelou & Bhatia, 2015; IEA, 2020). Regardless of the level of energy access solar can provide, the literature below summarizes the well documented (i) technical; (ii) social and economic; and (iii) political implications of SHS as well as the recent energy justice literature surrounding off-grid solar.

With regard to the technical aspects of solar, evaluations of SHS have found challenges regarding the installation, maintenance, and customer service (Azimoh et al., 2015). To improve the installation, maintenance and monitoring of the SHS, there has been a parallel rise in smart solar systems which use real time data monitoring (Bisaga et al., 2017). Other studies investigating the quality of the SHS revealed poor inverter efficiency, charge controllers, and batteries (Chowdhury & Mourshed, 2016) and called for warranties, carbon credit frameworks, and standardizations (Davies, 2018). Recent research on the reliability of electricity access based in Tanzania found that SHS provided more reliable electricity than local grid connections, however SHS outages were distributed less equitably than other sources (Ferrall et al., 2022).

Additionally, there has been research into the social and economic aspects of SHS. A review of studies on SHS found that that even though small solar systems cannot help households reach higher levels of energy access, the systems impact cost savings, improve the quality of lighting, and increase the amount of time children spent studying and the quality of education (Lemaire, 2018). In South Africa, a study evaluating SHS found that the electricity from SHS has a profound impact on rural livelihoods, but the limited capacity mediates the economic benefits (Azimoh et al., 2015). Another study in Kenya found that men were in charge of purchasing the SHS but were not spending much time in the house (Fingleton-Smith, 2018). Other research has found solar benefits women more since they are at home more (Ulsrud, 2020). And finally, the off-grid solar market faces affordability barriers (Baurzhan & Jenkins, 2016;

Grimm et al., 2020) that prevent the sector from reaching the last mile customer (Barrie & Cruickshank, 2017).

Finally, researchers have grappled with the political implications of SHS particularly as the national grid expands. Jaglin investigates how national grids coped with the 'PV revolution' and finds that parallel electricity paths lead to questions regarding the organization of electricity, the treatment of electricity as a common good, and how local territories cope with national objectives (Jaglin, 2019).

Non-gender-differentiated energy justice literature has investigated the adoption, affordability, usage, and quality of off-grid solar service (e.g., Azimoh et al., 2015; Baurzhan & Jenkins, 2016; Chowdhury & Mourshed, 2016; Grimm et al., 2020; Lemaire, 2018). Previous research into energy injustice has found that the off-grid market reproduces socio-economic inequities (Samarakoon, 2020), focuses too heavily on the technical hardware and financing (Ockwell & Byrne, 2017), and places financial burdens on low-income customers (Grimm et al., 2020; Muchunku et al., 2018).

Despite this research on the technical, social, economic, political, and even energy justice aspects of off-grid solar, evaluations have revealed that off-grid solar is still the preferred technology in some rural areas (Banerjee et al., 2013; Grimm et al., 2020). Recently, the off-grid solar market pivoted to focus on productive uses of solar and payment schemes in order to support its continued expansion. In our case study, we examine productive uses and payment schemes as two key pathways through which gender and class can mediate the distributional benefits of off-grid solar.

7.3.1 Productive Uses

Energy access literature has long cited the need for consumers to utilize off-grid energy for productive uses to increase the financial viability of deploying these systems (ESMAP, 2019; Hirmer & Guthrie, 2017; Kirubi et al., 2009). Full time employment from solar may not directly translate into benefits for women's agency or economic position, as women perform a disproportionate share of housework. Therefore, a focus on income generating uses without an explicit focus on gender, unwittingly perpetuates gender inequalities (Power for All, 2020). Sen (1999) argues that to evaluate social welfare, income, capabilities, education, and even rights must be equalized. However, each of these aspects of social welfare differ by gender in most societies. It remains to be seen if (and how) women benefit more than men.

In 1992 the United Nations' Food and Agriculture Organization (FAO) defined productive use of energy in rural areas as: 'one that involves the application of energy derived mainly from renewable resources to create goods or services either directly or indirectly for the production of income or value' (White, 2002). The indirect income or value could be extended store hours due to lighting or fewer hospital visits due to the decreased indoor air pollution (Svensson, 2010). Even though the definition includes 'value', in practice, both the literature and stakeholders focus on income production. The vague boundary around 'value' makes it difficult to evaluate and quantify (Svensson, 2010). Despite the vague definition beyond income generation, productive uses of electricity have been touted to 'reduce kWh unit costs, increase profitability, and promote economic development' (ESMAP, 2019: 16).

In a study of productive uses powered by off-grid solar, the most common productive uses were cell phone charging, barber shops, TV shows, cold beverage sales, and hostels (Svensson, 2010). Solar PV has been found to increase shops productivity in terms of transactions and lowered the user's operational costs by largely eliminating the need for recurring fuel expenses (Svensson, 2010). Although ESMAP claims that 'increasing productive uses of mini-grid electricity creates a win–win-win–win scenario for mini-grid developers, rural entrepreneurs, communities, and national utilities over time' (ESMAP, 2019: 17), it is unclear if all rural entrepreneurs and all within a community receive the same level of benefit. This is particularly salient when considering gender and socio-economic status (Boamah, 2020; Pueyo et al., 2020). Unfortunately, studies rarely disaggregate their analysis by gender when investigating productive uses.

In East Africa, only 25% of SHS customers are women. However, solar has led to more economic activities through more work hours, equal to 21 full time employments (FTEs) for every 100 SHS sold;

52% of the FTE are undertaken by women (Wheeldon et al., 2019). The African Development Bank declared that traditionally, development finance institutions (DFIs) have focused on large-scale, capital-intensive technology projects to expand energy access, while overlooking household energy uses such as food processing and procurement of water and fuel. This focus on productive uses outside of the home suggests that women may not be equally or equitably benefiting from these uses of solar.

7.3.2 Payment Schemes

Off-grid solar companies have started offering payment schemes to households who are unable to pay the entire upfront cost. Although these payment schemes for off-grid solar have mostly taken hold in East Africa, these models are starting to emerge in West Africa, South-East Asia, and Latin America (Sharma, 2017). Various models exist within the umbrella category of payment schemes, primarily differentiated across two dimensions. First, in terms of the long-term ownership of the system. Namely whether ownership of the system will transfer to the household upon completion of the payments after 6–36 months in a *lease-to-own* model, or whether the company retains ownership of the system, selling only the energy generated from the system similar to a micro-utility in an *energy-as-a-service* model (IRENA, 2020; Yadav et al., 2019). Second, in terms of the units purchased. Namely, whether kWh of energy or hours of time are exchanged for payments. For the purposes of this chapter, we define payment schemes for off-grid solar as smaller payments made over time as opposed to a one-time upfront cost.

In most schemes, when a customer's payment lapses, the system is locked remotely until the next payment is made, similar to a prepaid model. When a customer consistently fails to make their payments, the company may uninstall and repossess the system. Payments may be made manually with the assistance of field agents or through mobile money and more advanced information and communication technologies (ICT). The common pay-as-you-go (PAYG or PAYGo) financing model is used for both lease-to-own models and energy-as-a service model (Adwek et al., 2020). PAYG offers flexible payment amounts and timelines often enabled by mobile money and ICT.

While off-grid solar purchased on payment schemes has dominated the discourse in recent years, globally it is difficult to quantify the percentage of off-grid solar purchased via payment schemes. GOGLA only tracks the sales made by companies associated with GOGLA, which does not include generic products. In 2018, non-affiliated brands made up 55 and 80% of the market in Tanzania for SHS and pico products respectively (GOGLA, 2019). Within the GOGLA affiliated brands, there has been an increase in the use of payment schemes for SHS, particularly as the system size increases. This could indicate that customers are placing increased value on payment schemes to access larger, more expensive systems that they may be unable to purchase in a single upfront payment (GOGLA, 2019). The high upfront cost of SHS is a major barrier to low-income households (Bhattacharyya & Palit, 2016; Rolffs et al., 2015). Although we do not know how many generic products were purchased on payment schemes, it is important to note that branded products are typically of higher quality, and therefore more expensive than the generic (Rysankova et al., 2020).

To make these multiple payments, often PAYG systems rely on mobile money, a vital financial tool for low-income households. Suri and Jack (2016), for example, estimate that access to Kenyan mobile money increased consumption levels and lifted 2% of Kenyan households out of poverty. The impact was more pronounced for female-headed households who changed their financial behaviour (i.e., moved from agriculture into business) in response to the mobile bank account (Suri & Jack, 2016). Although mobile money has disproportionately benefited women, it is not clear that mobile money combined with a SHS does as well. The Consultative Group to Assist the Poor found that 'while there are some indications that the PAYG model is well suited to women's energy and financial needs and could potentially have a positive impact on their lives, it's clear that more rigorous research will be needed to better understand the impacts' (Kumaraswamy, 2021).

7.4 The Rise of Energy Justice Through Energy Access

Research on energy access has existed far longer than the emergent energy justice literature, therefore much energy access literature does not use the language of energy justice, even though the frameworks, tenants, principles and interests in energy access literature often align extremely well with energy justice theory. Only recently has this begun to change.

There has been an advent of energy justice research on energy access in Africa regarding both grid and off-grid electricity. As mentioned previously, Sovacool et al. (2016) identified energy poverty as his key example of a violation of distributive energy justice (Sovacool et al., 2016). Munro et al. (2017) illustrate how the pursuit of SDG7 simultaneously marginalizes producers and users of 'traditional' energy sources which serve as an important form of livelihood. This fundamentally questions the justice implications within the goal for universal energy access (Munro et al., 2017). Jacome and Ray evaluated the implications of post-paid and prepaid meter regimes in Unguja, Tanzania, finding that the prepaid meter may not be compatible with SDG7's call for universal access (Jacome & Ray, 2018). Munro (2020) examines how the urban poor experience heterogenous infrastructure and act as bricoleurs out of desperation, creatively using available materials to support their energy needs—whether they be on, off, below or beyond the grid.

Turning specifically to off-grid solar, there is a growing body of literature questioning whether off-grid solar market is truly attempting to include the low-income households and acting as the social and economic good it claims to be (Cross & Neumark, 2021). This emerging literature has found that in South Africa, Namibia, Ghana, and Kenya decentralized solar systems have generally only been affordable to higher income households (Boamah, 2020). Case studies of solar photovoltaic (PV) in Malawi revealed inequity in engagement and transparency for all stakeholders, inequity in the benefits resulting from the system, and inequity in the consideration of concerns from different stakeholders (van der Horst et al., 2021). A critical analysis of Mozambique's energy transition through the lens of the three elements of energy justice found that solar PV was installed unevenly throughout rural communities and burdened residents with unpayable loans and new expectations regarding its maintenance, service and training (Castán Broto et al., 2018).

Ockwell and Byrne (2017) found that solar companies who only focus on financing hardware and entrepreneurship have failed to meet the needs of their low-income customer. Other studies have found that even with microfinance the most affordable off-grid systems do not provide enough power to exceed basic energy needs (Boamah, 2019, 2020; Samarakoon et al., 2021). Cross and Neumark document the tumultuous relationship between customers and the solar energy companies in East Africa's prominent off-grid market, and the injustice in exploiting and ultimately excluding rural, low-income households (Cross & Neumark, 2021). Muchunku et al. found that vendors were disincentivized to target low-income people because their commission was based on the level of customer default (Muchunku et al., 2018).

Energy poverty, the lack of sufficient, affordable or reliable energy access, is inherently an issue of energy injustice. Research has critiqued off-grid solar technologies for adding additional financial burdens on to low-income households (Grimm et al., 2020; Muchunku et al., 2018). Kudo et al. (2019) and Furukawa (2014) challenge the presumption that access to solar alone can transform low-income lives.

Additionally, the literature has found injustice regarding the lack of full information regarding the solar systems among those with access. Studies in both off-grid solar and off-grid micro hydro have found that users have limited knowledge of the technology, their energy consumption, their payment plans, and the pros/cons of meter-based rates (Simpson et al., 2021).

Beyond injustices regarding affordability and information, the literature has considered *intra*generational energy injustice, specifically regarding gender. Women disproportionately bear the burden of energy poverty and low-income households typically spend higher percentages of their incomes on fuel (Fankhauser & Tepic, 2007). Discussions regarding the *potential* benefits of electricity access via solar home systems to women have dominated this field of literature. For example, prior research posits that tasks for 'traditional' women may become easier, lighting of streets will allow for safer travel, access to education increases as the time spent cooking and gathering fuel and water decreases, and cleaner stoves and lighting sources reduce indoor air pollution (Bose, 1993; Kohlin et al., 2011). However, much more time has been spent positing the potential benefits than evaluating whether they occur and to whom they accrue.

A few studies investigate how gender affects access, and the energy injustice implications. A case study of off-grid solar in Tanzania and Mozambique found that traditional thinking around gender issues poses a barrier to rural electrification through off-grid solar (Ahlborg & Hammar, 2014). Studies of SHS in Peru and Bangladesh evaluated the impact of solar on gender empowerment and found that women spent less time on agricultural activities, spent more time awake, less time collecting firewood, more time reading, and more time on other chores (Arraiz & Calero, 2015; Asaduzzaman et al., 2013; Khandker et al., 2014; Wamukonya, 2007). A study on a solar powered agricultural intervention found that women had less time to use the solar technology (Otte et al., 2018). However, Ockwell et al. (2021) call for further research into the gendered implications of solar technology, specifically after their work evaluating Lighting Africa in Kenya.

Notably, there is no substantial literature on the role of gender in energy's effect on enterprises and income generation (Pueyo et al., 2020). An evaluation of rural solar microenterprises in Tanzania found that most businesses were owned by men and men-owned businesses utilized more electricity than their female owned counterparts (Pueyo et al., 2020). Another study in rural Tanzania found that within a model that trained women to be solar engineers, the four women trained benefited from increased agency, wellbeing, and status within their community (Ali, 2015). It is unclear how women not trained benefited from the solar PV and if further economic opportunities for women resulted from the solar (Ali, 2015).

In the public sector, Tanzania's 2015 National Energy Policy and their Rural Electrification Agency specify a gender action plan. The private sector has female focused solar companies such as Solar Sister and developed the Tanzania Gender and Sustainability Energy Network (TANGSEN) (Power Africa, 2019). Despite this emerging literature and public and private sector initiatives, there is still a need for further literature to address the energy justice implications of off-grid solar in

Tanzania regarding gender and low-income households. This chapter builds on the off-grid solar and energy justice literature and the calls for further research into gender to evaluate whether off-grid solar disproportionately benefits (or harms) women and lower-income households, specifically within a rural setting.

7.5 Methodology

In this case study, we draw from 187 household energy surveys, 30 in-depth household interviews, 10 follow-up interviews, key-stakeholder interviews, participant observation and personal experiences in Shirati, Tanzania conducted through multiple field trips between 2017 and 2021.

During the first three-month field trip in 2017, the first author conducted 187 household energy surveys within four villages in Shirati, Tanzania. The focus of the survey was to collect baseline energy information to understand the energy landscape within the villages. This included questions on the national grid, solar (for both lighting, cooking, etc.), kerosene and other fuels. The survey did not collect direct income information from households but did incorporate the Progress out of Poverty Index (PPI) to gauge the socio-economic status of households surveyed. The PPI is a ten question survey, customized for each country to gauge relative poverty (Schreiner, 2016). The index is constructed using indicators such as household size, the home's building materials and the presence of appliances, tables, animals and crops. We utilize this as a class index. In addition to these household surveys, we interviewed key informants regarding their solar use throughout the villages (solar sellers, medical directors, school headmasters, rural electrification representatives, mechanics, etc.).

Following a constant comparison method under the grounded theory approach, we concurrently collected and analyzed data (Corbin & Strauss, 1990). These surveys and interviews led to further questions regarding primary uses, productive uses and payment systems. The first author conducted additional fieldwork and exploration of this topic throughout June to August of 2018 and 2019. Over the summer and fall of 2021, we conducted an extensive set of interviews, focused explicitly on the role of gender and off-grid solar uptake. This resulted in 30 semi-structured interviews and 8 follow-up interviews with female respondents from both female and male headed households. Households were selected to be representative of socio-economic status, tribe and religion in each village based on local knowledge of the villages. Socio-economic status was gauged initially by the housing materials (roof, walls and floor), the size of the compound, motorbikes outside the home, and any visible appliances (panels on the roof, satellite dishes, etc.). However, throughout the interview, we did ask for monthly income. By the end of these interviews and follow-ups, we reached a point where further interviews did not yield additional insight. The field team and first author transcribed, translated and annotated the interviews in the weeks immediately following the interviews. All surveys were conducted by the first author and her experienced translator for quality assurance. All interviews were conducted by the experienced translator alone due to Covid-19; however, she has worked extensively with the first author for years. We are confident in the interview and contextual expertise of our field team. All follow-up interviews were conducted by the first author and her translator.

We coded interviews for emergent themes, and then grouped those themes into code families (Corbin & Strauss, 1990). Second, we re-analyzed all interviews to ensure replicability and the quality of our work. Finally, the data was further analyzed in Dedoose, an online qualitative data analysis software, for code co-occurrence and frequency. The key-stakeholder interview, participant observation and personal experience are not included in the formal analysis, but inform the surveys, interview questions and the discussion of the results.

7.6 Results

7.6.1 Study Area and Socio Demographic Characteristics

We conducted the household energy survey in four villages (Nyamagongo [$n = 40$], Michire [$n = 39$], Kabwana [$n = 43$], and Obwyere [$n = 44$]) within Shirati, Tanzania, in Rorya District, Mara Region, Tanzania. We also conducted 21 surveys with respondents from various villages which were further away, yet still within Shirati. Shirati is a rural town of roughly 50,000 people situated three kilometres from Lake Victoria and 16 kilometres from the Kenyan border. Characteristics of the survey respondents are summarized in Table 7.1. The average household size was 6.3 individuals, while the average respondent was 39 years old. We targeted main cooks as our primary respondents as in Tanzania main cooks are typically female. Additionally, main cooks were the most knowledgeable regarding the household's energy consumption as cooking is responsible for the majority of the household's survival energy needs. However, we do note the limitation of collecting household level information from individual female respondents; 80% of main cooks (the primary respondent) were female. Most main cooks interviewed were married and had only completed primary education. Most respondents obtained some income from agriculture or business. However, most households pursue farming in addition to their primary occupation as a supplemental income source. The average PPI was 50 across all surveyed respondents.

All four villages experience distinct dry and rainy seasons (light rains from October to December and heavy rain from March to June) within the tropical climate. The sociodemographic characteristics of survey respondents differed slightly by village.

Kabwana is the smaller of the two main trading centres in Shirati. Kabwana has roughly fifteen shops including salons, pharmacies, vegetable stands and multi-purpose shops selling household necessities. The main grid runs through the main road of Kabwana, where 33% of households rely on business ventures as their source of income given the proximity to the trading post. At 40%, Kabwana had a slightly

Table 7.1 Household demographic information

Panel A: Demographic	Overall ($N = 187$)	Kabwana ($n = 43$)	Michire ($n = 39$)	Nyamagongo ($n = 40$)	Obwyere ($n = 44$)	Various[3] ($n = 21$)
Household size (individuals) Mean (s.d.)	6.3 (3.6)	5.9 (2.6)	5.8 (3.5)	6.5 (3.2)	6.6 (4.8)	7.2 (3.2)
Age (years) mean (s.d.)	39 (16)	37 (16)	40 (18)	41 (16)	38 (16)	42 (13)
Female-headed household (%)	30	40	21	25	27	38
Female main cook (%)	80	91	64	73	82	90
Occupation (%)						
Cares for home and children (%)	17	21	26	15	16	0
Farmer (%)	31	23	38	35	14	62
Business (%)	31	33	21	28	45	24
Other (%)	21	23	15	22	25	14
Marital status (%)						
Single (%)	**12**	**23**	8	**10**	**11**	**4**
Married (%)	**65**	**54**	72	**68**	**68**	**63**
Divorced (%)	**1**	**0**	2	**0**	**2**	**0**
Widow (%)	**20**	**21**	18	**15**	**18**	**33**
Education level (%)						
No education (%)	10	15	15	5	**5**	5
Primary school (%)	62	51	62	63	**61**	86
Secondary school (%)	21	28	15	20	**27**	5
University (%)	7	6	8	12	**7**	4
Progress out of poverty score (Index: 0–100) mean (s.d.)	50 (13)	57 (12)	48 (13)	43 (13)	53 (13)	45 (12)

All percentages and indices rounded to whole number. A few respondents preferred not to answer, which may lead the percentages to not exactly sum to 100%

[3] We also conducted 21 surveys with respondents from various villages which were further away, yet still within Shirati.

higher percentage of female-headed households. Kabwana is also slightly wealthier with a PPI of 57.

The village of Obwere has the largest trading centre in Shirati. Women from most of the surrounding villages flock to Obwyere on Mondays for market day to buy food, clothing and miscellaneous items. Sellers travel from Tarime, which is roughly an hour's drive away. The main grid also runs along the main road in Obwere. In Obwere, there are nine shops where customers can purchase solar panels and solar lanterns. The solar lanterns are also available at most shops that sell drinks, bread, soap and miscellaneous items. The solar shops sell both branded and generic solar products; however, Sundar is the most trusted brand in Shirati. Solar sellers either order their products from Mwanza or Dar es Salaam, the two largest cities in Tanzania, or go there themselves to retrieve the products. Forty-five percent of households rely on business from the market for most of their income. Obwere is also slightly wealthier with a PPI of 53.

Nyamagongo is a village of approximately 580 households on the outskirts of Shirati. It is a 10-minute drive from Kabwana and 15 minutes from Obwere by car or motorcycle. There is no major trading post, and most families rely on farming for income. The most common crop grown is corn. Construction of the national electricity grid is in progress along the main road through this village. Of the respondents, 35% farmed for most of their income. Nyamagongo had a slightly higher percentage of respondents attending university (12%), but a lower percentage of female-headed households (25%). Nyamagongo also had the lowest PPI of 43.

Michire is a fishing village bordering Lake Victoria. There is one trading post with small shacks selling vegetables, sodas, paraffin and other small supplies. It is a 10-minute drive to Kabwana and 15 minutes to Obwyere. Most households rely on farming and fishing for income. The Rural Electrification Agency, REA, is working in conjunction with the national energy utility grid, Tanzania Electric Supply Company (TANESCO), to reach houses in Michire along the main road. It should be noted that grid connection prices mentioned for Michire assume that the house is along the main road and does not require any extension. In

Michire, 38% of households were farmers. Michire had the highest rate of marriage with 72% of respondents. Michire had the lowest percentage of female-headed households (21%) and a slightly lower PPI of 48.

7.6.2 Overall Energy Landscape: Electricity, Solar, Kerosene, Etc.

Common themes arose within each village and across villages in relation to the main grid, solar, kerosene, diesel, and other fuels; 23% of households were connected to TANESCO, the national grid, and paid 11,700 TSH (~$5 USD) per month through their mobile phones, 50 cents at a time. The grid electricity tariff operates on a prepaid system where customers cannot run arrears. None of the households were using electricity to cook. Most households used firewood and charcoal for their cooking needs, but LPG has a market and some users in Shirati. The wealthier, more developed areas of Kabwana and Obwyere had lower percentages of firewood and charcoal use and higher percentages of gas use. Although the gas users were still using firewood and charcoal.

Although 97% of households want to connect to TANESCO, there is a lack of knowledge of what it costs, when the construction of poles begins, and how to get connected. The monthly fee for TANESCO is not perceived as expensive, while having the wires and poles extended to the home is cost prohibitive. Overall, the surveys revealed that women value electricity for lighting first, followed by radio and television, but not cooking. No family was using solar or kerosene for cooking, only for lighting. Despite its use only for lighting, solar was praised for the lack of smoke associated with kerosene.

Of the various payment schemes for off-grid solar systems, the *lease-to-own* model is the most common in the study area with relatively short payment terms of 5–6 months. However, families felt that these payment plans of solar retailers were unjust. Women often asked, '[if] the energy is free, why do we keep having to pay every month?' This feeling of injustice may possibly explain the lower percentage of systems sold on payment schemes. Solar companies that offered payment schemes were generally disliked throughout the community. Respondents viewed these agreements as expensive and compared the aggregate price to the one-time cost of a panel at the shop in Obwere. We, therefore, further expanded upon the topic of payment schemes in the qualitative interviews.

The average solar system size from the 187 surveys was 68 Watts, while the average size from the 30 in-depth interviews was 60 Watts with sizes ranging from 5 to 250 Watts. From surveys: 9% of surveyed households had a solar panel, 36% had a solar lantern, 8% had both; 22% of households had TANESCO, and 18% of those with solar purchased it on a payment scheme. Most of the interview respondents did not know the size of their system. The Global Association of the Off-grid Solar Energy Industry (GOGLA) defines SHS as over 11 Watts per person (Wp) of solar (Tier 1 access) whereas solar systems below 3Wp were considered lanterns (Tier 0 access), and those between 3 and 11 Wp were considered multi-light systems (Angelou & Bhatia, 2015; GOGLA, 2019) (Tables 7.2 and 7.3).

We investigated the relationship between solar use, PPI and female-headed households utilizing ordinary least squares regressions while controlling for education, religion and other sociodemographic characteristics. Neither having a female-headed household nor PPI was correlated with the use of a solar panel. Solar use broken down by phone charging, radio or television was also not affected by gender or PPI level. However, this lack of a statistically significant relationship reveals that solar is not particularly improving the lives of lower-income or female-headed households. This result is in contrast with results from rural Ethiopia that found that female-headed households were more likely to adopt solar (Guta, 2018) and similar contrasts with results from Senegal found that single, divorced, or widowed women were less likely to adopt solar (Ulsrud, 2020). Our results seem to suggest there is equality in the adoption of solar across female-headed and lower-income households; however, this does not imply there is equity in the off-grid solar. Women or female-headed households may have equal access to men; however, given the current difference in standing, the off-grid solar market must strive towards equity rather than equality.

Given this backdrop of the energy and solar landscape in Shirati and the lack of correlation between class and gender with solar use, we turn to

Table 7.2 Solar and grid use

	Kabwana (n = 43) (%)	Nyamagongo (n = 40) (%)	Michire (n = 39) (%)	Obwyere (n = 44) (%)	Various (n = 21) (%)	Overall (n = 187) (%)
Solar panel	0	35	3	0	5	9
Solar lantern	42	30	36	32	32	36
Both solar panel and lantern	7	13	10	2	10	8
TANESCO	44	5	15	32	0	22
Payment scheme (of those with solar)	40	27	7	25	0	18
TANESCO (grid) and solar	16	5	0	7	5	7
Given that household has solar						
Solar for lighting	100	100	100	100	100	100
Solar for phone charging	4	32	15	30	25	21
Solar for radio	4	20	12	26	25	17
Solar for TV	4	20	12	19	42	17

Table 7.3 Comparison of solar and kerosene

	Kabwana (n = 43) (%)	Nyamagongo (n = 40) (%)	Michire (n = 39) (%)	Obwyere (n = 44) (%)	Various (n = 21) (%)	Overall (n = 187) (%)
			Mean [CI]			
% using neither	18 [7, 29]	15 [4, 26]	5 [0, 12]	18 [7, 29]	5 [0, 18]	13 [8, 18]
% using only solar	33 [19, 47]	38 [25, 53]	46 [30, 62]	50 [35, 65]	52 [22, 82]	43 [36, 50]
% using only kerosene	25 [12, 38]	23 [10, 36]	23 [10, 36]	20 [8, 32]	19 [0, 43]	22 [16, 28]
% using both	25 [12, 38]	25 [12, 38]	26 [12, 40]	13 [3, 23]	24 [0, 50]	23 [17, 29]

the 30 in-depth interviews conducted with women specifically regarding solar as their primary source of energy, as a source of income, and as a financial burden on their household. We intentionally selected 30 female respondents from households that already had solar systems and were representative of socio-economic status, tribe and religion in each village based on local knowledge of the villages. We intentionally excluded households with only a solar lantern because this wattage only constitutes Tier 0 of ESMAP's Multi-Tier Framework (Angelou & Bhatia, 2015) and does not meet IEA's definition of electricity access (IEA, 2020). Since the lowest income households in Shirati only have solar lanterns (as opposed to panels), the interviews, notably, do not include the lowest income percentiles. Of the 30 households, only four were female-headed, as Shirati is a traditionally patriarchal society, but this also may reflect that female-headed households cannot afford solar systems. Twenty-one women reported having inconsistent income sources, while the average annual household expenditure was ~$1140 US, slightly higher than the GDP per capita of ~$1090 US. When asked about her income, one woman responded, 'we have no consistent steady income, we just work and expect to get what is enough for a day'.

7.6.3 Low Quality Products

A common complaint that individuals would explain even before starting the official interview was their disappointment with the quality of their solar products. The owner of one of the largest solar shops explained that there were higher quality products in Mwanza and Dar es Salaam, but he does not order them because 'the people of Shirati are not used to very expensive products'. We were unable to track the percentage of generic versus branded products; however, the shop sellers noted that customers preferred the generic lanterns as they were 5000 TSH (~$2 USD) cheaper than the branded companies.

Multiple respondents had broken components on their solar systems. Others complained that the quality of their solar rapidly decreased over time, explaining that they use solar 'for lights, no longer to charge the phones as the battery is not good'. Another complained that 'the solar is not as good as it used to be in the only two years since we bought it. But now, we cannot watch our television'. The battery was the highest reported issue. A respondent explained, 'the solar battery tends to be poor, that's why the solar also tends to work for a short period of time'. This led respondents to have to purchase new batteries fairly frequently. A respondent complained that they had to buy a new solar battery every year, while another said, 'I have changed the battery every year for almost four years'. The poor quality of products even led one respondent to say, 'I think we had a fake one because as the days goes on it is reducing its functioning'.

The presence of lower quality products in Shirati was not only because there are very few wealthy families in Shirati, but also because of its remote, rural location. Solar shops complained of the additional cost to transport the more expensive products to Shirati, given the perception that they would not sell.

Kumar and Truner (2019) engage with postcolonial theories of ethics in order to better grapple with different kinds of social ruins solar waste may represent. They highlight the energy justice challenges of solar, not only during its usable lifetime, but as a waste product supporting their argument with examples from Nairobi, Kenya and Bihar, India (Kumar & Truner, 2019). The extremely short lifetime of solar panels and batteries found in Shirati is concerning from the perspective of the amount of potentially hazardous waste generated over a short period of time (Kumar & Turner, 2019). Cross and Murray (2018) also document this trend in Bomet, Kenya, calling for energy transitions to acknowledge mass consumption, the subsequent waste, and engage with the current repair economy that relies on local technician. In Shirati, households reported rarely going to a local technician to fix their solar, but rather opted to wait to purchase a new panel or battery.

7.6.4 Primary Use

A common theme throughout the semi-structured interviews was whether the solar system was the household's primary source for electricity or whether the system was used as a secondary, backup source.

The interviews revealed that solar was mainly used only as a backup for electricity grid outages throughout Shirati. Although SHS are intended to provide energy access to unelectrified populations, households in Africa also utilize SHS as a secondary source in the face of unreliable national grids (Lee et al., 2016; Ondraczek, 2013). It is common for homes to have 'stacked' systems in which the grid and SHS have parallel circuits throughout the home. The household can consistently use both systems together, using one as backup when the other fails. Blackouts are common there, occurring without warning multiple times a week, for hours on end. There are periods throughout the year in which the electricity goes off every other day, seemingly from morning until sundown. Typically, wealthier households utilize solar for this backup purpose as opposed to lower-income households who cannot afford grid access or live in remote areas the grid has not reached. Previous literature from Rwanda has also found that households seemingly take a step down the energy ladder—the assumed linear transition from traditional to modern energy and larger systems—in obtaining solar in addition to their grid electricity (Bisaga & Parikh, 2018). A study of heterogenous infrastructure in Gulu Town, Uganda found that individuals act as energy bricoleurs using multiple sources of energy to meet their needs (Munro, 2020). This also suggests an injustice in solar's ability to reach lower-income households, despite its prevalence throughout the Global South.

If solar is their primary source of electricity, households utilize solar for lighting, phone charging, watching television but rarely for ironing. Households that use solar as a backup use the national grid for these services but opt for solar during the frequent blackouts. A respondent explained that 'our solar rarely gets to be used during the day because most of the time we use electricity', while another said, 'we have solar as a replacement of electricity when electricity goes off'.

Households did not feel that they could rely only on solar either. A respondent whose primary electricity was solar explained that 'in the rainy season the solar system does not get charged enough. Therefore, sometimes we use our phones for lighting'. Previous literature confirms this finding that solar cannot compete with grid electricity (Cross & Neumark, 2021). Respondents explained that the quality of their solar systems decreased quickly over time, preventing multiple respondents from utilizing all their electric appliances.

Households using solar as their primary source of energy had an average annual expenditure of 948 USD per year, while households using solar as a backup source had an average annual expenditure of $1560 US per year. This suggests that solar is relatively affordable to those hovering around the average income, but equally plays a prominent role as a backup source for wealthy rural households. The survey results show that solar lanterns reach even the lowest income households, but as previously mentioned, a single lantern does not constitute any tier of energy access. Households with solar as a secondary source of energy had purchased a system that cost 74% of their monthly income, while those with solar as a primary source of energy owned systems worth 55% of their monthly income. This suggests that solar systems used as backup were larger or more extensive.

All female-headed households in our in-depth interviews utilized solar as a secondary source of energy. Our sample size for female-headed households is very small, which could suggest that solar is not accessible to female-headed households without the means to obtain electricity (and which are lower-income households). None of the major solar reporting agencies or databases record whether solar is a primary or secondary source. Overall, there is an absence of literature regarding whether gender affects household use of solar as a primary or secondary source which this research fills.

7.6.5 Equal Benefit

There was a common perception of equality regarding the solar system (Fig. 7.1). When asked about how different family members benefited differently from the solar, a respondent utilizing solar for light, phone charging, and watching television explained that ‘no one benefits the least because we all have the same kind of use’, while another woman said, ‘I don’t think I benefit more from solar than other members of my household because we are all using solar for the same reason’. Households equated equality in access and benefit from the solar system with the

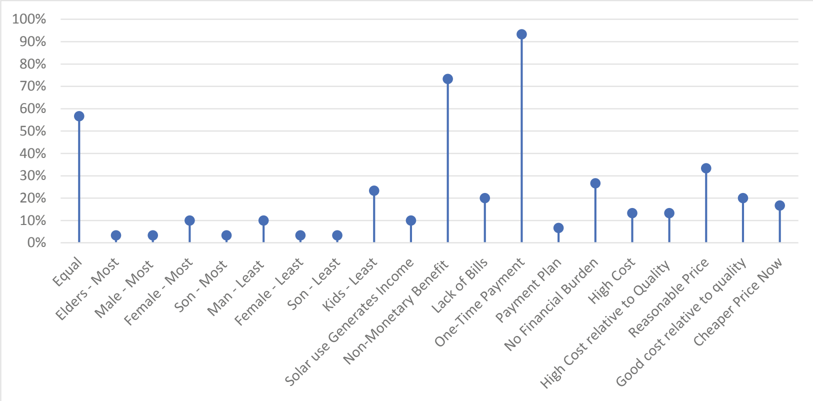

Fig. 7.1 Frequency of selected codes (*Note* Interviews were coded three times both by hand and in Dedoose. Values represent the percentage of respondents that were noted for the specific code. We organized our themes into groups regarding how the benefits from solar were distributed, depending on who the respondents felt benefited the most or the least, how the solar was used for productive uses [income and non-monetary benefits], and how the solar system was financed)

number of uses. In cases, when the woman felt that a household member benefited more or less than others it still corresponded to the number of uses. A woman who used solar to light three rooms in her home, to watch television and to charge her phone, explained 'my husband benefits the least because he normally leaves very early in the morning and returns late at night, so he does not watch TV and rarely charges his phone at home. It's only Sunday [when] you can find him at home'. However, another said, 'I think my husband benefits more than me because he watches television a lot more than any other person' and explained that her son benefited the least 'because he only uses solar to charge his phone, though not regularly as he does not stay much at home'. Other respondents described that 'the ones who benefit the least are the children because they do not have phones to charge'. The respondents who did report an inequality reflected on the amount of time each household member utilized each use of solar, while those who reported equality reflected only on the number of uses of solar available to each member. Although women reported benefiting equally from the solar system, no household reported having solar within the kitchen area, which has also been found in Kenya (Stojanovski et al., 2017). Previous studies have found inequity in electricity access through labelling household spaces and tracking the presence and use of electric appliances (Rosenberg et al., 2020). Households, even those with electricity and solar for backup, continue to have the typically female cooks hold a phone in their mouth as a flashlight as they cook family dinner. Therefore, a perception of equality may in practice not translate to true equality or the ideal of equity.

Claiming to know about the solar system was a ubiquitous theme, but then they also asked to know more. The female respondent would often go to ask her husband how much the system cost, and then return to the interview. This ambiguous result seemingly conflicts with our survey findings that reported confusion surrounding the payment schemes. Previous literature confirms that there is an injustice in the lack of information regarding solar energy (Simpson et al., 2021). We conducted the surveys and in-depth interviews in 2017 and 2021 respectively. This signals that although there has been an increase in the diffusion of information regarding solar within Shirati, it has not been sufficient to achieve full knowledge and confidence regarding the systems, particularly for women.

7.6.6 Solar Is Productive, but Rarely Generates Income

Respondents stressed the value derived from solar, regardless of whether it was a source of income. Respondents commented that their households greatly appreciated the lighting and phone charging from solar (Fig. 7.1). A respondent whose primary electricity is solar explained that 'We benefit from solar due to the fact that we do not stay in the dark at all, this solar helps us a lot through other needs like watching tv, as well as charging the phone and ironing are not possible but with the little that we have we are thankful. It's better than not having anything at all'. Another respondent using solar as a backup source of electricity noted, 'I definitely benefit from solar because with solar I can still have some activities done as usual [when the electricity is out]. For example, watching television, charging phones, as well as having lights, so with solar I benefit even if not monetarily'. Another secondary solar user said 'We are sure of having light. With Shirati, electricity tends to be a little bit disturbed sometimes. With solar we are sure of getting all the services we need'. Finally, a secondary user said, 'In case the electricity goes off I may not stay in the dark'. Additionally, a secondary user said, 'We benefit from solar because the kids are not bored since they can still watch television as usual when the electricity goes off'.

Only three of the 30 households interviewed utilized solar for income generating uses (Fig. 7.1). This included a household utilizing solar to run a barber shop and charge phones, a household running a small theatre from their living room for soccer games and movies, and finally a household only charging phones. All three respondents reported using the money obtained from these enterprises to purchase food and school fees for their children. None of the householding utilizing solar for income generation were female-headed households.

A respondent's husband started the barber shop two years ago in 2019 with only solar energy, and then in 2020, connected the shop to the national grid. The shop uses both their solar panels and the national grid because the respondent's spouse is afraid that the solar battery will die out if they do not use it for a long time. Therefore, the shop uses the grid to boil water and to power the fan, the television and the speaker inside the shop, while using solar for the haircutting and styling tools. The solar panels cannot power water boiling or large appliances. The shop has bulbs from both the solar panel and the national grid. The shop typically has 10 customers (both men and women) a day and each cut costs 1000 TSH (~$0.5 USD). The respondent explained 'Through solar he is sure to work throughout the day and may continue providing service to customers in case there is no electricity also because it's the work we depend on.' The respondent's husband has even hired another male barber but claimed to be unable to hire a woman. He claimed that women must be hired at the female salons.

Another respondent's spouse ran a movie theatre using a projector and a sheet. The theatre runs films one to two nights a week and charges

500 TSH (~$0.25 US) to attend. Attendance depends on the movie, but roughly 10–20 people come to each viewing. When there is a soccer game, 50–60 individuals huddle to watch.

Finally, a third respondent charges phones for a small fee. They charge 200 TSH (~$0.115 USD) for non-smart phones, and up to 400 TSH (~$0.25 USD) for smart phones. However, the respondent explained that she did not have that many customers, only when the grid electricity was out.

Some respondents, particularly those using solar only for light or those from lower-income households, were using neighbour's solar or grid electricity to charge their phones or even their batteries (if their panel was broken) for free. Other respondents were allowing their neighbours to charge phones free of charge. A respondent explained that '[the female neighbour] is just giving me help'. This revealed that some households had the opportunity to generate income from their solar but chose not to in order to help their neighbours. Charging neighbours' phones did not generate income, but built social capital. Additionally, it reveals that perhaps some productive uses of solar will not prove to generate income due to close community ties.

7.6.7 One-Time Cost and the Burden of Frequent Payments

The majority of the respondents reported purchasing the SHS through a one-time payment, rather than a payment plan. Four households had payment schemes to purchase their solar, but now own their systems. Only eight households mentioned that the solar system was a financial burden. The percentage of solar systems sold on payment schemes is notably low (Fig. 7.1).

Generally, respondents did not have favourable views of the payment plans, although these perceptions were not from personal experience. A respondent had heard about payment plans from a neighbour and said it was very expensive as you had to pay 2000 TSH (~$1 USD) every two days for an entire year. He then acknowledged that he'd rather pay for a less expensive solar, even if it was a one-time cost. A respondent who had purchased solar through a lease-to-own model from a solar company and paid 40,000 TSH (~$17 USD) per month for three months but did not see it as a financial burden as they now own the product and 'we did not pay for it for so long'. The financial burden was not associated with the total amount, but rather the length of time of the payment plan.

The low rate of respondents opting for payment plans could be due to the feeling of injustice surrounding the payment plans. It would also be due to the fact that low-income households cannot afford the SHS even with financial payment plans and the households purchasing the SHS can afford the SHS without the payment plans. This could also be due to households disliking frequent or lengthy payments, even if the individual payments are smaller.

An unforeseen benefit of the solar was that households did not have to continuously worry or account for a cost associated with solar after the initial purchase. Previous literature has documented the low, irregular, and inconsistent incomes of the poor (Collins et al., 2010) that plague households with constant worries about recurring bills (Mullainathan & Shafir, 2013). Households reported that their solar system did not pose a financial burden on their household because it was a one-time payment. A woman explained that 'we only paid for the solar once, so we had no financial burden'. Another respondent explained that 'paying little by little seems like a burden to us. I fear that I may not get the money'. This fear of debt or inability to make the payment is reinforced by Cross and Neumark (2021) who found the repossession of solar equipment to be an extremely shameful experience for the consumers.

In follow-up interviews, respondents explained that they preferred the one-time payment or paying at the store little by little because 'I might not have the money when I need it according to the agreement, so I would rather stay with the less expensive one that I can pay one time'. Additionally, households explained benefiting from solar because after that one-time payment 'there are no charges', while another noted benefiting from solar because she does not 'pay any bills for solar'.

One woman explained that 'I usually gets money once, so by the time I get money I just want to buy everything that is required, so when I got the money, I could not think of anything else, I just went to buy the solar'. A woman explained that 'sometimes [payment plans are] a burden, because sometimes I may fail to get that money, as sometimes we even fail to get food, so if I have money, I'll just use it. This reveals the difficulty households face to smooth irregular incomes, which small recurring payments require.

The interviews also revealed that some households that did not have incomes that came in large irregular increments were bringing money to shop owners in Obwere little by little until they reached the full amount for the panel, battery, bulbs and/or other appliances. A shop owner explained that if the customer pays any amount, he provides them a receipt for the solar and once they have paid the full amount, they can pick up their solar. In this arrangement, the customer does not have to sign an agreement with a solar company and can take as much time as they need to reach the full amount on their own schedule. Households still considered this a one-time payment. They viewed it as saving up for their solar through the shop.

Other households saved up for their solar at home through a lockbox, called a *kibubu*. In a follow-up interview, a woman explained that she saved for her solar at home because 'the family was not that much big, I could manage [the money]'; however, now, she saves through the shop (bringing the owner money little by little) because her family is larger, and if she saves the money at home, she may use it for something else.

This is an interesting finding as payment schedules are often touted as a way to alleviate the financial burdens of the poor. In theory, financial schemes break down high upfront costs into small payments, easing affordability and liquidity constraints that the poor face (Collins et al., 2010). These results however seem to suggest that the frequency of the small payments adds an additional burden onto low-income households. With a one-time payment for solar, households are freed from this seemingly endless financial struggle at least for one aspect of their needs. Even households who are, in essence, paying little by little just individually with the shopkeeper are free from an agreement that would burden their money management.

Some energy justice studies suggest that financial schemes are a path to increase just accessibility of solar energy to lower-income households (Boamah, 2020; Monyei et al., 2018; Winther et al., 2018). While other energy justice literature has questioned whether PAYG technology is actually affordable for the lowest-income households (Grimm et al., 2020; Muchunku et al., 2018) even if the upfront cost is parsed out over time. Other research from Benin has also found that PAYG companies target creditworthy customers and question PAYG's ability to reach 'last mile' consumers (Barry & Creti, 2020). This result is compounded by the fact that in Benin female-headed households were more likely to purchase PAYG solar (Barry & Creti, 2020).

We agree that payment plans can increase access, but this increased access should be balanced with the acknowledgement that a parallel injustice may be occurring in regard to the psychological burden. Lower-income households may not have 50 or 70% of their monthly expenditure readily available; payment schemes can alleviate this in equity of access but may increase the inequity in the overall burden of financing energy access.

7.6.8 Solar Home Systems Are Not Reaching the Lowest Incomes

Our interviews were with women from households who already have solar. However, the surveys and our ethnographic work revealed that the lowest incomes can only afford solar lanterns, not systems. Therefore, off-grid solar is still perpetuating an energy access gap between classes.

7.7 Discussion

Our case study reveals that the mediating effects of gender on the usage of a solar systems within a household are ambiguous. Simply obtaining a SHS fails to disproportionately benefit women. This level of energy access does not seem to be actively interwoven with gender empowerment. Our study shows that although solar does not seem to actively disadvantage women, their deployment is not a clear win for gender equality as was previously promised, however it is also not a clear violation of energy justice for women. Achieving equity from a capabilities approach would call for solar's benefits to be distributed according to individual circumstances, while a primary goods' approach to equity would lead to each individual obtaining the same level of electricity access from solar. Our case study reveals that solar may be achieving equality under a primary good's approach, but as Sen argues primary goods do not map to the same capability for every person (Sen, 1979, 1992). This is particularly salient in terms of gender. Even within the interviews, this distinction arose. Those that claimed equal distribution were primarily evaluating the distribution from a primary goods approach: how many uses, while those who recognized a difference in access focused on the time utilizing the use of solar and the capability achieved from that use. Fundamentally, SDG7 takes a primary goods approach in wanting to achieve a certain tier or basic bundle of electricity for each individual. However, this mandate ignores the different starting points across genders and the achievable capacity given those goods. Given these differentials between genders, equality or a primary goods approach to equity is not enough. The global community must prioritize marginalized genders and income groups within the off-grid solar market and electricity access.

A surprising result of our study was the role of solar for children. A critical mass of respondents noted their children benefiting the least. This was true in terms of appliance use or phone charging; however, the few households that obtained income through productive uses of their SHS used that income for school fees and additional food for their children. This reveals the potential disconnect between the perception and practice of equality or equity. Again, children may not receive the entire primary goods bundle, but may receive elevated capacity from their parent's solar use. Our results suggest that off-grid solar may yet be an avenue for energy justice for children for low-income households. Other energy justice research has investigated the adoption of off-grid solar by youth in Tanzania (Simpson et al., 2021), but further research should investigate the effects on grade school children.

Turning to the availability component of energy justice, we found that the highest quality solar products were not available in Shirati as the shop owners perceived the rural, lower-income community to not be able to afford these products. Additionally, the higher quality products were practically not available to the respondents who would have preferred a lower quality product than opt for a payment scheme. Poor quality products led respondents to limit their electricity uses and appliances, purchase new batteries frequently, or use a neighbour's panel to recharge their own battery. Therefore, there is an availability injustice as the off-grid solar market in Shirati fails to provide 'sufficient energy resources of high quality' (Sovacool et al., 2016: 5).

Half of the households utilized solar as a primary source of electricity. In our case study, off-grid solar is both for low–middle income households as well as a convenient backup source for middle- and higher-income Tanzanians. This is not inherently problematic; reliability and backup sources are very important for energy access resilience especially given the intermittency of the grid. However, the literature and solar community rarely acknowledge this secondary use in sub-Saharan Africa. The reality is that solar is used to both provide access to low-income households and provide reliability to higher income groups.

Including the affordability component of energy justice as well as the intragenerational, our results find that financial payment systems may be unjustly further burdening low-income households with frequent payments. Further research should investigate the psychological effects of financial payments, particularly in regard to off-grid solar. These results may only be applicable to the income levels that can currently afford solar. The psychological burden may be worth it to extremely low-income households to be able to afford the energy access; however, the literature should address and investigate this trade-off. Overall, our results suggest that the current market and distribution of off-grid solar is not a clear win for women or disadvantaged income groups.

Finally, we found a lack of income generating uses of solar, but a plethora of still productive uses. Despite the rise in interest in income generating uses from solar (Alstone et al., 2015; The World Bank, 2011a, 2011b), our results suggest that these uses for solar have not reached rural, low-income communities, and do not seem to be disproportionately helping women. Therefore, the solar community should target rural, low-income communities and women to own solar for income generation. Solar leading to more work hours for women is progress, but we must also work to close the ownership gap. Additionally, the prominence of women noting that they were benefiting from solar, even if not monetarily, suggests that we should prioritize solar regardless of whether it generates income. The off-grid solar community should focus on the services and value that solar energy adds to these households regardless of additional monetary benefit. Further efforts are needed to quantify the indirect productive uses of solar. Our results reveal that off-grid solar has benefits beyond income, but its reach is currently limited.

7.8 Conclusion: A Fraying Thread?

At the centre of this discussion lies a paradox: SHS are promoted to increase the quality of life and economic prospects for women, children and low-income groups, but solar systems beyond lanterns remain out of reach of the lowest income groups and women and children do not seem to benefit substantially more than men. Off-grid solar benefits users, although not always monetarily. Our case study does not find clear benefits specifically for women or low-income groups, suggesting that off-grid solar usage may be equal, and thus not perpetuating current injustices, but still not equitable.

The different modalities available to meet household electrification needs has received a great deal of attention; however, coupling the technology for electrification with socially appropriate, equal, or equitable access is an area where a great deal of work is needed by international financing and on-the-ground community partners. This case study provides a quantitative and qualitative view of the unrealized potential for sustainable energy systems to redefine and equitably meet the needs of under-served segments of society.

Further work in the field is needed to ensure that women and low-income groups are included and prioritized. Researchers and policymakers should differentiate and report impact data by both gender and income. Although energy access has the potential to enable a wide range of SDGs, for now, the justice gap remains. Energy access, or the golden thread tying together multiple SDGs, proves to be fraying without concerted efforts to ensure equity.

Acknowledgements This work was approved under Exempt Research under the University of Notre Dame's IRB Protocol ID: 17-02-3603. We thank the Sustainable Materials Program at Google, and the Zaffaroni, Karsten Family Foundations for their support, as well as the James and Katherine Lau Foundation for their support. AGW acknowledges Dr. Isha Ray for additional advising support.

References

Adwek, G., Boxiong, S., Ndolo, P. O., Siagi, Z. O., Chepsaigutt, C., Kemunto, C. M., et al. (2020). *The solar energy access in Kenya: A review focusing on Pay-As-You-Go solar home system. Environment, Development and Sustainability* (Vol. 22). Springer Netherlands. https://doi.org/10.1007/s10668-019-00372-x

Ahlborg, H., & Hammar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique—Grid-extension, off-grid, and renewable energy technologies. *Renewable Energy, 61*, 117–124. https://doi.org/10.1016/j.renene.2012.09.057

Ali, B. M. (2015). *Solar PV electricity's progress, pitfalls and potential* [Master's thesis, Norwegian University of Life Sciences].

Alstone, P., Gershenson, D., & Kammen, D. M. (2015). Decentralized energy systems for clean electricity access. *Nature Climate Change, 5*(4), 305–314. https://doi.org/10.1038/nclimate2512

Angelou, N., & Bhatia, M. (2015). *Beyond connections: Energy access redefined*. World Bank.

Arraiz, I., & Calero, C. (2015, May). *From candles to light: The impact of rural electrification* (Inter-American Development Bank Working Paper No. IDB-WP-599, p. 22). http://www.iadb.org

Asaduzzaman, M., Yunus, M., Haque, A. K. E., Azad, A. A. M., Neelormi, S., & Hossain, M. A. (2013). *Power from the Sun: An evaluation of institutional effectiveness and impact of solar home systems in Bangladesh* (pp. 1–123). http://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/Bangladesh_Idcol_Assessment.pdf

Azimoh, C., Klintenberg, P., Wallin, F., & Karlsson, B. (2015). Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa. *Applied Energy, 155*, 354–364.

Baker, S., DeVar, S., & Prakash, S. (2019). *The energy justice workbook*. Initiative for Energy Justice | iejusa.org, pp. 1–76.

Banerjee, S. G., Bhatia, M., Portale, E., Schers, J., Dorner, D., Azuela, G. E., et al. (2013). *Global tracking framework*: *Sustainable energy for all* (Vol. 3). The World Bank. http://documents.worldbank.org/curated/en/2013/05/17765643/global-tracking-framework-vol-3-3-main-report

Barrie, J., & Cruickshank, H. J. (2017). Shedding light on the last mile: A study on the diffusion of pay as you go solar home Systems in Central East Africa. *Energy Policy*, *107* (July 2016), 425–436.

Barry, M. S., & Creti, A. (2020). Pay-as-you-go contracts for electricity access: Bridging the 'last mile' gap? A case study in Benin. *Energy Economics, 90*, 104843. https://doi.org/10.1016/j.eneco.2020.104843

Baurzhan, S., & Jenkins, G. P. (2016). Off-grid solar PV: Is it an affordable or appropriate solution for rural electrification in Sub-Saharan African countries? *Renewable and Sustainable Energy Reviews, 60*, 1405–1418. https://doi.org/10.1016/J.RSER.2016.03.016

Bhattacharyya, S. C., & Palit, D. (2016). Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required? *Energy Policy, 94*, 166–178. https://doi.org/10.1016/j.enpol.2016.04.010

Bisaga, I., & Parikh, P. (2018). To climb or not to climb? Investigating energy use behaviour among Solar Home System adopters through energy ladder and social practice lens. *Energy Research and Social Science, 44* (June), 293–303. https://doi.org/10.1016/j.erss.2018.05.019

Bisaga, I., Puźniak-Holford, N., Grealish, A., Baker-Brian, C., & Parikh, P. (2017). Scalable off-grid energy services enabled by IoT: A case study of BBOXX SMART Solar. *Energy Policy, 109*, 199–207. https://doi.org/10.1016/j.enpol.2017.07.004

Boamah, F. (2019). Emerging low-carbon energy landscapes and energy innovation dilemmas in the Kenyan Periphery. *Annals of the American Association of Geographers, 110*, 145–165.

Boamah, F. (2020). Desirable or debatable? Putting Africa's decentralised solar energy futures in context. *Energy Research and Social Science*, *62* (December 2019), 101390. https://doi.org/10.1016/j.erss.2019.101390

Bose, S. (1993). Women, work, and household electrification in Rural India. In *Money, energy, and welfare* (pp. 143–181). Oxford University Press.

Bouckaert, S., Pales, A. F., McGlade, C., Remme, U., Wanner, B., Varro, L., et al. (2021). *Net zero by 2050: A roadmap for the global energy sector*. https://iea.blob.core.windows.net/assets/beceb956-0dcf-4d73-89fe-1310e3046d68/NetZeroby2050-ARoadmapfortheGlobalEnergySector_CORR.pdf
Casillas, C., & Kammen, D. (2010, November). The energy-poverty-climate nexus. *Science, 330*(6008), 1181–1182.
Castán Broto, V., Baptista, I., Kirshner, J., Smith, S., & Neves Alves, S. (2018). Energy justice and sustainability transitions in Mozambique. *Applied Energy, 228*(June), 645–655.
Chant, S. (2004). Dangerous equations? How female-headed Households became the poorest of the poor: Causes, consequences and cautions. *IDS Bulletin, 35*(4), 19–26.
Chowdhury, S. A., & Mourshed, M. (2016). Off-grid electrification with solar home systems: An appraisal of the quality of components. *Renewable Energy, 97*, 585–598.
Chua, P., Bhavnani, K. K., & Foran, J. (2000). Women, culture, development: A new paradigm for development studies? *Ethnic and Racial Studies, 23*(5), 820–841.
Collins, D., Morduch, J., Rutherford, S., & Ruthven, O. (2010). *Portfolios of the poor*. Princeton University Press.
Corbin, J., & Strauss, A. (1990) Grounded Theory Research: Procedures, Canons, and Evaluative Criteria.
Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. *Energy Research and Social Science, 44*(April), 100–109.
Cross, J., & Neumark, T. (2021). Solar power and its discontents: Critiquing off-grid infrastructures of inclusion in East Africa. *Development and Change, 52*(4), 902–926.
Davies, G. (2018). Clean energy product markets in sub-Saharan Africa: Complex market devices and power asymmetries. *Energy Research & Social Science, 42*, 80–89.
ESMAP. (2019). *Mini grids for half a billion people: Market outlook and handbook for decision makers*. https://openknowledge.worldbank.org/handle/10986/31926. Accessed 19 Oct 2020.
Fankhauser, S., & Tepic, S. (2007). Can poor consumers pay for energy and water? An affordability analysis for transition countries. *Energy Policy, 35*(2), 1038–1049.
Fathallah, J., & Pyakurel, P. (2020). Addressing gender in energy studies. *Energy Research & Social Science, 65*, 101461.

Ferrall, I., Callaway, D., & Kammen, D. (2022). Measuring the reliability of SDG 7: The reasons, timing, and fairness of outage distribution for household electricity access solutions. *Environmental Research Communications, 4*(5), 055001.
Fingleton-Smith, E. (2018). The lights are on but no (men) are home: The effect of traditional gender roles on perceptions of energy in Kenya. *Energy Research & Social Science, 40*, 211–219.
Furukawa, C. (2014). Do solar lamps help children study? Contrary evidence from a pilot study in Uganda. *Journal of Development Studies, 50*(2), 319–341. https://econpapers.repec.org/RePEc:taf:jdevst:v:50:y:2014:i:2:p:319-341
GOGLA. (2019, December). *Global off-grid solar market report semi-annual sales and impact data July–December 2019* (pp. 1–88).
Govindan, M., Palit, D., Murali, R., & Sankar, D. (2019). Gender in electricity policymaking in India, Nepal, and Kenya. In G. Bombaerts, K. Jenkins, Y. A. Sanusi, & W. Guoyu (Eds.), *Energy justice across borders* (pp. 111–136). Springer Open. https://doi.org/10.1007/978-3-030-24021-9
Grimm, M., Lenz, L., Peters, J., & Sievert, M. (2020). Demand for off-grid solar electricity: Experimental evidence from Rwanda. *Journal of the Association of Environmental and Resource Economists, 7*(3), 417–454. https://doi.org/10.1086/707384
Guta, D. D. (2018). Determinants of household adoption of solar energy technology in rural Ethiopia. *Journal of Cleaner Production, 204*, 193–204. https://doi.org/10.1016/j.jclepro.2018.09.016
Heffron, R., Stephan, H., & Jenkins, K. (2013). Advancing energy justice: The triumvirate of tenets. *International Energy Law Review, 32*(3), 107–110.
Hirmer, S., & Guthrie, P. (2017). The benefits of energy appliances in the off-grid energy sector based on seven off-grid initiatives in rural Uganda. *Renewable and Sustainable Energy Reviews, 79*, 924–934. https://doi.org/10.1016/j.rser.2017.05.152
IEA. (2020). Defining energy access: 2020 methodology. *IEA*. https://www.iea.org/articles/defining-energy-access-2020-methodology. Accessed 12 Oct 2021.
IEA (2021). *The energy progress report SDG7*. www.worldbank.org
IRENA. (2020). *Pay-as-you-go models* (pp. 1–22).
Jackson, C. (1996). Rescuing gender from the poverty trap. *World Development, 24*(3), 489–504. https://doi.org/10.1016/0305-750X(95)00150-B

Jacome, V., & Ray, I. (2018). The prepaid electric meter: Rights, relationships and reification in Unguja, Tanzania. *World Development, 105*(January), 262–272. https://doi.org/10.1016/j.worlddev.2018.01.007

Jaglin, S. (2019). Urban electricity systems in a time of 'solar revolution': Hybridisations and local technopolitical regime(s) in Western Cape (South Africa). In *RGS-IGB Annual International Conference*. Royal Geographical Society.

Jeuland, M., Fetter, T., Li, Y., Pattanayak, S., Usmani, F., Bluffstone, R., et al. (2021). Is energy the golden thread? A systematic review of the impacts of modern and traditional energy use in low-and middle-income countries. *Renewable and Sustainable Energy Reviews, 135*, 110406. https://doi.org/10.1016/j.rser.2020.110406

Kabeer, N. (1994). *Reversed realities: Gender hierarchies in development thought / Naila Kabeer*. Verso.

Khandker, S. R., Samad, H. A., Sadeque, Z. K. M., Asaduzzaman, M., Yunus, M., & Haque, A. K. E. (2014). *Surge in solar-powered homes: Experience in off-grid rural Bangladesh*. https://openknowledge.worldbank.org/bitstream/handle/10986/20427/913490PUB097810B00PUBLIC00100802014.pdf?sequence=1

Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009). Community-based electric micro-grids can contribute to rural development: Evidence from Kenya. *World Development*. https://doi.org/10.1016/j.worlddev.2008.11.005

Koepke, M., Monstadt, J., Pilo', F., & Otsuki, K. (2021). Rethinking energy transitions in Southern cities: Urban and infrastructural heterogeneity in Dar es Salaam. *Energy Research and Social Science, 74*(December 2020), 101937. https://doi.org/10.1016/j.erss.2021.101937

Kohlin, G., Sills, E. O., Pattanayak, S. K., & Wilfong, C. (2011). *Energy, gender and development: What are the linkages? Where is the Evidence?* The World Bank.

Kudo, Y., Shonchoy, A. S., & Takahashi, K. (2019). Short-term impacts of solar lanterns on child health: Experimental evidence from Bangladesh. *The Journal of Development Studies, 55*(11), 2329–2346. https://doi.org/10.1080/00220388.2018.1443207

Kumar, A., & Turner, B. (2019). Sociomaterial solar waste: Afterlives and lives after of small solar. In G. Bombaerts, K. Jenkins, Y. A. Sanusi, & W. Guoyu (Eds.), *Energy justice across borders* (pp. 155–176). Springer Open.

Kumaraswamy, S. K. (2021). Does PAYGo solar improve women's lives? A look at the evidence. *CGAP*. https://www.cgap.org/blog/does-paygo-solar-improve-womens-lives-look-evidence

Lee, K., Miguel, E., & Wolfram, C. (2016). Appliance ownership and aspirations among electric grid and home solar households in rural Kenya. *American Economic Review, 106*(5), 89–94. https://doi.org/10.1257/aer.p20161097

Lemaire, X. (2018). Solar home systems and solar lanterns in rural areas of the Global South: What impact? *Wires Energy and Environment, 7*(5), e301. https://doi.org/10.1002/wene.301

Listo, R. (2018). Gender myths in energy poverty literature: A critical discourse analysis. *Energy Research & Social Science, 38*, 9–18. https://doi.org/10.1016/j.erss.2018.01.010

Luo, C., Posen, I. D., & MacLean, H. L. (2021). Does location matter? Investigating the spatial and socio-economic drivers of residential energy use in Dar es Salaam. *Environmental Research Letters*, *16*(2). https://doi.org/10.1088/1748-9326/abd42e

Monyei, C. G., Adewumi, A. O., & Jenkins, K. E. H. (2018). Energy (in)justice in off-grid rural electrification policy: South Africa in focus. *Energy Research & Social Science, 44*, 152–171. https://doi.org/10.1016/J.ERSS.2018.05.002

Muchunku, C., Ulsrud, K., Palit, D., & Jonker-Klunne, W. (2018). Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? *Wires Energy and Environment, 7*(3), e282. https://doi.org/10.1002/wene.282

Mullainathan, S., & Shafir, E. (2013). *Scarcity: Why having too little means so much* (1st ed.). Times Books.

Munro, P. (2020). On, off, below and beyond the urban electrical grid the energy bricoleurs of Gulu Town. *Urban Geography, 41*(3), 428–447. https://doi.org/10.1080/02723638.2019.1698867

Munro, P., van der Horst, G., & Healy, S. (2017). Energy justice for all? Rethinking Sustainable Development Goal 7 through struggles over traditional energy practices in Sierra Leone. *Energy Policy*, *105*(November 2016), 635–641. https://doi.org/10.1016/j.enpol.2017.01.038

Ockwell, D., & Byrne, R. (2017). *Sustainable Energy for All: Innovation, technology and pro-poor green revolutions* (1st ed.). Routledge.

Ockwell, D., Byrne, R., Atela, J., Chengo, V., Onsongo, E., Todd, J. F., et al. (2021). Transforming access to clean energy technologies in the global south: Learning from lighting Africa in Kenya. *Energies, 14*(14), 1–24.

Ojong, N. (2020). *The everyday life of the poor in Cameroon: The role of social networks in meeting needs*. Routledge.
Ojong, N. (2021a). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.
Ojong, N. (2021b). Solar home systems in South Asia: Examining adoption, energy consumption, and social practices. *Sustainability, 13*(14), 7754.
Ondraczek, J. (2013). The sun rises in the east (of Africa): A comparison of the development and status of solar energy markets in Kenya and Tanzania. *Energy Policy, 56*, 407–417. https://doi.org/10.1016/j.enpol.2013.01.007
Otte, P. P., Tivana, L. D., Phinney, R., Bernardo, R., & Davidsson, H. (2018). The importance of gender roles and relations in rural agricultural technology development: A case study on solar fruit drying in Mozambique. *Gender, Technology and Development, 22*(1), 40–58. https://doi.org/10.1080/09718524.2018.1444442
Phillips, K. D. (2020). Prelude to a grid. *The Cambridge Journal of Anthropology, 38*(2), 71–87. https://doi.org/10.3167/cja.2020.380206
Power Africa. (2019, October). Off-grid solar market assessment. *US Agency of International Development (USAID)*, pp. 1–47.
Power for All. (2020, November). *Decentralized renewables: Empowering woman as sustainable energy leaders* (pp. 32–33).
Pueyo, A., Carreras, M., & Ngoo, G. (2020). Exploring the linkages between energy, gender, and enterprise: Evidence from Tanzania. *World Development, 128*, 104840. https://doi.org/10.1016/j.worlddev.2019.104840
Rawls, J. (1971). *A theory of justice*. Harvard University Press.
Rolffs, P., Ockwell, D., & Byrne, R. (2015). Beyond technology and finance: Pay-as-you-go sustainable energy access and theories of social change. *Environment and Planning A, 47*(12), 2609–2627. https://doi.org/10.1177/0308518X15615368
Rosenberg, M., Armanios, D. E., Aklin, M., & Jaramillo, P. (2020). Evidence of gender inequality in energy use from a mixed-methods study in India. *Nature Sustainability, 3*(2), 110–118. https://doi.org/10.1038/s41893-019-0447-3
Rysankova, D., Peters, K., & Sturm, R. (2020, March). *2020 Off-grid solar market trends report*. GOGLA. *International Finance Corporation 2020* (pp. 1–304). https://www.gogla.org/resources/2020-off-grid-solar-market-trends-report

Samarakoon, S. (2019). A justice and wellbeing centered framework for analysing energy poverty in the Global South. *Ecological Economics, 165,* 106385. https://doi.org/10.1016/j.ecolecon.2019.10638

Samarakoon, S. (2020). The troubled path to ending darkness: Energy injustice encounters in Malawi's off-grid solar market. *Energy Research and Social Science, 69*(February), 101712. https://doi.org/10.1016/j.erss.2020.101712

Samarakoon, S., Bartlett, A., & Munro, P. (2021). Somewhat original: Energy ethics in Malawi's off-grid solar market. *Environmental Sociology, 7*(3), 164–175. https://doi.org/10.1080/23251042.2021.1893428

Sangtin Writers Collective, & Nagar, R. (2006). *Playing with Fire: Feminist thought and activism through seven lives in India*. University of Minnesota Press.

Schreiner, M. (2016). *Tanzania 2011 Progress out of Poverty Index® (PPI®): Design Memo.* http://www.progressoutofpoverty.org/country/tanzaniahttp://www.microfinance.com/#Tanzania

Sen, A. (1979). Equality of what? *The Tanner Lecture on Human Values*, 36–44.https://doi.org/10.4135/9781446215272.n5

Sen, A. (1992). *Inequality reexamined*. Clarendon Press.

Sen, A. (1999). *Development as Freedom.* Random House.

Sharma, A. (2017, December). *Going greenfield with utility pay-as-you-go models*, 1–13.

Simpson, N. P., Rabenold, C. J., Sowman, M., & Shearing, C. D. (2021). Adoption rationales and effects of off-grid renewable energy access for African youth: A case study from Tanzania. *Renewable and Sustainable Energy Reviews*, *141*(April 2020), 110793. https://doi.org/10.1016/j.rser.2021.110793

Sovacool, B. K., Heffron, R. J., McCauley, D., & Goldthau, A. (2016). Energy decisions reframed as justice and ethical concerns. *Nature Energy*, *1*(May). https://doi.org/10.1038/nenergy.2016.24

Stojanovski, O., Thurber, M., & Wolak, F. (2017). Rural energy access through solar home systems: Use patterns and opportunities for improvement. *Energy for Sustainable Development, 37*, 33–50. https://doi.org/10.1016/j.esd.2016.11.003

Suri, T., & Jack, W. (2016). The long-run poverty and gender impacts of mobile money. *Science, 354*(6317), 1288–1292.

Svensson, J. (2010). Investigation of productive use by solar PVs in rural Tanzania. Chalmers University of Technology, 1–61. https://hdl.handle.net/20.500.12380/136685

Tanzania National Bureau of Statistics. (2018). *The 2017–2018 household budget survey-dataset*. Dar es Salaam.
The World Bank. (2011a). *Household cookstoves, environment, health, and climate change: A new look at an old problem. The international bank for reconstruction and development/The World Bank*.
The World Bank. (2011b). *One goal, Two paths: Achieving universal access to modern energy in East Asia and the Pacific*. https://doi.org/10.1596/978-0-8213-8837-2
Ulsrud, K. (2020). Access to electricity for all and the role of decentralized solar power in sub-Saharan Africa. *Norsk Geografisk Tidsskrift, 74*(1), 54–63. https://doi.org/10.1080/00291951.2020.1736145
van der Horst, D., Grant, R., Montero, A. M., & Garneviciene, A. (2021). Energy Justice and Social Acceptance of Renewable Energy Projects in the Global South. In S. Batel & D. Rudolph (Eds.), *A critical approach to the social acceptance of renewable energy infrastructures: Going beyond green growth and sustainability* (pp. 217–234). Springer International Publishing. https://doi.org/10.1007/978-3-030-73699-6_12
Wamukonya, N. (2007). Solar home system electrification as a viable technology option for Africa's development. *Energy Policy, 35*(1), 6–14. https://doi.org/10.1016/j.enpol.2005.08.019
Wheeldon, S., Ketelaars, S., de Dinechin, E., de Chorivit, G., Reynolds, O., & Laevens, C. (2019). Powering *Opportunity in East Africa proving off-grid solar is a power tool for change* (p. 76).
White, R. D. (2002). GEF/FAO workshop on productive uses of renewable energy: Experience, strategies, and project development. *Development*, *FAO Headqu*, 1–43. http://www.gefweb.org/ResultsandImpact/Experience_and_Lessons/GEF-FAO_productive_uses_workshop.pdf
Winther, T., Ulsrud, K., & Saini, A. (2018). Solar powered electricity access: Implications for women's empowerment in rural Kenya. *Energy Research and Social Science, 44*(March), 61–74. https://doi.org/10.1016/j.erss.2018.04.017
Yadav, P., Heynen, A. P., & Palit, D. (2019). Pay-as-you-go financing: A model for viable and widespread deployment of solar home systems in rural India. *Energy for Sustainable Development, 48*, 139–153. https://doi.org/10.1016/j.esd.2018.12.005

8

On-Grid and Off-Grid Electrification in Kenya: Who Are Left Behind and Why?

Kirsten Ulsrud and Anjali Saini

8.1 Introduction

'Leave no one behind' is a key ambition of the 2030 sustainable development goals[1] (SDGs), and in 2020 a report about SDG7 on sustainable energy for all was entitled 'The last decade to leave no one behind'. According to that report, about 620 million people would be unlikely

[1] https://unsdg.un.org/2030-agenda/universal-values.

K. Ulsrud (✉)
Solar Exchange & Cicero - Center for International Climate Research, Oslo, Norway
e-mail: kirsten.solarexchange@outlook.com

A. Saini
Seacrester Consulting, Nairobi, Kenya

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_8

to have access to electricity by 2030, and the majority of these would reside in sub-Saharan Africa.

Thus, despite a great deal of progress in electrification, both through on-grid and off-grid solutions, many social groups remain excluded. In this chapter we show some of the reasons why these groups have little chance to benefit from current strategies of governments, donors, private sector actors, and NGOs (IEA, 2019, 2020, 2021). In addition to those who are not included in any kind of electricity provision, those who are included are often affected by the lack of operational and economic sustainability of grid and off-grid solutions, and they are often constrained from using electricity for purposes beyond basic electricity services.

Through the case of Kenya, we show why there is need for reconsideration of the ideology and approaches to electricity provision in sub-Saharan Africa, based on the lessons learned during the last decades. Kenya is a relevant country due to its high achievements in both grid and off-grid electrification and due to the wide range of strategies and delivery models for off-grid solar PV that have been tested and implemented. Even here, significant portions of rural communities are likely to remain left behind without access to any source of electricity of acceptable quality and lighting lumen levels for many years to come.

Although off-grid solar technologies are central in this chapter, we also bring in grid electrification for several reasons. First, we see a blurring of lines: off-grid solutions also being used in on-grid areas as we explain later on. Second, although off-grid solutions have so far been treated as far less important than grid electrification, rural electrification strategies in Kenya are now taking into account their applicability in contexts where it is seen as inefficient and too costly for grid extensions.

Using an energy justice framework, we give a nuanced picture of who has access to electricity in Kenya, what kind of access they have, who is left behind and why. We discuss the central issue of affordability, people's constraints, and common situations of poverty and vulnerability. We further discuss how current electrification strategies of different kinds of actors work to address the challenges. We present unpublished and published findings from our own case studies, other research on electrification in Kenya and statistical information.

An important theme in our analysis is the role of private sector solutions in off-grid areas. We discuss the current expectations for commercial operation of off-grid electricity provision, and look at the issue from different actors' perspectives, including the private and public sectors and multinational organizations. We discuss the pros and cons of this dominant expectation for private sector-led solutions to serve off-grid populations, the role of the state and the possibility to imagine different and complementary strategies. We emphasize the potential for more open ended, diverse and creative socio-technical innovation on off-grid access models, less limited by market thinking, but still with the private sector companies' important contributions, and with much stronger emphasis on access for all as well as long-term operational and economic sustainability.

8.2 Research Methods

This chapter draws on three research projects, long-term interaction with stakeholders in on-grid and off-grid electrification in Kenya, and long-term observation of specific off-grid solar initiatives, in addition to energy statistics. The three research projects were entitled Solar Transitions, Solar xChange and EFEWEE. The first and second were funded by Research Council of Norway, and the third was funded by DFID through the Energia programme. All three were led from the University of Oslo, Norway. The purpose of the Solar Transitions and Solar xChange projects was to understand a range of aspects that influence the functioning and scalability of village scale solar PV delivery models including mini-grids. These aspects ranged from usability and affordability of the delivery models to the wider socio-technical systems and contextual factors at multiple levels. The purpose of the EFEWEE project was to investigate factors that influence empowerment of women through access to electricity. The project gave insight into challenges of electricity access seen from different actors perspective, and dynamics between grid and off-grid electricity provision.

The published findings from these three research projects will be referred to where relevant, and additional findings will be presented.

The details of the data collection can be found elsewhere (Ulsrud, 2015; Ulsrud et al., 2015, 2017, 2018, 2019; University of Oslo et al. 2019; Winther et al. 2018). This study is based on in-depth interviews, focus group discussions, observation and action research. These were complemented by household surveys. Kitui and HomaBay Counties are the main geographical settings for the research, while some data has also been collected in Turkana.

Villages for data collection were selected based on the presence of on-grid and off-grid electricity provision to obtain variety. There was also variation in livelihood opportunities and vulnerability to drought and crop failure, as well as remoteness. Household participants were selected with the aim of obtaining variation in their characteristics such as gender, age, type of electricity access, lack of access, wealth level and distance from village centres. The selected villages in Homa Bay were God Bura, Kiwa Island, God Liech and Ligongo (Gwassi location). In Kitui County, Ikisaya, Ndovoini, Malalani (Malalani location) and Endau, Kalungu and Kaunange (Endau location) received the most attention, while a handful of other villages around the Endau Hill were also involved.

Data were collected from 2009 onwards, and consisted of 128 semi-structured interviews and 15 focus group discussions with households, businesses and public employees in villages, the surveys which had 70, 1100, 18 and 207 participants, 58 qualitative interviews and meetings with actors at district, county, national and international levels (public, private, NGOs and development partners). In a cluster of villages in Kitui county, an action research project was carried out during more than 25 visits between 2009 and 2018. The research groups were interdisciplinary with various social scientists and energy practitioners (including several engineers) from Europe, Africa and Asia.

We give additional details on methods in the different parts of the chapter where we present the findings. The chapter also draws on statistics from Kenya's 2019 national census data[2]; the World Bank's global electrification database (access to electricity)[3]; sales data from the Global

[2] https://www.knbs.or.ke/.

[3] https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

Off Grid Lighting Association (GOGLA) solar market reports,[4] and Kenya's Integrated Household Budget Survey of 2015/2016.[5]

8.3 A Brief Socio-Technical History of Off-Grid Solar PV in Kenya

Kenya is in many ways a successful country in off-grid solar power. Since pioneering efforts in the 1980s, an increasingly diverse and dynamic field has developed due to the efforts of a range of different actors over the last four decades (Ockwell & Byrne, 2017; Ondraczek, 2013). Solar home systems, solar lanterns and other small lighting systems, solar and hybrid mini-grids, standalone solar PV systems at public facilities (health clinics, schools, district offices), solar water pumps, and other kinds of off-grid solar PV systems have been installed and used. Energy Centres, charging systems, solar agents and rental of portable lamps have also been explored (Muchunku et al., 2018; Ulsrud et al., 2018). There has been a diversity of arrangements for planning, implementation, financing, payment, operation and maintenance. For each type of solar PV system, gradually evolving business models or other delivery models have been created through learning by doing by the driving actors. Incremental, continuous innovation of many different kinds has clearly been crucial. In addition, the government has installed utility scale solar power in their isolated power grids based on pioneering initiatives by individuals within the government a decade ago (Ulsrud et al., 2017).

It is the details of off-grid solar electricity models that determine how they work in practice in the long run, how well they fit with people's energy needs, people's ability to pay, and daily routines, and other aspects of life in a particular social, cultural and geographical context (Bastholm & Henning, 2014; Muchunku et al., 2018; Ulsrud et al., 2018). Such details, many of which are related to social inclusion, have been in focus for the efforts of a diversity of actors in and

[4] https://www.gogla.org/publications.

[5] https://www.knbs.or.ke/publications/.

beyond Kenya, spanning from small and large private sector companies, government departments in the energy sector, NGOs, consultancy companies, research organizations, and industry bodies (e.g., the Kenya Renewable Energy Association, KEREA) to development partners (e.g., GIZ, DFID/FCDO, DANIDA) and large and small development banks such as the World Bank and NDF, as well as financing programmes like AECF, EEP, the European Research Council, and the Norwegian Research Council's programmes including Norglobal (Brix Pedersen & Nygaard, 2018; Ockwell & Byrne, 2017; Ulsrud et al., 2017). Much has gone wrong in the course of trying, failing and learning on previously un-tested activities, some of them appearing as having taken place ahead of their time, such as early attempts to find technical solutions for payment control, which have later matured. The activities have also demonstrated many of the challenges of providing useful energy services to the low-income majority.

This long-term, creative and fruitful process and learning through both success and failure includes incremental innovation in business models, creation of training courses and licensing procedures for solar technicians, inclusion of off-grid solar PV and other renewable energy in legislation and regulation, and other important institutional innovation. The process also includes comprehensive learning from the users' experiences, users innovation, preferences and disappointments, and from various attempts to improve affordability for users (Muchunku et al., 2018; Ockwell & Byrne, 2017; Ulsrud et al., 2018). While mature innovation in the global manufacturing industry has substantially brought down prices and improved the technology and ease of installation, actors based in Kenya have contributed in important ways to establish new ways for people to pay for the systems incrementally over time hence, access and affordability has improved.

This comprehensive stream of efforts and their intended and unintended effects and interactions can be seen as a long-term process of socio-technical 'system-building' in Kenya, where processes at multiple scales interact, including sub-national, national and international scales (Brix Pedersen & Nygaard, 2018; Ockwell & Byrne, 2017; Phillips & Newell & Phillips, 2016; Sareen & Haarstad, 2021; Ulsrud et al., 2017). Such 'system-innovation' is an incremental and relatively slow process that potentially takes the emerging technologies and socio-technical systems from being something unconventional and unfamiliar in a society towards a more normalized, refined and trusted kind of technology that is increasingly integrated and embedded in society. This includes the adaptation of technologies to the sociocultural context in a given geographical area (Ulsrud et al., 2015).

Institutional innovation, or institutionalization including regulation and legislation, is a crucial part of the process, and one of the slowest and most difficult parts (Brix Pedersen & Nygaard, 2018; Ulsrud, 2020). This kind of process is necessary for a gradual normalization of a technology, according to theories on technological change; transitions; and systemic change in energy systems (Fuenfschilling & Truffer, 2014).

In Kenya, solar PV technology, including off-grid models, have become gradually more normalized through the process briefly described above. It is far from mainstream, however, but there is a growing interest in the technology among actors who usually focus on conventional solutions for electricity supply and access (the actors representing the more established energy regime).

In the Kenya National Electrification Strategy (KNES) the Government of Kenya recognizes solar home systems as a cost-effective electrification strategy for households that do not fall within the immediate scope of grid densification and intensification, grid extension or mini-grid development plans (KNES, 2018).[6] That is, households that will not expect to see any form of grid or mini-grid connection within the next three years.

Given all this progress, could it just be a question of time before every household that needs electricity access is reached and before off-grid solutions receive the same level of attention and resources as the centralized mainstream electrification? To answer this question, we turn to concepts of energy justice.

[6] Grid densification is defined as installing additional transformers on existing Kenya Power medium voltage feeders and laterals to connect housing clusters within 600 m of existing Kenya Power distribution transformers. Grid intensification is defined as installing additional transformers to reach housing clusters more than 600 m from existing transformers. These are housing clusters that can be reached by new transformers along existing lines as well as by extending short (up to 2 km) and medium voltage lines.

8.4 An Energy Justice View of On-Grid and Off-Grid Solar Electrification in Kenya

Energy justice theories are research frameworks used to highlight issues of fairness and justice in access to energy and are useful in considering how energy systems could be made more inclusive and equitable (McCauley et al., 2019). They have been increasingly used in relation to studies on socio-technical change at different levels of analysis, such as transitions in energy systems at the national level, and the concept of 'just transitions' has become prominent (Lacey-Barnacle & Bird, 2018).

Although our interdisciplinary and trans-disciplinary field research over the past decade did not explicitly use energy justice frameworks or concepts, we find it useful to apply these retrospectively to analyse our findings through a set of new and different lenses. We use the three aspects of energy justice most applied—distributional, recognition and procedural justice—to understand issues of social inclusion at local, county and national levels in Kenya.

Distributional justice means the fair distribution of energy infrastructure and services. In addition to fairness in the allocation and access to energy, the concept also includes a consideration of fair distribution in the impacts of the energy provision (Jenkins et al., 2018).

Recognition justice means that various social groups and their needs in relation to energy supply are recognized, and that there are concerns for how stigmatization, disrespect or 'othering' of marginalized or deprived groups may influence or lead to misrecognition (Lacey-Barnacle & Bird, 2018).

Procedural justice means justice in the mechanisms through which decision-making about energy occurs (Jenkins et al., 2018), including gender equality. In order to achieve procedural justice (and thus avoid unfair processes or procedural inequalities), there should be 'cross-cutting participation' of marginalized groups and concerns of who is included or not.

When analyzing energy justice, it is important to look for injustice, unsustainability and lack of democracy (Jenkins et al., 2018) and, in turn, their causes. Research on energy justice can also be seen as a political struggle to fight injustice (Jenkins et al., 2018). Moreover, energy justice frameworks could be used to strengthen policy planning, the implementation or management of energy solutions and for citizens to advocate for their rights to energy access. In the following sections, we identify a range of aspects within distributional, recognition and procedural justice in on-grid and off-grid electrification in Kenya.

8.5 Distributional Justice in Access to Electricity in Kenya

First, we discuss distributional justice in access to conventional electricity provision through centralized grid supply, which is important and provides electricity to large numbers of people in the Kenyan society. Thereafter, we discuss distributional justice in access to off-grid solar PV electricity, which is becoming increasingly important, meets some of the shortcomings of the grid-based system, and undoubtedly has a large potential for the future. When analyzing who is left behind in access to electricity, it is necessary to understand the opportunities as well as shortcomings of both kinds of energy systems and their combinations and interactions. The two kinds of systems are extremely different, but also very complementary.

8.5.1 Grid Connectivity in Kenya—Looking Behind the Numbers

Kenya Power states that the 'country has recorded one of the fastest connectivity rates in the world […] with over 70% of Kenyan households having access to electricity' and 8.4 million connected customers in villages, towns and cities across the country (Kenya Power, 2021). Large efforts have been put into grid extension to new areas, huge investments have been made, and large loans taken up.

There are a number of data sources indicating national electrification rates in Kenya. The World Bank global electrification database indicator is *access to electricity (percentage of population with access to electricity according to data from national surveys, industry and international sources*[7]*)* and in 2019 this national rate was 69.7%, with average rate of 90.8% in urban areas and 61.694% in rural areas.[8] The most recent census data (2019) counts just over 12 million households in the country, with an average of 3.9 people per household and a population of 46.8 million. Whilst the census data does not specifically state an electrification rate, a reasonable proxy may be used as a considering indicator of households that *use* grid electricity for lighting, which, according to the data, is 50.4% of all households nationally (26.3% in rural areas; 88.4% in urban areas (KNBS, 2019).

Thus, there are discrepancies between what is considered access to grid electricity, measured through grid connection rates on the one hand, and the grid electricity consumption rates on the other. When compared to our field observation and findings, even more discrepancies arise, and explanations appear. Not all households with a connection to the grid are using electricity, for different reasons, including poorly functioning or completely non-functioning supply (Lee et al., 2016; Winther et al., 2018; fieldwork data from Kitui and Homa Bay). Inability to pay regularly is another barrier for people's actual access to electricity. Recent media reports indicate that the average monthly consumption of rural households connected to the grid is 6kWh; that is, less than $1 US per month, or just 3.34 Kenyan shillings (KES) per day, indicating that rural homes are using electricity primarily for lighting and phone charging and not other household electrical appliances, 'revealing the low living standards among a majority of Kenyan households' (Alushula, 2021). Further, the 2021 Kenya Power annual report notes a significant number of 'non-vending' pre-paid meters, which means that the households where these meters are placed do not use electricity at all

[7] https://databank.worldbank.org/metadataglossary/world-development-indicators/series/EG.ELC.ACCS.ZS.

[8] Ibid.

despite having a grid connection (Kenya Power, 2021). A connection is not enough.

The high national connection rate to the grid is somehow surprising when compared to observations/research results on the ground, although the relatively low rural connection rate makes the picture more understandable. A common sight when travelling in eastern and western Kenya is that many unconnected homes can be observed near the gridlines. What such random observations at least indicate is that there must be large geographical variations in access between different areas where the grid is present. Moreover, our data from Kitui county in Eastern Kenya and Homa Bay county in western Kenya show that the rate in local areas with a grid can be very low, as further described in Sect. 8.5.2.

8.5.2 Off-Grid Solar Electricity in Kenya: Beyond Sales Data

The number of people with access to electricity from off-grid solar (including lighting of acceptable lumen levels) is also uncertain.

Supply data is one source of information. Companies that are signed up (as 'affiliates') to the Global Off Grid Lighting Association (GOGLA), report their semi-annual sales figures to the association, which then aggregates and publishes the data in a series of industry reports. It is a reasonable proxy for estimating electricity access (total sales of quality verified products), but does not account for the supply of systems by companies who are not signed up ('non-affiliates', quality unknown, much less data available) to the GOGLA reporting mechanisms. For Kenya, the estimated market share of non-affiliates is a significant 46% (GOGLA, 2020).

In its most recent country brief for Kenya, GOGLA estimates 6.38 million people across the country access Tier 1 energy services and 1.1 million people access Tier 2 energy services (GOGLA, 2019a, 2019b). These are impact indicators built using cumulative sales data from 2016 onwards (see Fig. 8.1) and methodologies that have evolved over time that make assumptions about household sizes and other significant parameters.

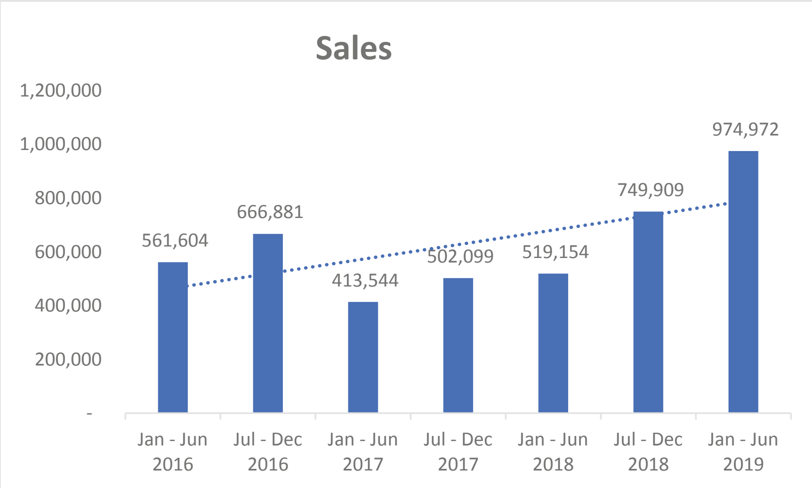

Fig. 8.1 Sales of portable lanterns, multi-light systems and solar home systems (*Source Authors' computation based on data from* GOGLA, 2019a)

Table 8.1 GOGLA sales data (GOGLA, 2019b, 2021)

Solar system size (Wp)	Jan–June 2019 sales ('000s)	Jan–June 2019 % of total sales	Jan–June 2021 sales ('000s)	Jan–June 2021 % of total sales
0–1.5	385	39.49	738	37.01
1.5–3	259	26.56	555	27.83
3–10	153	15.69	429	21.51
11–20	30	3.08	94	4.71
21–49	114	11.69	109	5.42
50–100	33	3.38	62	3.11
100+	1	0.10	8	0.40

Table 8.1 shows the GOGLA Jan–June 2021 sales data disaggregated into sales data for the different sizes of solar system, contrasted with Jan–June 2019 data. The data illustrates that approximately 65% of sales by GOGLA affiliates in the market are for systems that are less than 3Wp; and over 80% of all sales are for systems less than 10Wp. There has been significant growth in the 3–10Wp segment, which could be attributed to various subsidy programmes that target this particular system size.

It must not be forgotten, however, that sales figures do not give a realistic picture of how many people actually have access to electricity from such systems at a given point in time. The numbers do not tell how many of the systems are currently in use, and available research indicates that many of them are most likely not functioning any longer after a few years (Cross & Murray, 2018; Muchunku et al., 2018). This is due to such factors as lacking access to repair and maintenance services and difficulties in obtaining spare parts, including replacement batteries. In fact, many of the newer solar kits are not made for battery replacement at all. For the most common types of systems, a typical battery life seems to be 2–3 years, and a common warranty period for pay-as-you-go (PAYGO) systems is the duration of the PAYGO period, around 12 months, but ranging from 2 to 6 months for smaller systems. Saving money for battery replacement is also a challenge for the users. However, the rapid growth of solar PV purchase shows the increasing popularity of the technology.

Kenya's national census data includes a data set on the use of solar electricity for lighting which can give a more realistic picture. The data does not consider solar exclusively, however, since a household is able to state multiple sources of lighting such as grid electricity, solar lighting, torches, kerosene lamps, etc. It is also not possible from the data to say what kind of solar system a household has or what quantity, neither is it possible to say whether solar is the predominant source used. Of just over 12 million households, 19.3% on average state they use solar lighting; 29.9% in rural areas and 2.4% in urban areas (KNBS, 2019). This would imply nationally approximately 2.3 million households (~9 million people[9]) with a source of solar electricity for lighting and 2.2 million (~8.5 million people) of these households situated in rural areas. The differences between the GOGLA estimates and the census data have several explanations ranging from different time periods or different interpretations (e.g., as mentioned before, having a solar home system versus the actual functionality of the system) through to the biasing effect of the GOGLA non-affiliate sales.

[9] Based on an average household size of 3.9 people (KNBS, 2019).

8.5.3 Overlap Between On-Grid and Off-Grid Electricity Access

When analyzing access to electricity from on-grid and off-grid systems it is also necessary to keep in mind that the people with off-grid solar electricity are not necessarily additional to those with a grid connection. The on-grid and off-grid systems are to some extent overlapping because some of those who use solar power are also connected to the grid and use solar as a back-up when there are power cuts in the grid supply, and at other times for suitable purposes. According to our research in Homa Bay county by Lake Victoria in 2017, the few households with a grid connection mostly also owned a solar home system.

The majority of off-grid solar systems in our different study areas, however, were used by households and other kinds of users without a grid connection. But to say something certain about how many households/people in Kenya who have access to grid or off-grid electricity or both, and how many households that do not have access to any of these options is very difficult.

A surprising finding in the villages studied in Homa Bay County is that there was a much larger number of off-grid solar PV systems than grid connections in the villages where the grid was present. In addition, the density of off-grid systems was higher in grid-connected villages than in purely off-grid areas. A likely explanation based on our interviews is that villages outside the selected routes for grid installations are smaller villages with less diverse income opportunities, so that fewer people can afford to use solar. Fewer solar companies also visit such places, it seems.

In another of our study areas, Kitui county, even fewer people used the grid in places where it was present, and this is not surprising, because the settlement pattern is even more dispersed here than in the Homa Bay villages. A transformer in the market area of a typical village here might reach a handful of shops and homes, while hundreds of homes are too far from the transformer and too dispersed to justify the installation of additional transformers and branching of the gridlines along their route towards the next village.

8.5.4 Significant Differences Within Communities—Distributional Justice at the Local Level

An issue of energy justice that our own research has shed light on is the importance of understanding the local differences in people's chances to get access to electricity and use it in beneficial ways. The ability to get access to on- and off-grid solutions tends to differ greatly between different people/households in one and the same community (Muchunku et al., 2018; Ulsrud, 2015, 2020; Winther et al., 2018). One can therefore claim that distribution of energy infrastructure and services is not fair and that distributional justice is thereby lacking at the local level.

This kind of understanding or focus is a consequence of our research on mini-grids, energy centres and similar village scale off-grid systems, where the goal of reaching as many people as possible in each village or rural location is usually very important. With household level solutions, this is much less highlighted by suppliers as well as by researchers. But a focus on each village/place/community is crucial in order to understand who is left behind and why. In other words, village-level research with data collection at the household level is necessary. We will come back to this in the section on recognition justice.

8.6 Recognition Justice

Various research on energy access, energy poverty, and on- and off-grid electrification has identified many ways in which social differentiation affect people's chances to use electricity. It shows how different social groups must be recognized in the work to provide electricity to the population, such as people living in different geographical areas or in specific kinds of settlements, people of different genders, people with different livelihoods and income patterns, and people living at different distances from main roads, markets or other central areas (Muchunku et al., 2018; Ojong, 2021a, 2021b; Ulsrud, 2015; Winther et al., 2018).

8.6.1 Recognition of 'Underserved' Geographical Areas

The government of Kenya and its development partners express recognition of people in different geographical areas (which might be called 'geographical recognition') by acknowledging a group of counties in Kenya with much lower rates of access to electricity than the rest of the country. They also recognize that access in these counties must be provided with different solutions than the standard ones. They have defined a group of 14 counties (out of Kenya's 47 counties) as 'underserved' when it comes to electricity access and other public services such as roads and water. These are Turkana, Mandera, Garissa, Tana River, West Pokot, Marsabit, Samburu, Isiolo, Wajir, Lamu, Kilifi, Kwale, Taita-Taveta and Narok. They constitute 72% of Kenya's land area and 20% of the people.[10]

The Government of Kenya has initiated a large project on off-grid solar electricity in these 14 counties in cooperation with World Bank. This is the Kenya Off-grid Solar Access Project (K-OSAP) for undeserved counties, which works on creating off-grid solar electricity to households, enterprises and community facilities. In total, 1100 community facilities including health, education and public administration facilities will be electrified with solar, and get solar water pumps installed.[11]

8.6.2 Recognition of the 'Underserved' People also Outside the 'Underserved' Counties

The underserved counties identified and targeted by the Government of Kenya's KOSAP programme are the poorest counties in the country, and it is commendable that the KOSAP programme is attempting to address the electrification challenges in those counties.

However, recognition justice also allows a further nuancing and recognition that whilst areas may be considered as 'served' by the presence of

[10] https://kosap-fm.or.ke/.

[11] https://kosap-fm.or.ke/.

the grid (or by mini-grids; or the presence of solar home systems companies) levels of poverty mean that underserved populations exist right across the country. In terms of absolute numbers, the 2015/2016 Kenya Integrated Household Budget Survey (KIHBS) shows high numbers of overall poor people in, for example, areas such as Nairobi City and Nakuru Counties, even if the numbers only form a small percentage of the total populations in those wealthier counties (KNBS, 2018).

Table 8.2 illustrates this point, with estimates of the number of poor people nationally; in our study counties of Kitui and Homa Bay; and in Nairobi and Nakuru for contrast.

In the definitions of poverty used by the KIHBS, 'overall poverty' considers households total consumption expenditure of less than Kshs 3252 in rural and peri-urban areas, and less than Kshs 5995 in urban areas (KNBS, 2018). Consumption expenditures are defined through 'food' and 'non-food' components, with the non-food components consisting of expenditures that include, inter alia: education; health medication; water; cooking and lighting fuels; transport; communication; and clothing (KNBS, 2018).

Table 8.3 shows KIHBS analysis of data indicating national averages in the shares of food and non-food consumption expenditures. We also include the data for our study counties of Kitui and Homa Bay for comparison.

Table 8.2 Kenya census data on numbers of poor people

	Population ('000)	Number of poor ('000)
National	45,371	16,401
National—rural	29,127	11,687
National—peri-urban	3340	920
National—core-urban	12,905	3795
Kitui County	1098	522
Homa Bay County	1072	360
Nairobi City	4463	745
Nakuru County	2031	592

Source KNBS (2018)

Table 8.3 Shares of food and non-food consumption expenditures

	% share of food expenditure	% share of non-food expenditure
National	54.3	45.7
National—rural	64.7	35.3
National—peri-urban	58	42
National—core-urban	46.6	53.4
Kitui County	62.5	37.5
Homa Bay County	65.6	34.4

Source KNBS (2018)

For the overall poor across the country, the KIHBS data implies that an average of Kshs 1148 is spent per month on non-food items in rural areas; Kshs 2116 in urban. Whilst it was beyond the scope of our research to conduct detailed analysis of the breakdown in the non-food expenditures basket, it is not a challenge to see why a still significant proportion of people in the country remain unable to pay for solar home systems, citing that they cannot afford the payments as their main reason (Dubey et al., 2019).

It is also not a challenge to see why many of the target group of participants for receiving highly subsidized connections from the Government's Last Mile Connectivity Programme for the grid either remain without connections (not prioritized within their expenditures), or, those connected often remain unable to afford to actually consume the power.

Our field observations mirror these findings. Simply driving to and from the studied villages, one can see that even though grid lines are overhead, small-holder farms located even just a few hundred meters from transformers tend to remain unconnected.

In Kitui County, where we have carried out detailed research in one of the districts, we see that just a small minority is connected to the grid, and that small scale solar power is the only option for a large majority. However, in 2015, more than half of these people were not able to use such off-grid solutions either, and we found the main reason to be affordability. According to our survey with 1100 respondents in 11 villages in

October 2015, 53% of the respondents spent less on lighting per day (0–8 KES per day) than what it would cost to use solar lanterns of reasonable quality (which costed 10 KES per day for rental and later through pay-as-you-go in this area). Kerosene, candles and small torches were the most common lighting sources at the time of the study. This low level of lighting expenditure among the poorest majority of a local population is likely to be similar today, and also in other geographical areas. According to an analysis of household lighting expenditure or electricity expenditure based on the older Kenya Household Budget Survey in 2005/2006, the median expenditure on lighting in Kenya was less than 160 KES per month (5–6 KES per day). In the lowest income quartiles, the median expenditure was 100 KES per month (Ondraczek et al., 2021). Although we did not analyse the more recent 2015/2016 KIHBS data as part of our research, we expect that the overall situation for the poor hasn't changed much.

8.6.3 Recognition of the Importance of 'Solar Lanterns'

As much as electricity provision needs some standardization in order to be effective, it is also necessary to recognize variation in energy needs in different parts of the population. An example of the importance of adaptation of technologies to sociocultural contexts is that portable solar lights of good quality and high and flexible lumen levels (2–3 brightness settings) deserves attention. For instance, according to our research, portable lanterns of good quality have appeared as very well adapted to the needs of many of the households in some sociocultural contexts in Kenya. They are suitable for outdoor and indoor use, easy to move around, robust, and flexible in use, according to our interviews and observations. The introduction of pay-as-you-go for such lanterns, not only for multiple light systems, has been an important innovation that has increased the actual and potential inclusiveness of solar electricity. Due to falling below Tier 1 in UN's multi-tier framework, however, lanterns are not being included in the KOSAP programme, which covers areas where people have found such lanterns practical not only in single-room traditional houses and when moving between houses in a compound, but also when moving outside at night, looking after the livestock animals and scaring hyenas away from their goats at night (mentioned by people in Kitui and Turkana counties).

Access to single lights has been mentioned with sarcasm by leading African and other advocates for energy supply, and this seems to have a powerful effect. It is sometimes used as part of arguments about external actors imposing solutions on Africa that they would not accept for themselves. The issue has to be nuanced, however, based on people's own choices and feedback and based on social scientific studies from different geographical areas. Interviews (and presence over time) with women, men, old and young in Ikisaya village in Kitui county, where most of the households are agro-pastoralists and living on scattered farms, showed that the lanterns were moved around inside different buildings, including homes and small businesses, giving light to paperwork, reading, handicraft, cooking and eating outside or inside, walking along the road, taking care of children late at night, checking the animals or going to a toilet shed. Different family members used the lanterns in turns, since usually only one lantern was kept by each family. A good lumen level was important, and good reliability and predictability in terms of not shutting off in the middle of important activities. The person responsible for cooking could easily carry the light to the cooking area, which was often outdoors or in a separate shed. However, without doubt, there are many lanterns as well as SHS that would not serve people well. The examples above suggest that recognition of social practices is also an important kind of recognition justice, and that social practices must be recognized in order to understand important needs for electricity. This is important in order to make electricity provision (on- and off-grid) fairer, more inclusive and more useful for the citizens.

8.6.4 Recognition of the Un-Electrified People in Electrified Areas

Those people who are perhaps the most easily forgotten are those who live in 'electrified' areas, but who are not themselves 'electrified' and might need off-grid solutions because the grid is not accessible for them. In a large number of electrified villages, they are most likely a majority as indicated by research in 'electrified' villages, as mentioned above (Lee et al., 2016; Ulsrud, 2020; Winther et al., 2018). Grid densification and intensification will not be enough because large numbers of households are still very likely to be too far from transformers or unable to afford a grid connection including the monthly bills. Internal wiring was mentioned as one of the largest expenses of obtaining a grid connection (interviews with households and a technician in Homa Bay). Some find solar more affordable or practical than the grid.

It is also easy to forget or ignore those who are 'electrified' in terms of having a connection to the grid, but also suffer from very unreliable power supply. These people are part of the impressive access figures, but they have no or poor access. It is at the same time understandable that Kenya Power/the government meet difficulties in maintaining all the long lines, which is expensive and takes time due to stretching over vast geographical areas. There are also tough conditions for the lines, for instance due to heavy rains that wear out the pole fundaments.

8.6.5 Recognition of the Importance of Solar Electricity in Grid Areas

As mentioned under distributional justice, solar power dominated in the grid-connected villages we visited, in terms of much larger numbers of households having solar than a grid connection. In the selected villages in Homa Bay, for instance in 2017, approximately 35% of the population used solar only, while 6% had a grid connection (Ulsrud, 2020; Winther et al., 2018). And as mentioned above, people with a grid connection tried to compensate for an unreliable grid by using solar as a back-up, or rather part of their electricity supply, and then used the grid for other purposes when it was on. However, the majority did not have any of these (59%) and would most likely have needed help in order to obtain a small solar system. The ability to combine the two options is the privilege of the most well-off and most centrally located households in a locality. We also observed a few very wealthy households[12] compared to the typical households in the area, well-off enough to pay for the additional poles and lines required to extend the grid to their houses, even if these were at a significant distance from the nearest transformers.

When we asked people with both solutions to compare the two options and their desirability, a common answer was that the grid can be used for more appliances than the solar but the solar is more stable. This was households that could afford to have a fridge and other appliances intended for use with the grid electricity. Moreover, their solar home system was not sized for such use, but rather for lighting, phone charging and perhaps radio, TV, fan or similar. Many people in the area might wish for a grid connection without having the chance to connect in the foreseeable future due to the constraints described before, including being too far from the nearest transformer. However, solar seems to be much more accessible and perhaps in some cases more attractive for people than a grid connection, both for those who could only use small systems and for the very few households that had covered their roof with solar panels.

Barriers to Combining On-Grid and Off-Grid Solutions in Rural Electrification

In a conversation with an expert on on- and off-grid electrification in Kenya, we described the apparent mix of grid and off-grid electricity in the same villages, and suggested that such a mix needs to become part of energy planning, because one can no longer assume that the grid can reach all within each local community. The immediate response was that the solutions that people obtain on their own (i.e., off-grid solar) should not matter for electrification planning. This response is understandable since the established thinking within the energy sector, including the involved donors and banks is that some areas will be electrified through

[12] In the cases interviewed, either relatives of politicians or of successful businesspeople who were based in major urban areas such as Nairobi or Kisumu, but with origins and/or strong links to the areas where the research was carried out. The houses mentioned were built similar in size and scale to large houses typically seen in wealthy suburbs of Nairobi and Kisumu.

grid extension, while other areas might have to be electrified with other means, especially off-grid solar PV. However, the emerging practices indicate that people should not be left to solve their electricity needs on their own in situations where the grids that pass through their areas are not accessible to them, even if grid densification strategies can help to some extent.

A recognition of such situations (or emerging trends) would arguably mean that the involved actors, especially the government and the donors/banks need to adapt their strategies and how they work with private sector actors in (rural) electrification. We acknowledge that the idea of facilitating a mix of on and off-grid solutions in the same geographical areas is currently unrealistic because it would require a significant change in mindset in established ways of thinking and organizing implementation, financing, operation and maintenance of rural electricity provision. The narrative on solar electricity as a 'second best' solution[13] also has to be addressed, not least by making sure that the users have practical, durable and affordable solutions.

One could say that a merging of grid and off-grid electrification in the same areas would require a merging of competing energy pathways. For individual experts who have been strongly engaged in grid extension for many years, who have carried out grid extension programmes and struggled to convince people that the grid is as affordable as off-grid solar PV and less expensive per kilowatt-hour, it is not straightforward to start appreciating the inclusion of off-grid solar PV as a completely integrated element in rural electrification. One expert expressed that the accept of such a strategy would be the same as admitting that grid extension does not work.

One of the experts who had made significant efforts on grid extension in Kenya (connected to a development bank) was disappointed to hear about the domination of off-grid solar in the grid-connected areas we had studied, and was of the opinion that the solar companies should not promote their services and products in areas where the grid was

[13] Whether tacit or implicit through various channels such as policy choices; political promises; user experiences; technology quality etc.

already installed—indicating that the companies had pushed people to make wrong choices and thus reduced the number of grid customers. However, solar is not just a necessity for people who need an alternative to the grid, it is also something that evidently has an enormous potential for the future and can be more cost-effective than grid extension.

8.6.6 Recognition of Heterogeneity in Supply of Solar Home Systems

An omission in the discourse on electrification through solar home systems is in the heterogeneity of suppliers and in the supply of systems. As stated earlier, GOGLA estimates that 46% of market share is taken by companies who are not signed up to GOGLA reporting systems ('non-affiliates') (GOGLA, 2020). Whilst it is beyond the scope of this chapter to go into this aspect in any detail, recognition of it is important. It impacts most especially in poor rural markets, where cheaper products have penetrated. Perceptions are that the majority of the products are poor quality—they may not always be so, but the reality is that far too little is known about them: who supplies them; and the type and quality of the systems supplied. It is an area requiring further research to understand this 'grey' market.

It is expected that many of the participants within the segment are domestic companies across the supply chain (importers, wholesalers, retailers, small traders) with neither the resources to access accreditation nor the clout to influence or be included in electrification policy or strategy. The companies thus far have operated without the grants and subsidies available to larger accredited players, and yet it could be argued that they are more robust (even if they are small in scale) and, because they operate very locally, are able to access deeper rural markets. What role can such companies, including informal traders, have in last-mile solar electrification? Should non-affiliated products be recognized in some way in solar electrification plans—with the ultimate ambition that they level up on their quality standards over time?

A related issue is in standardized parts and repairability of systems, an aspect that is at odds with PAYGO (where the incentive is not to make systems repairable by anyone so that warranties are not voided). Secondary markets in electronics (e.g., mobile phones) are inevitable and recognition of this in the solar home system sector is an important factor in considering greater longevity of the solar systems: standardization; accessible replacement parts; and wider networks of solar technicians. The authors acknowledge the significant challenges in all of this, but we still assert they need to be recognized and therefore included into the solar electrification discussion.

Also, outside of the scope of this chapter, but nevertheless an emerging issue is the latent environmental impacts of solar PV electrification. These take a different form to the environmental and health impacts of kerosene and other fossil-based fuels or dry cell batteries currently in use. They may include toxins in components leached into the natural environment but also the dangers arising (e.g., noxious fumes) from practices such as burning of insulation in order to recover copper wiring, a practice widely done by local electricians. Such issues tend to be acknowledged but rarely properly considered (with solutions, allocated resources) in planning, in part because of the challenges of doing so. For more information about this topic, references include Cross and Murray (2018) and recent publications by Beyond the Grid fund for Africa[14]; CLASP[15]; and the Energy and Environment Partnership Trust Fund (EEP Africa).[16]

8.7 Procedural Justice and Participatory Processes

An important aspect of procedural justice concerns how to bring in the perspectives and experiences of those who are marginalized in access to electricity, having little or poor or no access and being vulnerable in several ways. This can be seen from two different sides. On the

[14] https://www.nefco.int/news/promoting-responsible-e-waste-management-in-the-off-grid-sector-the-beyond-the-grid-fund-for-africa-approach/.

[15] https://www.clasp.ngo/research/all/innovations-in-off-grid-solar-e-waste-management/.

[16] https://eepafrica.org/webinar-solar-e-waste-innovations-in-africa/.

one hand, procedural justice may depend on powerful actors' commitment to understanding people's needs, including what kinds of electricity provision/off-grid systems might support their daily activities; and their potentials for income generation with electricity. On the other hand, we ask how voices of local community groups (especially those that are marginalized); civil rights and advocacy groups at all levels may be strengthened in order to ensure meaningful participation in consultative processes by those powerful actors.

We argue that both these aspects of procedural justice are strengthened through the use of social sciences to lift and amplify voices otherwise not heard or rarely listened to—many of whom are among those left behind in electrification. Social scientists can thereby give glimpses into the realities of those who could benefit from changes in current strategies for rural electrification. However, this depends on the recognition of such studies including qualitative social science studies and participatory methods among decision makers.

8.7.1 Experiences from a Participatory Process on Off-Grid Solar Power

One example of direct use of social science-based research for understanding needs and the suitability of potential solutions, was the Ikisaya Energy Centre project for access to off-grid solar electricity mentioned earlier. This was an action research project led by the University of Oslo, Norway, in cooperation with partners from Kenya, India and Austria. We were part of it, through research and practical implementation. The goal was to develop a model for electricity access that would suit in Kenyan landscapes, in common types of geographical areas in terms of settlement patterns, and the social, cultural, economic and political context. As part of the cooperation with local citizens, several public meetings were held, but since it would be impossible to get the views of all kinds of social groups through such meetings, qualitative household interviews and quantitative surveys were conducted in different parts of the local geography, both during the planning process, shortly after implementation and several years later.

Our experiences from using these methods were that not only foreign researchers and practitioners, but also the Kenyan ones needed the deeper and more comprehensive understanding of what life may be like for different people in the project area, and how the conditions of life differed within the local population. The project also demonstrated that experts equipped with social science-based research methods were able to gain understandings that added to the practitioners' expertise and understanding and helped adapting electricity services to the social and cultural context including people's practical needs, preferences, technical skills, and to some extent, economic constraints. For some people, deep poverty and very fluctuating incomes between agricultural seasons and drought periods forced them to prioritize more pressing expenses than those for lighting, such as food, clothing, school fees, medicine, agricultural inputs and hospital bills.

An important lesson was also that the use of average numbers, which has been common in studies and discussions on affordability of the switch from kerosene to solar, can be very misleading when it comes to understanding issues of affordability. In the Ikisaya solar project area, a survey in 2010 gave an average expenditure on lighting of approximately 10 US cents/10 KES per day, which was also the daily cost of good quality solar lighting plus phone charging services developed by the project. Our 2015 survey, however, showed that less than 50% of the respondents spent this average amount or above. The majority spent much less, and could thus not afford the available solutions. This illustrates that median values and grouping into expenditure brackets, (e.g., 0–3 KES per day, 4–7 KES per day, etc.) are much more helpful than average values in such situations.

Having tried to be in the practitioners' shoes, through action research, we have experienced the challenges of finding ways of fulfilling the needs, suggestions and wishes of the involved citizens. We have experienced that such inputs are not always possible to take into account, whatever large our willingness to do it is, due to economic and other constraints. In the Ikisaya Solar Energy Centre project, there were several research results that could not be fully taken into account for reasons of the costs it would lead to, or consequent risks to future economic sustainability. For instance, people suggested the use of additional electricity services such as electric irons to replace irons heated with charcoal as a useful service for tailors. However, with the electric irons available at that time, this would take up a large part of the capacity of 2.1 kW, and a larger investment in solar panels, inverters and batteries was not possible within the available funds. Moreover, such an increased power generation capacity would increase long-term operation costs, not the least in terms of future battery replacement costs, which is among the key expenses for solar power generation and highly depends on the capacity of the batteries. This is a classic dilemma between important social features of energy systems including economic opportunities for users on the one hand and economic sustainability, profitability and upscaling on the other (Ulsrud, 2015; Ulsrud et al., 2019).

8.7.2 A Study on Participation and Outcomes in Large Power Projects

Two other examples of participatory processes have been studied in the project 'Seeing Conflict at the Margins', which examines two cases of large-scale power generation through wind energy (Lake Turkana Wind Power, LTWP) and geothermal energy at Ol Karia.[17] Although the research project only indirectly addresses access to electricity, it is an interesting finding that at Ol Karia, resettlement plans for the pastoralist people previously occupying the land included the provision of built-up houses with electricity connections, yet, the electricity is unaffordable to many. In the Lake Turkana project, on the other hand, local conflicts resulting from the project has led to the exclusion of some people creating an 'absurd situation' in which there are groups of people, living under the shadows of the turbines that generate over 300 MW of power for the grid, yet who have no access to any kind of electricity provision at all (Drew, 2018).

Both power projects had extensive consultative processes (including environmental and social impact assessments) by a range of powerful actors: project developers; international financiers; national and local

[17] https://seeingconflict.org/.

government. The research project 'Seeing Conflict at the Margins' suggests how such processes could be strengthened to allow a diversity of voices to be heard and listened to; build a better understanding of local politics, dynamics and struggles that may otherwise remain 'hidden' to external experts and may even bring about new sources of conflict; and, of course, to better realize the promises and prospects of development projects to bring better prosperity locally.[18]

8.8 Strategies for Overcoming Challenges to Off-Grid Solar Electrification in Kenya

The sections above point to a range of challenges that need to be overcome in order to provide equitable, sustainable and useful electricity access for all. We have shown that people are left behind in different ways and for different reasons and here we wish to discuss the deeper reasons for the injustices and problems and how people can be more included in the future. These are large and challenging questions, however, which need to be investigated and analyzed in much more comprehensive ways than what is possible here.

The majority of the efforts on off-grid solar in Kenya over the last decade have been firmly placed in the kind of thinking often labelled as 'neo-liberal', where the trust in private markets as the best mechanism to meet social needs is strong, and where incentives for private sector companies are the most prominent support mechanism in addition to various financing mechanisms from banks and investors (Byrne et al., 2018; Newell & Phillips, 2016).

Private sector actors have put in massive efforts and contributed strongly to the achievements within off-grid solar electricity in Kenya, and for a while, these achievements were purely described as a private sector-led success story where markets have developed freely, without subsidies (Jakobson, 2007; Ondraczek, 2013). However, this image has been corrected in convincing ways by Ockwell and Byrne (2017) who demonstrate that 'the success of the Kenyan market for off-grid solar

[18] https://seeingconflict.org/.

electrical services can be attributed to a range of targeted interventions by key actors over time'. They find that this success 'most certainly was not a simple case of free market forces driving success', but, similar to the evolution of emergent industries and sectors globally, public funding and support to the private sector and other actors was important for the building up of a novel and emergent socio-technical innovation system. Private sector actors in Kenya acted both with and without public funding and support. Moreover, private sector actors pursued a range of activities in addition to conventional rent-seeking activities, especially a range of capacity building activities, building of actor-networks and engagement in political efforts over time, in cooperation with NGOs, donors and many others, as mentioned earlier (Byrne et al., 2018; Ockwell & Byrne, 2017).

A range of incentives and support to private sector actors for making electricity services available for the poor have been tested by donors and other financiers. For example, grant financing has been available for pilot and demonstration projects to create scalable business models (or delivery models), information and training programmes, study visits, research, testing facilities, development of pay-as-you-go (PAYGO) technology and a range of advocacy activities. Grants have also been provided to support private sector entry into geographical areas where the chances to succeed were weaker due to poor infrastructure or sparse population densities. Results-based financing (RBF), in effect a supply side subsidy, has increasingly been used to try and incentivize companies by covering the higher costs of unit sales in these areas.

There has now been over five years' experience with RBF financing in Kenya, mainly for solar home systems and to some extent for solar lanterns, through development partner programmes such as Endev,[19] and more recently the KOSAP programme described above.[20] In addition to these, there has been an emergence of newer RBF instruments, for example a facility by the Africa Enterprise Challenge Fund (AECF) that provides an additional 20% 'pro-poor bonus' for companies that can

[19] https://endev.info/countries/kenya/.

[20] https://www.kosap-fm.or.ke/standalone-solar-systems-for-households-results-based-financing-rbf-facility/.

show they have utilized 25% or more of their verified RBF facilities to reach poor households.[21] The AECF is also managing a challenge fund specific for refugee communities in Northern Kenya that has clean energy objectives.[22] In addition to support for the more mainstream GOGLA-affiliated off-grid solar companies, the fund also has a mechanism to support micro and small businesses with financing and business capacity development.

These types of market entry grants and RBF instruments have shown successes in widening markets for off-grid solar companies making their products and services available in geographical areas where they might not otherwise go, even though there is still low presence of companies in such areas due to high costs and risks of establishing sales networks in vast geographical areas with high logistics costs to reach the customers both for sales and after sales services. It is also debatable whether and to what extent the instruments have deepened markets and are reaching poorer households. Our observations from field research, interviews and conversations with the private sector indicate that the less well-off still cannot afford the products. To what extent the newer approaches (based on learnings from earlier versions), such as the pro-poor bonus and the support of locally embedded small businesses, are succeeding is yet to be seen, as they are relatively early in their application.

In addition to the difficulties mentioned above, our conversations with solar supply companies indicate that temporary, shifting, or administratively burdensome support mechanisms and incentives through donor projects are also problematic. If part of the intent of the donor projects is to develop markets in specific areas, then a longer-term horizon for the intervention is needed, but that might be beyond what is acceptable in the currently constricted donor and public funding environment. A general challenge for the companies, despite RBF, is that it is too risky and expensive for companies to provide consumer finance over long time like they do with PAYGO, to customers with little or no credit history or income information.

21 https://www.aecfafrica.org/react-rbf.

22 https://www.aecfafrica.org/portfolio/Kakuma-Kalobeyei-Challenge-Fund.

It is important to understand the challenges and struggles of the involved actors both to survive as businesses, and to make both donors and investors satisfied. However, it is also important to notice that the focus of public funding (including international funding) appears to be clustering around certain kinds of support mechanisms, most notably, RBF for companies selling solar home systems (incl. multi-light systems). This is not a bad thing, as it contributes to high sales of household level solar systems and to further improvements of RBF designs, but it might also create a narrow environment for creative development of alternative solar PV models for the future.

The use of demand side subsidies is a support mechanism under testing in Kenya, in the Mwangaza Mashinani project.[23] The concept is that vulnerable households under the national safety net programme receive an additional amount to their government cash transfers in order to use this top up to pay, in instalments, for a Tier 1 solar system provided by companies that were selected to participate in the project trial. This has been trialled 2018–2020 in Kilifi and Garissa counties with SIDA funding and now undergoing an expansion with UNICEF funding. The initial project targeted 1500 households and the expansion targets 3500.

Initial indications showed better success in Kilifi County versus Garissa. It is suggested that the latter was in part due to specific challenges relating to pastoralist communities—so perhaps there are different approaches that need to be trialled in such highly dispersed and mobile communities. Further, on average, 70% of those signed up to the initial project chose to use their cash transfer top ups for the purpose intended.[24] At the time of writing, there have not been any published evaluations or lessons learned reports from this project. It is expected that these will soon be published by the project and on platforms such as the GOGLA end-user subsidy learning lab.[25]

[23] https://energy4impact.org/news/solar-home-energy-scheme-brings-power-poor-people-rural-kenya.

[24] End User Subsidies Lab Webinar: How Kenya's Energy Cash Plus initiative addresses affordability. https://www.youtube.com/watch?v=GGkmTFMgVEY.

[25] https://www.gogla.org/end-user-subsidies-lab.

Micro-SMEs, as mentioned earlier, are small local distributors of products and services who are embedded within communities. These may be among the non-GOGLA-affiliated companies and are currently excluded from the business support mechanisms and incentives that the larger and dominant solar suppliers and their distributors are able to access. Many of these businesses may operate too informally to work with the larger suppliers (for example in accessing credit for inventory) and yet have the potential to be additional—and innovative channels for last mile distribution and to contribute to socially inclusive electricity services. In Homa Bay County, for example, we observed some small businesses in fishing villages that rent out solar lanterns to fishermen and their families. Support programmes for the future may look to the inclusion of such micro-enterprises and alternative kinds of initiatives, at the same time as focussing on improvement of product quality issues.

Village-level electricity models such as mini-grids often have useful characteristics, seen from an energy justice perspective. Many of them include services that are useful for communities as a whole, and strive to reach as many people as possible in each place (Ulsrud et al., 2018). Such models do not seem to get much attention in Kenya currently, and the mini-grid component of the KOSAP project seems to move more slowly than the solar systems for households component. Issues of tariff-setting and licensing have been discussed, and might not yet be fully solved. These are politically difficult issues. Moreover, according to our research, another key challenge for such place-specific installations as mini-grids, charging hubs, energy centres and community solar water pumps is their dependence of having enough customers within their geographical reach, and a sufficient portion of these in a position to afford some extent of usage. (For an example from Senegal, see Ulsrud et al., 2019). Thus, a chronic problem for such electricity models is low income, despite massive efforts and well-designed services and payment systems. People wish to use electricity services, but the ability to pay is often very low and fluctuating among large parts of the population in each place (Ulsrud et al., 2018). Companies that sell solar home systems and solar lanterns solve the problem of few customers in each locality by marketing their products in wide areas. Such footloose companies therefore also reduce the customer base of mini-grids and other village-level systems by competing for the same customers. This is natural, and gives a choice to those who can pay, but it is important to be aware of this as one of the reasons why village-level models meet very different challenges than those of household level models.

This leads us to a field of important off-grid solar electricity services that benefit all citizens, but where long-term operational sustainability is not yet taken care of in a way that works well. This is the field of public institutions, where solar electricity is important for health clinics, schools and community water pumps in off-grid areas. Our impression is, based on a few observed examples and remarks from energy sector actors over the years, that such crucial services for all end up being non-functional after some time, often at the first need for battery replacement or other major maintenance. The reason, as far as we can see without having done a country wide investigation of this challenge, is that there is not yet an effective and realistic institutional arrangement in place for how the costs of such maintenance can be covered and who can ensure a professional and quick repair. The current arrangement is that the schools, health clinics or local administrations must accumulate funds on their own for such maintenance based on savings or user payments. This appears as unrealistic due to the high amounts required for re-investment in battery banks or repair of water pumps. An example of the latter can be observed in a remote place in Kitui county, where the local public administration has accumulated an amount for maintenance of a solar water pump through the citizens' payment for water. The problem is, however, that the pump needs repair for a much higher amount. For this reason, the pump has been non-functional for more than three years, in a community that urgently needs the water, while the county government that made the installation does not have any responsibility for the long-term operation. In this way, a large investment has gone to waste.

A necessary question to discuss in relation to socially inclusive electricity provision is therefore who should pay for the long-term maintenance of public solar electricity systems. An idea could be, for instance, to include such maintenance in the routines for maintenance of the centralized grid. A related question that needs more discussion is also who and what is recognized as important in rural electrification, what deserves to be subsidized, and how streamlined and market oriented the support for off-grid solar electricity should be. Should there be some more diversity and creativity in strategies and support mechanisms, with some more emphasis on social welfare and long-term sustainability of existing and future solar installations? These are questions related to the political economy of energy, including whose economic and political interests and power are strong and dominant (see, for example, Newell & Phillips, 2016; Byrne et al., 2018).

8.9 Conclusion

What does it mean to 'leave no one behind', and what does it require? How can everyone be included in electricity provision, which is affordable, useful and well-functioning in the long run? These are key questions in relation to efforts for access to electricity for all, and we have aimed to shed light on who are still left behind in on- and off-grid electrification in Kenya and why. We have thereby provided insights for the continuous work on access to energy for all. The situation in Kenya can give relevant insights also for other countries in sub-Saharan Africa, because of Kenya's significant achievements in on- and off-grid electrification and because of comparable problems of poverty and other conditions for rural electrification.

Our analysis of distributional justice shows the importance of combining different kinds of data, both quantitative and qualitative, national level and other levels to get a realistic picture of people's ability to use electricity. We have shown the contrast between numbers of grid connections (about 70% of the households in 2021) and the percentage of households that use electricity according to census data (50.4% of the households in 2019). Other sources of data, including our own field research and the 2021 Kenya Power annual report show that households with grid connections do not necessarily use electricity, or when they do, the consumption level is often similar to those with off-grid solar home systems, where lighting and phone charging are the most common applications. Some of the reasons for this low level of consumption of grid electricity include poorly functioning or non-functioning supply and an inability by many people to pay regularly due to low and fluctuating incomes.

The number of people with access to electricity from off-grid solar also has to be understood by combining different sources of data, and here, the answers are even more uncertain than for grid electricity. We have contrasted sales figures of GOGLA-affiliated companies with census data but also note that a significant proportion of sales in the market are estimated to be non-affiliate sales and there is not much known about these, as there is no data available. Whilst sales data are often used to estimate how many people have access to solar systems, there are still many un-knowns, such as how many of the household level systems are actually functioning; how many have been purchased by households that replaced or added to a previous one; how many are owned by people who are also connected to the grid; and how many hours of lighting (and other applications) per week the household is actually able to use.

Some insights about such issues can be provided through case studies because they show situations that may have similarities in wider geographical areas with comparable social, economic, geographic and cultural characteristics. Our case studies in Homa Bay and Kitui counties indicate that the ability to get access to and to actually use on- and off-grid solutions differ greatly between different households in the same rural place. Significant portions of the households tend to be left behind due to deep poverty. Such households struggle to pay for food and other daily necessities more important for survival than electricity. So, despite high and impressive achievements in providing access to electricity in Kenya, the discussions must continue on what is equitable and fair and which alternative strategies for on- and off-grid electrification could be explored to address distributional injustices.

Recognition justice has appeared as an important aspect of our analysis, with five key conclusions. Firstly, in addition to the recognition of 14 underserved counties by the government of Kenya, we argue for the recognition of underserved areas and people also outside these counties. This is because there are large areas in other counties with similar characteristics and conditions in terms of lacking grid infrastructure, low presence of off-grid solar actors and high poverty levels.

Secondly, the decisions made in the past that defined solar lanterns as part of Tier 0 in the UN multi-tier framework and the later decision to exclude them from current strategies for electricity access in Kenya (including the KOSAP programme) can be questioned based on our research findings. We have found that portable solar lanterns (single light solar systems) with a good lumen level and robust design are more practical and desirable than multiple light systems for some households in some sociocultural contexts, including areas with similar characteristics to large parts of the KOSAP counties. This does not mean that people necessarily should be counted as being 'electrified' when having a solar lantern, but that such technology should not be excluded from the support mechanisms for off-grid solar electricity. People should have a choice based on what is practical for them. Moreover, some of the households that are not able to pay for a multiple light system are able to pay for a solar lantern/single light system. If they wish and are able to add a multiple light system later, they can do so. The support mechanisms for the companies that sell solar are not limited to one product sold per household. The problem is, however, that many of those households that might find lanterns to be a practical solution in their everyday life, might not even afford these lowest cost types of solar equipment. This brings us back to the issue of affordability, which is one of the largest, remaining challenges for socially inclusive electricity provision in Kenya. The example of solar lanterns, however, shows that other aspects of social inclusion and energy justice are important too. It shows why social practices, living conditions and livelihoods need to be understood in order to make electricity provision more suitable for people's needs and constraining conditions.

Thirdly, the recognition of who is left behind or underserved needs to take place at lower geographical scales than the country or county scale. Our analysis has shown that the village and household scale (or level) is where it becomes possible to understand the different reasons why the current solutions for electricity provision are far from reaching all households even where several options are available in their home area. This is in line with an argument by Lacey-Barnacle and Bird (2018) on the importance of studying energy justice at the local community level in addition to the higher levels of analysis commonly seen in the energy justice literature.

Fourthly, there seems to be insufficient recognition of the 'un-electrified' people in 'electrified' localities. These people often constitute a significant portion of the citizens in a rural location with electricity grids present.

Fifthly, and related to the previous point, there is little recognition of the need for off-grid solar to provide electricity to the households left behind in grid electrified areas. As shown by our case studies in some grid-connected villages in Kitui and Homa Bay counties, large parts of the population may live too far from a transformer to be connected to the grid, and even with grid densification and intensification as suggested in the current national electrification strategy, this is likely to remain an important constraining issue. The mixing of on- and off-grid solutions that already takes place indicates that an integration of grid- and off-grid solutions would be fruitful in order to include all those who are not able to solve the problem on their own. Grid-connected areas should therefore not be ignored in programmes for the provision of solar electricity. Seen in this light, it appears as unjust that the grid system in rural areas is heavily subsidized while solar solutions receive much less support.

Regarding procedural justice, we have presented a few examples and lessons and looked at the role of social science in contributing to understandings of differing realities on the ground. As pointed out by critiques of comprehensive participatory processes and social science studies, it is unrealistic to carry out such processes everywhere during on- and off-grid electrification. However, we argue that it is still important to do this in selected places and at suitable time intervals in order to ensure a high level of understanding of ongoing social changes, the needs and opportunities for different social groups within village communities and different societies in different parts of a country. This is a valuable type of knowledge for national planning processes, and universities and research funders should contribute to such work.

Acknowledgements We would like to extend our thanks to all the team members of the Solar Transitions, Solar xChange and EFEWEE projects for the joint research work that has made this chapter possible. We warmly thank all individuals and organizations in Kenya who have contributed with their valuable knowledge, experience and time during our data collection, and the University of Oslo, as the owner of all three research projects. We are also very grateful to the funding institutions—the Research Council of Norway (Solar Transitions and Solar xChange) and DFID through the Energia programme (EFEWEE).

References

Alushula, P. (2021, July 5 Monday). Kenya Power revenues hit as rural homes use Sh 3.34 daily. *Business Daily*. Retrieved March 27, 2022, from https://www.businessdailyafrica.com/bd/corporate/companies/kenya-power-revenues-hit-as-rural-homes-use-sh3-30-daily-3461252

Bastholm, C., & Henning, A. (2014). The use of three perspectives to make implementation studies more culturally informed. *Energy, Sustainability and Society, 4*(1), 3. https://doi.org/10.1186/2192-0567-4-3

Brix Pedersen, M., & Nygaard, I. (2018). System building in the Kenyan electrification regime: The case of private solar mini-grid development. *Energy Research and Social Science, 42*, 211–223.

Byrne, R., Meva, K., & Ockwell, D. (2018). A political economy of niche building: Neoliberal—development encounters in photovoltaic electrification in Kenya. *Energy Research and Social Science, 44*, 6016.

Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. *Energy Research and Social Science, 44*, 100–109.

Drew, J. A. (2018). Pastoralism in the shadow of a windfarm: An ethnography of people, places and belonging in Northern Kenya. Phd thesis, University of Sussex.

Dubey S., Adovor, E., Rysankova, D., Portale, E., & Koo, B. (2019). *Kenya beyond connections. Access to electricity and clean cooking in Kenya based on the Multitier Framework survey and data analysis*. ESMAP. World Bank.

Fuenfschilling, L., & Truffer, B. (2014). The structuration of social-technical regimes—Conceptual foundations from institutional theory. *Research Policy, 43*(4), 772–791.

GOGLA. (2019a). *Kenya country brief*. Retrieved March 27, 2022, from https://www.gogla.org/resources/country-brief-kenya

GOGLA. (2019b). *Global off-grid solar market report. Semi-annual sales and impact data. January–June 2019b*. GOGLA.
GOGLA. (2020). *Standardised impact metrics for the off-grid solar energy sector. Executive summary, April 2020*. GOGLA.
GOGLA. (2021). *Global off-grid solar market report. Semi-annual sales and impact data. January–June 2021.* GOGLA.
IEA. (2019). *Tracking SDG7: The energy progress report, 2019*. IEA. Retrieved March 27, 2022, from https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2019
IEA. (2020). *Tracking SDG7: The energy progress report, 2020*. IEA. Retrieved March 27, 2022, from https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2020
IEA. (2021). *Tracking SDG7: The energy progress report, 2021.* IEA. Retrieved March 27, 2022, from https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2021
Jakobson, A. (2007). Connective power: Solar electrification and social change in Kenya. *World Development, 35*(1), 144–162.
Jenkins, K., Sovacool, B. K., & McCauley, D. (2018). Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change. *Energy Policy, 117*, 66–74.
KNBS. (2018). *Basic report 2015/6 Kenya integrated household budget survey (KIHBS).* Kenya National Bureau of Statistics.
KNBS. (2019). *2019 Kenya population and housing census volume IV: Distribution of population by socio-economic characteristics*. Kenya National Bureau of Statistics.
Kenya National Electrification Strategy: Key Highlights (KNES). (2018). Ministry of Energy, The Government of Kenya.
Kenya Power. (2021). *Kenya Power abridged annual report and financial statements for the year ended 30th June 2021.* Kenya Power.
Lacey-Barnacle. M., & Bird, C.M. (2018). Intermediating energy justice? The role of intermediaries in the civic energy sector in a time of austerity. *Applied Energy* 22671–81. S0306261918308055. https://doi.org/10.1016/j.apenergy.2018.05.088
Lee, K., Brewer, E., Christiano, C., Meyo, F., Miguel, E., Podolsky, M., Rosa, J., & Wolfram, C. (2016). Electrification for 'under grid' households in rural Kenya. *Development Engineering, 1*, 26–35.
McCauley, D., Ramasar, V., Heffron, R. J., Sovarcool, B. K., Mebratu, D., & Mundaca, L. (2019). Energy justice in the transition to low carbon energy

systems: Exploring key themes in interdisciplinary research. *Applied Energy, 233–234*, 916–921.

Muchunku, C., Ulsrud, K., Palit, D. & Jonker-Klunne, W. (2018, January 3). Diffusion of solar in East Africa: what can be learned from private sector delivery models? *WIREs Energy and Environment, 7*(3).

Newell, P., & Phillips, J. (2016). Neoliberal energy transitions in the South: Kenyan experiences. *Geoforum, 74*, 39–48.

Ockwell, D., & Byrne, R. (2017). *Sustainable energy for all: Innovation, technology and pro-poor green transformations*. Routledge.

Ojong, N. (2021a). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.

Ojong, N. (2021b). Solar home systems in South Asia: Examining adoption, energy consumption, and social practices. *Sustainability, 13*(14), 7754.

Ondraczek, J. (2013). The sun rises in the east (of Africa): A comparison of the development and status of solar energy markets in Kenya and Tanzania. *Energy Policy, 56*(1), 407–417.

Ondraczek, J., Stover, J., Lay, J., & Jacobson, A. (2021). Household lighting fuel costs in Kenya. *Market Intelligence Note, issue 2, Dec 2021.* Lighting Africa, Lighting Global.

Sareen, S., & Haarstad, H. (2021). Decision-making and scalar biases in solar photovoltaics roll-out. *Current Opinion in Environment Sustainability, 51*, 24–29.

University of Oslo, TERI, Seacrester Consulting and Dunamai Energy. (2019). Women's empowerment and electricity access: How do grid and off-grid systems enhance or restrict gender equality? *Research report RA1.* Energia.

Ulsrud, K. (2015). *Village-level solar power in practice: Transfer of socio-technical innovations between India and Kenya* [PhD Dissertation, Department of Sociology and Human Geography, Faculty of Social Sciences]. University of Oslo.

Ulsrud, K. (2020). Access to electricity for all and the of decentralized solar power in sub-Saharan Africa. *Norwegian Journal of Geography, 74*(1), 54–63. https://doi.org/10.1080/00291951.2020.1736145

Ulsrud, K., Muchunku, C., Palit, D., & Kirubi, G. (2019). *Solar energy, mini-grids and sustainable energy access: Practical experiences, lessons and solutions from Senegal*. Routledge.

Ulsrud, K., Rohracher, H., & Muchunku, C. (2017). Spatial transfer of innovations: South-South learning on village-scale solar power supply between India and Kenya. *Energy Policy, 114*, 89–97.

Ulsrud, K., Rohracher, H., Winther, T., Muchunku, C., & Palit, D. (2018). Pathways to electricity for all: What makes village-scale solar power successful? *Energy Research and Social Science, 44*, 32–40.
Ulsrud, K., Winther, T., Palit, D., & Rohracher, H. (2015). Village-level solar power in Africa: Accelerating access to electricity services through a socio-technical design in Kenya. *Energy Research & Social Science, 5*, 34–44.
Winther, T., Ulsrud, K., & Saini, A. (2018). Solar powered electricity access: Implications for women's empowerment in rural Kenya. *Energy Research and Social Science, 44*, 61–74.

Part III

Enabling Uptake: Constraints and Opportunities

9

Solar Home Systems in Rural Landscapes: Examining the Forces Shaping Solar Home Systems Adoption in Southeast Nigeria

Edlyne E. Anugwom

9.1 Introduction

This chapter examines the socioeconomic factors that shape SHS adoption in off-grid rural communities in Nigeria. To this end, it focuses on how socioeconomic factors like income, gender, age, and even perceptions, shape the adoption of SHS in these communities.

For Nigeria, with an estimated population of over 200 million inhabitants, renewable energy has a critical role to play regarding access to electricity. Therefore, the focus on Nigeria in this chapter, apart from adding to the existing literature, would inter alia provide insights on the issues of acceptability, affordability, and gender in the adoption of the SHS in off-grid rural areas.

E. E. Anugwom (✉)
University of Nigeria, Nsukka, Nigeria
e-mail: akommiri@gmail.com; edlyne.anugwom@unn.edu.ng

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*,
Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_9

Rural areas in Nigeria often suffer from socio-economic and development marginalization which make reliance on crude energy sources and wood fuel seem attractive. In fact, solid biomass and waste account for about 80% of the total primary energy consumed in Nigeria (Ben-Iwo et al., 2016). Despite policy statements, climate change mitigation efforts in Nigeria are to say the least very meagre and much more so in the rural areas where the quest for daily bread and abject poverty make renewable energy concerns almost non-existent.

As has been argued by Diji and Bamiro (2012), there is a need to diversify Nigeria's energy mix, especially by focusing on unexploited and underexploited energy resources. In this light, such diversification would include increasing and promoting SHS adoption especially among rural dwellers who are often considered outside the orbit of modern technological developments.

Thus, off-grid solar technologies, especially the SHS remains a credible pathway to extending access to electricity to rural communities especially in developing societies like Nigeria. This technology, apart from its affordability and simplicity, has the capacity of promoting socio-economic development in rural communities. As a result, 'off-grid renewable energy systems have transformed our ability to deliver secure affordable electricity to rural communities all over the world, […] breaking a cycle of energy poverty that has held back socio-economic progress for hundreds of millions of people' (Amin, 2019: 3).

Several factors underpin and support the utilization of SHS, especially in the rural areas. These include the relatively low cost, environmental consideration, and apparent inexhaustible nature; unlike fossil fuels, and even biomass energy. It is also relatively simple to operate and use with low maintenance and service costs; quick turnaround time especially in terms of achieving quick access to energy; abundance of sunlight in most of SSA including Nigeria which implies continuous availability and reliability.

However, the culture and social heritage of a people play critical roles in their adoption or rejection of any innovation in rural communities. Culture which embodies the collective values, beliefs, and ways of life of a people can be expected to have a significant influence in their attitude towards adoption of renewable energy. The role of culture in the adoption process has been apprehended by some scholars (see Boamah, 2020; Sovacool et al., 2020; Strauss & Love, 2013). Based on a comprehensive review of the literature SHS in SSA, Ojong (2021a) avers that culture influences the adoption of SHS and should be taken seriously in research on SHS instead of being perceived as peripheral. In other words, there is reason to believe that culture plays a central role in shaping SHS adoption. Thus, 'the perceptions and beliefs of individuals exert an important influence on the acceptance or not of renewable energy projects in various parts of the world. Therefore, it is advisable to reflect on the meaning of social action that predominates in a given community' (Colmenares-Quintero et al., 2020: 10).

Clearly, culture and people's belief systems shape their perception and mould their opinion and attitudes to renewable energy including issues of acceptance and adoption in general (Baitanayeva et al., 2020; Delicado et al., 2016; Eun-Sung et al., 2018; Komendatova et al., 2018; Ojong, 2021b). However, the influence of public perception and beliefs on renewable energy development and adoption is not restricted to the developing world or sub-Saharan Africa. Issues related to public beliefs, worldviews, and perceptions have also factored strongly in renewable energy policies, acceptance, and adoption efforts elsewhere (Anderson et al., 2017; Devine-Wright, 2005; Johansen & Emborg, 2018; Sposato & Hampl, 2018).

That said, few empirical studies of SHS have been conducted in Nigeria, and even fewer studies have focused on rural areas. This chapter, based on a case study in Southeast Nigeria, adds to the limited literature on the socio-economic factors which shape SHS adoption in rural communities.

9.2 Overview of Nigerian's Rural Energy Landscape

Nigeria's rural energy policy thrust, and intervention may be seen as driven by the acute realization that focusing on off-grid rural communities is a critical part of the goals of achieving sustainable development. Thus, if the country must meet the demands of SDG 7 for universal electricity access by 2030, then off-grid communities demand renewed and concerted attention. In effect, 'off-grid renewable energy solutions represent a viable electrification solution that is rapidly scalable, environmentally sustainable, can be tailored to local conditions and importantly has the potential to empower rural communities, especially the youth and women' (IRENA, 2019: 5). In other words, apart from energizing the rural areas, renewable energy sources like SHS would help in the effort to address marginalization and exclusion in rural enclaves. Taking on board the needs of women and the youth make off-grid renewables standout options to addressing the limitations and encumbrances of traditional life in a heavily patrimonial society.

Nigeria's rural electrification was established at about 22.62% in 2017 (Index Mundi, 2019) which indicates that about 80 million Nigerians are literally in darkness. The above scenario owes largely to the obvious high costs of grid extension, which is put at about $10,000 per kilometre (Amaza & Agbaegbu, 2018). This high cost subsists even though there are little returns on such investment, as rural dwellers are commonly poor, use far less than supplied, and are generally unwilling to pay much for metered electricity. In fact, the prevailing practice is that most rural communities connected to the national grid are largely unmetered, but collectively pay minimal pro-rata tariff each month (which ranges from between N500 and N1000 per household).[1] Therefore, energy in this case is considered more as a social good to be provided by government rather than an economic good. The above perception has not radically changed even with the privatization of electricity distribution in the country.

The national policy thrust towards rural electrification in Nigeria began around 1991 when the government took major steps towards expanding rural electrification. At this point the emphasis was on connecting the headquarters of all local governments and selected communities to the national grid under a programme known as Nigerian Rural Electrification Programme (NREP). It was the above that ultimately crystallized into the establishment of an agency charged with rural electrification in 2006. The agency named the Rural Electrification

[1] This is around $1–2 US a month.

Agency (REA) was supposed to pursue the task of rural electrification through such measures as grid extension, utilization of isolated and mini-grid systems, and more critically through renewable energy power generation. Interestingly, the above federal government initiative was copied by the sub-federal (state) governments that established State Rural Electrification Boards in the 36 states in Nigeria. The REA is considered very imperative in the bid to achieve 75% rural electrification by 2020 and increase the coverage to 90% in 2030 (Amaza & Agbaegbu, 2018).

Be the above as it may seem, the REA has been squarely saddled with the task of developing the off-grid market in the country. The agency in view of this responsibility established the off-grid electrification strategy as an integral part of Nigeria's Power Sector Recovery Programme (PSRP). The agency's focus on off-grid electrification is a dominant component of the PSRP. Put succinctly, the PRSP inter alia is a series of policy actions and interventions that the Federal Government of Nigeria (FGN) would implement within a five-year period to restore the financial viability of the power sector and improve both transparency and service delivery as well as reduce energy theft and losses (REA, 2017).

To achieve its core mandate, the REA also established the Rural Electrification Fund (REF) as a support pillar of the central government's Rural Electrification Strategy and Implementation Plan (RESIP). The objective of the REA was to help finance the expansion of rural electrification in Nigeria utilizing both on-grid and off-grid solutions. While these initiatives appear commendable and goal-oriented and have even drawn the support of multilateral development agencies like the World Bank, the reality on the ground and the experiences of the average rural household in Nigeria do not bear out the expected salutary effects of these initiatives.

Equally in the mix now is a relatively new initiative called Decentralized Renewable Energy (DRE), which aims to decentralize renewable energy at sub-federal levels. The DRE, if it attracts the buy-in of state governments and the private sector would be a veritable tool for increasing rural electrification and lessening the burden on the national grid. States are encouraged to seriously mainstream DRE options into their rural electrification programmes as well as support and partner private sector initiatives along this line. While the policy appears sound on paper, its implementation and effectiveness are yet to be determined especially with reference to the lofty aim of achieving 90% rural electrification by 2030.

Despite the establishment of the Rural Electrification Boards (REBs) to focus on the electricity and energy access needs of rural communities, there is still a good number of rural enclaves that are both off-grid and without reliable alternative access. The REA has also not been as efficient as expected and has often seemed overwhelmed by the energy needs of Nigerians in the rural areas. Equally limiting the efforts of these agencies are several factors including dearth of facilities, technology incapacity and predictable structural constraints. The above incapacity opens the terrain of off-grid renewable energy provision for private sector investors and innovators though the limited market scope and low economic situation of many rural areas do not guarantee attractive returns on investment especially in the short run.

9.3 Conceptual Framework

The study derives its theoretical lens from the ideas of Cherp and Jewell (2014) regarding the critical factors that drive energy security. At the heart of the debate about the adoption of SHS and other renewable energy sources is whether they embody energy security especially from the perspective of the users. In consideration of energy security, the so-called 4As approach (viz., availability, affordability, accessibility, and acceptability; see Cherp & Jewell, 2014) may be useful especially in a study of rural off-grid communities. However, particularly telling for a developing nation like Nigeria would be the issues of affordability and acceptability.

While affordability tackles the economic cost of adoption often perceived by policy makers and planners as the only tangible obstacle to adoption of renewable energy once availability is assured; acceptability concerns itself with how the renewable energy in question is perceived and accepted by the people as not only providing required energy but satisfying in evidently better ways their needs for energy especially at the household level. Acceptability is incidentally influenced by beliefs and perceptions much more than experience and technical knowledge. In such a situation, the adoption of a renewable energy source like the SHS especially in a typical rural area must contend with issues of acceptability. Thus, policy towards encouraging or scaling-up adoption may be more productive if targeted towards demystifying the canons of disbelief and half-truths regarding SHS.

9.4 Methodology

The study adopted the Rapid Rural Appraisal (RRA) as its methodological framework. In this case, the study sought to understand the rural conditions of communities with regards to energy and energy needs. Given the limitation imposed by time for the study, the RRA was deemed to be an apt and systemic approach that would provide insights into the energy situation and challenges of these rural communities. RRA is a well-established approach to studying different dimensions of life in rural communities in developing societies. Thus, it has been employed in studying such issues as agricultural production, nutrition, effectiveness of extension services, conflict, as well as monitoring and evaluation and needs assessment. Perhaps its strength lies in the fact that it is a qualitative iterative but community-based method which allows for the voice of those being studied to be heard. In a broad sense,

> [R]apid rural appraisal forms part of the attempt to learn about rural conditions in a cost-effective way. Such appraisal involves avoiding the traps of quick and dirty or long and dirty methods and using instead methods that are more cost-effective. (Chambers, 1981: 95)

In line with the above, the approach provides a reliable method for learning from and along with rural people and reduces occurrence of the outsider-insider interference in social research. Therefore, the study adopted two key RRA methods; viz., the face-to-face questionnaire and Key Persons Interviews (KIIs) as data collection tools.

The study utilized two purposively selected off-grid communities in two local government areas in Enugu State, Southeastern Nigeria as its study areas. These communities can be considered typical and representative of off-grid rural areas in Nigeria. Given the remote nature of these areas, inhabitants comprised mainly of farmers, hunters, palm wine tappers, etc.

The face-to-face questionnaire contained both open-ended or unstructured questions and close-ended or structured questions. The close-ended questions were designed in the form of a typical Likert scale instrument and thus elicited responses ranging from 1 or strongly disagree to 5 or strongly agree from the respondents. A total of 56 respondents were sampled for the questionnaire and the selection of the respondents depended on the purposive method using the criteria of availability and willingness to participate in the study. The KII was utilized in interviewing purposively chosen ten respondents (comprising men, women and youth) identified as opinion leaders or gatekeepers in the community. In total therefore, the study depended on a combined sample size of 66 respondents. The study instrument was developed and subjected to expert validation and pilot test in a neighbouring off-grid community before being used. The data analysis was carried out utilizing a combination of both quantitative and qualitative methods (descriptive, numerical, percentage).

9.5 Contextualizing the Study

The study was conducted in two communities viz. Nomeh Unateze (Nkanu-East LGA) and Itchi (Igbo-Eze South LGA) in Enugu State, Southeast Nigeria.

Nomeh Unateze is a town in Nkanu-East local government Area of Enugu State. It has a population of about 10,000 citizens (NBS, 2006), with a projected increase of 2.4% annually. It is bordered on the North by Ugbawka, on the northeast by Mburubu, Oduma on the southeast and Nenwe on the southwest. Nomeh is known for its agricultural produce, especially rice, yam, cassava, palm oil and various types of vegetables. A river, known as *Nvuna*, snakes through all the villages of Nomeh, providing drinking water as well as aquatic environment that supports an all-year round farming though irrigation. There is a railway network that passes through the southeast parts of Nigeria and Nomeh town is one of the towns with a train stop. The estimated distance of Nomeh Unateze from Enugu urban, the capital city of Enugu State is about 30 kilometers.

Itchi is an autonomous community located in Igbo-Eze South local government of Enugu State, Nigeria. It is bordered by Ibagwa-Aka on the north, Enugu-Ezike on the east, Nkala-Agu Obukpa on the South and Unadu on the west. The major economic activity of the dwellers in Itchi town is farming with crops such as yam, oil palm, okra and vegetables grown in the area. The community also boasts of a vibrant trade sector which hosts several markets such as the Nkwo Ibagwa and the Eke Itchi markets. Other important economic activities of the people of Igbo-Eze South LGA include palm wine tapping, craftsmanship, blacksmithing and livestock farming. The town has no nearby functional infrastructure and no access to electricity from the national grid. It has an estimated population of 22,000 inhabitants, with a projected increase rate of 3% annually (NBS, 2006). Itchi lies about 26 kilometres away from the nearest urban city, Nsukka.

9.6 Results

9.6.1 Sociodemographic Characteristics of the Respondents

Despite the location of the study in typical rural communities marked by patrimony, the researcher made attempts to include both male and female respondents in the study. A total of 56 respondents (32 from Nomeh Unateze and 24 from Itchi) were utilized in the face-to-face questionnaire while a purposively chosen ten respondents (five from each community) from these communities were subjected to the KIIs. In all, 68% (38 respondents) of the respondents were males while 32% (18 respondents) were females. In addition, respondents were chosen from all income or economic categories though those with relative high income in these rural enclaves would be the equivalent of low-income earners in typical urban areas given the low economic activity in these areas. However, the respondents were fairly distributed in low (20,000–90,000), middle (91,000–110,000) and high (111,000 and above) annual income categories.

Incidentally, over 85% of the respondents are married or widowed as expected, while only a few were bachelor-household heads. The average household size was 4–6 persons which predominated while large households of 7 persons and above made up about 10% of the sample. In terms of education, the respondents are largely illiterate with a few possessing the equivalent of secondary school certificate.

With regards to occupation, the respondents are clustered around the four main occupations in these rural enclaves viz. farming, hunting, petty trading, and palm-tapping. The occupations of the respondents are shown in Table 9.1.

The above occupational categories reflect the level of economic activity in these communities. Given the low population of these communities, the non-availability of grid energy, very poor infrastructure base (lack of access roads and even portable water) and what the respondents saw as government neglect over the years, economic activities are severely limited and localized. Be the above as it may, the demographic characteristics above should be taken as representative of the members of these communities.

Table 9.1 Distribution of respondents by occupation

Occupation	Quantity	Percentage
Farmers	20	36
Petty traders (mostly women)	14	25
Palm tappers	06	21
Hunters	12	11
Others (commercial motorcyclists, shoe repairers, etc.)	04	7
Total	**56**	**100**

9.6.2 Knowledge of SHS by the Respondents

Interestingly, an overwhelming majority of the respondents have either seen or heard about SHS. Contrary to our expectations, some of the respondents showed a more than rudimentary knowledge of the system. However, almost all of them saw it as the preserve of the privileged, and in some cases, saw their residences as not fit enough for the SHS. In a typical case, one of them stated, 'yes, I know the solar thing and I know it gives people light in the night. But I cannot see myself possessing it, is it in this house or another that I would put something like that? It is for people who live in good houses'.[2] Another also quipped, 'I know about the solar energy, I have seen it in someone's house in Enugu [the state capital] but we are village people here, and we cannot dream of such a thing. It is for people in the big towns like Nsukka'.[3]

9.6.3 Willingness to Adopt the SHS

There was largely no ambivalence here as almost all the respondents expressed willingness to adopt the SHS. They were also unanimous in stating that their communities would gladly offer land for the citing of a mini-grid. The general mood was that the communities which are not in the national grid would heartedly welcome any form of help in meeting their energy needs. Typical of the above sentiments is the opinion, 'yes, I would readily accept the solar in my house. It would provide us light and even reduce the cost of fuel and the noise made by the generator of neighbours in the night'.[4] Another respondent while expressing willingness to adopt stated that the SHS would be beneficial in terms of, 'seeing at night and watching TV for those that have it. As for me, it would help me charge my [mobile] phone and stop going to charge it at the market as I now do'.[5]

[2] Farmer in his early 40s, Itchi (16 September 2021).

[3] Commercial motorcyclist in his mid-30s, Nomeh Unateze (17 August 2021).

[4] Farmer in his 40s, Ugwu Afor, Nomeh (14 August 2021).

[5] 60-year-old hunter, Afor Nomeh (18 August 2021).

Apart from three respondents who showed no willingness, but were rather pessimistic, the rest were willing to adopt. In the views of one of the pessimists, 'I cannot say whether I would adopt or not until I see it and know what is involved. This would not be the first time we have heard things from government or people like you and nothing eventually happened'.[6] A view which ironically underlines the general distrust of local or rural people with regards to programmes and promises from the government or its agencies. Distrust evidently built over years of unmet expectations and unkept promises.

However, the above willingness to adopt was expressed without knowledge of the financial implications or economic cost of adoption and the fact that willingness often comes at a cost. Therefore, it would be interesting to ascertain how prepared these people are to match their adoption willingness with money.

9.6.4 Socioeconomic Factors in Adoption

Predictably, this was a deal breaker in these communities. As the sociodemographic analysis showed, those who could be regarded as high-income earners in these communities earn around ₦120,000 or slightly above per annum (roughly equivalent to less than $300 US). However, our investigation reveals that the average cost of installing even basic SHS (which is what most households in these communities need) is about ₦300,000 (about three times the annual income of the high earners in these communities). The above suggests that a community mini-grid approach may work better as it could realistically reduce the economic burden on these households. To further gauge how economically committed these respondents are to their adoption willingness, we sought to ascertain the percentage of their annual income they could put into adopting the SHS or energy from a mini-grid. The responses are shown in Table 9.2.

As shown in Table 9.2, a good number of the respondents are not willing to devote more than 15% of their annual income to adoption. In

[6] 55-year-old shoe repairer, Afor Nomeh (25 August 2021).

Table 9.2 Distribution of respondents by income allocation to SHS adoption

Potential allocation to SHS	Number	Percentage
8–15%	20	36
16–25%	16	29
26–35%	12	21
36% and above	08	14
Total	**56**	**100**

fact, only about 14% of these respondents are willing to devote more than 35% of their income to adoption (only one of the respondents stated willingness to devote 40% of his yearly earnings to adoption).

Perhaps epitomizing the results in Table 9.2 is the contention:

> [T]here are many pressing needs in my family. So, devoting any reasonable amount of money to the solar energy adoption may be impossible unless we either stop feeding or the children stop school. It is going to be very difficult for me and many others in this village.[7]

9.6.5 Perceptions and Beliefs Affecting Adoption of SHS

There was generally no identified cultural barrier to adoption and the people seem to overwhelmingly believe that their communities would be willing to give land to establish mini-grids which is one of the intervention programmes of the REA in Nigeria. The only belief encountered ranged from those who stated that the installation of the SHS panels on roofs makes the water usually collected from this source contaminated (a lot of these people depend on such source of water for cooking, bathing and other domestic uses); those who did not believe in its efficiency and ability to meet their household needs; to those who argued that the adoption of the SHS would condemn them to be perpetually cut off from the national grid. For instance:

[7] Cassava farmer and garri processor in his mid-50s, Itchi (18 September 2021).

> we need to be careful with this solar energy thing, it might be a way to make us source our own energy. The government brought light to other nearby communities and left us out, why? This thing [SHS] may be a ruse by the government to wash its hands off bringing light to us unlike others.[8]

Arguing on a similar note, a young father in his early 30s held:

> I am just looking at how things would work in this country. How come we are now being indirectly encouraged to source for light from another source and not NEPA [old name of the public grid manager]? Other people have come here also preaching about solar energy, we would need the government to do what is its responsibility, that is give us light like others.[9]

9.6.6 Gender Issues in Adoption of SHS in Off-Grid Rural Enclaves

The study was equally interested in the extent to which renewables like SHS would live up to their touted ability to address gender inequalities especially in rural communities. Thus, we are driven to understand how energy access and adoption are influenced by gender (see Winther et al., 2020).

Interestingly, all the female respondents in the sample stated willingness to adopt the SHS, and none of them were in the category of those who want to devote the lowest percentage of their income to adoption of SHS. However, the disposition of women towards adoption of the SHS may have something to do with the fact that they are seen as the main demographic category to benefit. In fact, the respondents were asked to indicate what segment of the population would benefit most from SHS adoption. The results are shown in Table 9.3.

Table 9.3 shows that the two groups seen as likely to benefit most from the SHS are youth and women. Several respondents stated that

---

[8] Primary school teacher in her late 40s, Itchi (24 September 2021).

[9] Nomeh Unateze (21 August 2021).

Table 9.3 Distribution of respondents by opinion on the group likely to benefit most from SHS

Category	Number	Percentage
Men	5	9
Women	31	55
Youth	14	25
Children	6	11
Total	**56**	**100**

the youth need the SHS specially to charge mobile phones and watch television, but a greater number stated that women were the likely prime beneficiaries since they are the ones who do all sorts of domestic chores and help the young children with their homework at night.

One of the male respondents interviewed stated matter-of-factly, 'the women are the ones who would benefit the most; they are the ones who really need the light. They always have things to do all the time so long as they are awake'.[10] Further highlighting the above, another male interviewee opined, 'of course, the women need the light most. They are the ones who cook at night, process food, maintain the house. They are always busy and having light at night would be helpful to them'.[11] The women themselves are not with a different perspective on this. One stated, 'we are the ones who need the light especially at night. It would make life easier and in fact women in this village would live longer if they had light at night'.[12] Agreeing, a prominent woman leader averred, 'it would be like a dream come true for most women. For me personally it would mean taking better care of my family, spending quality time at night and performing various chores including cooking without much stress'.[13]

As the foregoing findings show, over 50% of the respondents (including both males and females) saw the SHS as more beneficial to the women. In the views of one of the respondents, 'women are the ones who perform chores like cooking, sewing and even thrashing of crops in the

[10] 65-year-old gatekeeper, Itchi (23 September 2021).

[11] Local titled man in his late 60s, Nomeh Unateze (20 August 2021).

[12] Petty trader in her late 30s, Itchi (17 September 2021).

[13] Woman leader in her mid-40s, Nomeh Unateze (20 August 2021).

night. They need the light for these and even taking care of young children and babies'.[14] Therefore, in a manner of putting it while SHS may not thaw or erode the structural barriers of inequality in rural communities, it could empower women and make them better able to deal with their everyday household chores and providing care for their children.

9.7 Discussion

Even from a rudimentary scale or perspective, the SHS which guarantees access to basic electricity can improve quality of life in the rural areas. Thus, the findings of the study reaffirm the belief that renewable energy in off-grid rural communities can facilitate socio-economic progress (see Amin, 2019). In other words, the mere access to such basic energy services or services as mobile phone charging and lighting has significant socio-economic benefits in the form of reduced spending on traditional fuels, better lighting, and even enhanced connectivity (GOGLA, 2018). The above sentiments are perhaps better captured in the contention that off-grid technologies with their (distributed and decentralized forms) nature, 'offers the opportunity to maximize the socioeconomic benefits of energy access by engaging local capacities along different segments of the value chain' (IRENA, 2019: 9). So, the findings underline the common truism that, SHS offers obvious economic benefits since it can reduce the cost of energy for households who previously spent heavily on such other alternatives like kerosene and battery powered torches (see REA, 2017).

Be the above as it may, the findings of the present study also reveal that the respondents, despite being resident in rural enclaves, are familiar with what the SHS is in general, and a few even stated that some people had come to them with proposals about installing SHS in their homes. However, the above familiarity and knowledge of the system do not guarantee the adoption of the system since there are economic considerations involved in this decision. Hence, while the respondents overwhelmingly

[14] Household head in his 60s, Nomeh Unateze (23 August 2021).

stated willingness to adopt, their economic status especially with reference to the percentage they are willing to commit to installing SHS and the cost of such installation makes adoption a likely uphill task for these people. However, these findings resonate with earlier studies that show that economic status is very crucial to adoption of renewable energy (see, Anugwom et al., 2020).

Despite the above observations, the findings equally align with the sentiments that rural dwellers would likely adopt SHS if economic wherewithal permits. While willingness-to-pay (WTP) may be critical in decisions regarding off-grid solutions for rural areas, there is need to understand that there is a difference between WTP and ability-to-pay (ATP). As the present study clearly shows, while a good number of households or respondents are willing to pay, economic constraints limit translating this willingness to actual payment or capacity to pay. Therefore, despite acknowledged low socio-economic status of most rural dwellers, SHS appears attractive since it is still one of the most affordable and accessible energy sources. In fact, it had been reported that there is a general and significant drop of between 73 and 80% in both the cost of the solar PV module and even LED lights and batteries between 2009 and 2016 (IFC, 2018; IRENA, 2018).

Even though a case can be made that adoption of the SHS is not solely driven by economic factors (see Ojong, 2021a), low economic status of end-users and the economic or commercial instability of a given location may affect both adoption and investment in the technology in a very significant sense. The above fact is borne out by our findings which indicate that while most rural households expressed willingness to adopt, their economic situation may imperil this wish. Thus, in rural Nigeria, low economic status of rural dwellers features prominently as bulwark to adoption. The situation in Nigeria, incidentally, is that most of the off-grid rural areas are typically located in interior areas often with daunting spatial or geographical characteristics that make access difficult. Apart from these physical features, such communities as the two we studied show, are usually characterized by very low economic and commercial activity, and populated either by subsistence farmers and old people or young people looking for the next opportunity to migrate to the cities. So, such locations are not attractive to investors who would surely be worried and warded off by the apparent very low returns on investment in renewable energy technology.

In the absence of a viable market or robust financial system that either props up the economic capacity of end-users or mobilizes technology investors and innovators, investment in off-grid renewables becomes very difficult and hardly viable. The above brings up the issue of role of subsidies and economic incentives on adoption. Studies show that subsidies greatly increase the uptake of solar energy (see Grimm & Peters, 2016; Meriggi et al., 2021). In other words, subsidy enables households to overcome the financial or economic burden of adoption, at least in the short run.

There is apparently no contesting the reality that linking communities, especially off-grid communities to energy sources are very important to overall goals of social inclusion. Interestingly, off-grid energy systems like SHS have the advantage or capacity to reach rural and remote areas despite the nature of their topography or physical features (see Jung et al., 2018; Lal & Raturi, 2012). While efforts to cover off-grid communities in energy initiatives forms part of achieving this objective of the sustainable development goals (SDGs), the efforts to understand and accommodate how their beliefs and perceptions or social heritage affects adoption and usage of renewable energy are critical components of the desire to achieve a fit between spatial-social location and energy sources for different communities and regions. Thus,

> [C]urrently, the sustainable development goals (SDGs) have made explicit the need to ensure energy production capacities in every region no matter how isolated and reduce the dependence of communities on conventional electrical systems. Each geographical area has an energy potential derived from its renewable natural resources. This makes knowledge of the communities and their social, cultural and environmental potentials among others, indispensable. (Colmenares-Quintero et al., 2020: 7)

Be this as it may, the study here shows no community-wide beliefs and values that could undermine the adoption of SHS while the respondents see the communities as willing to give land and space for mini-grid installation if there is need. However, at the level of the individual, there are pockets of beliefs and stereotypical ideas of the deleterious effects of solar panels on water collected from the roof; and the fact that one's dwelling unit must be good enough and modern before the individual aspires to such convenience. In fact, a good number of the respondents see their houses as unfit for SHS installation.

The findings generally agree with the contention that improving access to affordable and reliable energy can increase income, improve productivity, and drive socio-economic development (IRENA, 2016). While the above benefits are general, they are much more influential and incisive in the rural enclaves than the urban areas. Rural areas are incidentally the agricultural belt and food sources of urban dwellers and improving or enabling access to energy in these areas would tremendously improve productivity and livelihood systems in general and enhance inclusion in development.

The study also unravelled the gender dimension to SHS adoption in these communities. This is by no means a novel dimension to the discourse on energy access in Africa. As a matter of fact, renewable energy, especially solar energy, has been examined from its ability to empower women in Africa (see Hirmer & Guthrie, 2017; Winther et al., 2018). The findings show that off-grid solar energy may help women perform household chores better, and even engage in or expand micro-economic opportunities.

According to Ojong (2021a), it is necessary to examine the link between SHS uptake, gender and other forms of social difference in the case of a developing area like sub-Saharan Africa since the obvious impetus behind recent surge in SHS's uptake is to decrease or lessen spatial inequalities in the access to energy and/or power supply inequalities and injustices. However, our concern here is to examine the relationship between gender and SHS adoption in a typical off-grid rural community in Nigeria. Our findings indicate that while men were more aware of the SHS and other renewables, more women than men showed a disposition towards adoption (30–40%). Perhaps the above situation may be related to women's perception that SHS may make their lives better in some ways and even impact on the quality of life of the family particularly children who can utilize the light from SHS to extend their study hours. In fact, the findings equally establish that community members generally perceive both the youth and women as likely prime beneficiaries of the SHS.

This thinking is in line with the observation of IRENA (2019) that off-grid renewable energy has the potential to empower rural communities especially the youth and women. Incidentally, studies from other places indicate that RE at home can impact positively on women (see Gray-Anatki, 2016). Despite the above, one should be cautious in assuming that adoption of SHS makes women automatic beneficiaries since adoption of the SHS can even reproduce existing inequality in the society (see Gray-Anatki, 2016; Ojong, 2021a, 2022; Stock & Birkenholtz, 2020).

The findings of the study generally concur with the postulation of the 4As approach to energy adoption. To this end, it has unravelled especially the influential roles of both affordability and acceptance in adoption of renewable energy. However, while our information reveals that there is general acceptance of SHS as renewable energy source, it raises issues regarding affordability. Thus, the ability of rural dwellers to bear the economic burden of the SHS is critical in the adoption process. The economic quandary results from both the limited financial capacity of these rural dwellers and their unwillingness to devote considerable percentage of their annual earnings to the adoption of SHS as shown in the study. Perhaps, the mini-grid solution may be more viable and would lessen the household financial burden of adoption.

In addition to the foregoing, our study would suggest that some major issues with SHS adoption and usage in typical rural areas include design considerations (avoiding poor design); empowerment (of rural households) especially in terms of knowledge and nullifying beliefs; end-user satisfaction (in terms of hours of light supply and meeting heavier household needs for unlimited lighting); transfer of maintenance skills especially for rudimentary tasks like changing bulbs; financial capacity of rural households (to pay for installation and even maintenance).

9.8 Conclusion

Probably the greatest drawback of SHS adoption by rural dwellers as evidenced in this study is the relatively initial high installation cost though this has not diminished the relevance of SHS as an emerging alternative source of energy in these locations which is further boosted by its simple nature and emission free generation of energy (see Kabiri et al., 2018). But as Kabiri et al. rightly argued, over the years the cost of SHS has significantly decreased while the efficiency has increased over the same period. Also, ongoing research and empirical studies indicate further whittling down of the cost of SHS and improvement in efficiency and reliability.

However, one crucial issue that has been unravelled by this study is the need to make a nuanced distinction between willingness to pay and ability to pay for renewable energy. While WTP may be critical in decisions regarding off-grid solutions for rural areas, there is need to understand that there is a difference between WTP and ATP. As the present study clearly shows while a good number of households or respondents are willing to pay, economic constraints limit translating this willingness to actual payment or capacity to pay. As the cases of Senegal, Rwanda and Burkina Faso indicate willingness to pay for electricity diminishes as households' income declines (Sievert & Steinbuks, 2020).

One touted route to improve and scale-up energy/electrification access in Nigeria is through improving the attractiveness of off-grid solutions. In this sense, there have been moves and strategies by the REA and the federal government to create an enabling environment for the growth of the off-grid market. Such strategies which range from provision of enabling regulations, de-risking projects, streamlining competitive tendering process to provision of finance especially through the World Bank and helping with identifying and selecting sites (REA, 2017), are, incidentally, tied to attracting private sector investors to the mini-grid market. However, apart from the disconnect often seen between these strategies and reality, the influence of political factors and the traditional neglect of social and cultural forces have bedevilled private investment in this area. In fact, apart from the turbine projects in the Niger Delta and a few other select sites across the nation, not much has been done in the area of scaling-up renewable energy use and adoption.

As the REA (2017) contends, off-grid solutions can be very viable and could unlock an enormous market opportunity. In other words, off-grid solutions are viable in the country not only because of the availability of resources for the technology but equally because of the market opportunity it portends in the sub-Saharan African region.

There is no overstating the need for popularization of renewable energy sources especially in the rural areas where farming activities make energy needs of households considerable. The SHS offers the opportunity for citizens or ordinary people to get on board in the quest for renewable energy given its relative cheap cost and friendly technology. However, citizens participation in both renewable energy policy and planning have been perceived as influential in ensuring public acceptance of renewable energy schemes (see Botta, 2019; Warren & McFadyen, 2010). In other words, getting the community members or rural dwellers involved at all stages in renewable energy adoption facilitates both the adoption process and creation of a critical mass of adopters who can stimulate further adoption in the community.

As the IFC (2018) posits such factors as rising incomes, expansion of infrastructure, rural connectivity and easily available consumer finance can increase the appeal of off-grid energy solutions. However, these factors are either attainable or likely where there is a concerted and systematic effort. But in Nigeria, the situation is radically different. This is unfortunate since lack of electricity access or reliable alternative energy sources hampers both growth and general development in rural areas in the developing world (see Laufer & Schafer, 2011).

The findings of the study suggest that even a mini-grid option may not be affordable in these communities except where there are massive economic incentives from the government. It also implies that private sector investment may be difficult to attract since these rural enclaves offer limited prospects of recouping or making any profit from this in both the short and medium run. Therefore, off-grid electricity would probably work in Nigeria's rural areas from the perspective of adopting the community mini-grid approach supported by the infusion of considerable financial incentives from the government. Private sector investment may thus be anchored on substantial financial incentives from the government especially in the short-run period.

References

Amaza, M., & Agbaegbu, C. (2018, May). Nigeria: The next big frontier for rural electricity access. *Power for All*. https://www.powerforall.org>nigeria

Amin, A. Z. (2019). Preface. In IRENA (Ed.), *Off-grid renewable energy solutions to expand electricity access: An opportunity not to be missed*. IRENA.

Anderson, B., Bohmelt, T., & Ward, H. (2017). Public opinion and environmental policy output: A cross-national analysis of energy policies in Europe. *Environmental Research Letters II.*

Anugwom, E. E., Anugwom, K. N., & Eya, O. I. (2020). Clean energy transition in a developing society: Perceptions on the socioeconomic determinants of solar home systems adoption among urban households in south-eastern Nigeria. *African Journal of Science, Technology, Innovation and Development*. https://doi.org/10.1080/20421338.2020.1764176

Baitanayeva, B., Yerezhepova, A., Nurmanova, B., & Andabayeva, G. (2020). *Current state and problems of alternative energy development in the world*. E3S Web of Conferences 159, 07004. https://doi.org/10.1051/e3sconf/202015907004

Ben-Iwo, J., Manovic, V., & Longhurst, P. (2016). Biomass resources and biofuels potential for the production of transportation fuels in Nigeria. *Renewable and Sustainable Energy Reviews, 63*, 172–192.

Boamah, F. (2020). Emerging low-carbon energy landscapes and energy innovation dilemmas in the Kenyan periphery. *Annals of American Association of Geographers, 110*, 145–165.

Botta, E. (2019). An experimental approach to climate finance: The impact of auction design and policy uncertainty on renewable energy equity costs in Europe. *Energy Policy*, 133. https://doi.org/10.1016/j.enpol.2019.06.047

Chambers, R. (1981). Rapid rural appraisal: Rationale and repertoire. *Public Administration and Development, 1* (2): 95–106.

Cherp, A., & Jewell, J. (2014). The concept of energy security: Beyond the four As. *Energy Policy, 75*, 415–421.
Colmenares-Quintero, R. F., Benavides-Castillo, J. M., Rojas, N., & Stansfield, K. E. (2020). Community perceptions, beliefs, and acceptability of renewable energies projects; a systematic mapping study. *Cogent Psychology, 7*(1), 171715534. https://doi.org/10.1080/23311908.20201715534
Delicado, A., Figueiredo, E., & Silva, L. (2016). Community perceptions of renewable energies in Portugal: Impacts on environment, landscape and local development. *Energy Research and Social Science, 13*, 84–93.
Devine-Wright, P. (2005). Local aspects of UK renewable energy development: Exploring public beliefs and policy implications. *Local Environment, 10*(1), 57–69.
Diji, C. J., & Bamiro, O. A. (2012). A short excursion into Nigeria energy supply mix. In A. O. Deneloye, L. O. Oyekunle, & A. Ogunbayo (Eds.), *Ogunye: Giant strides in engineering education research and innovations*. University of Lagos Press.
Eun-Sung, K., Ji-Burn, C. H., & Yungseok, S. (2018). Korean traditional beliefs and renewable energy transitions: Pungsu, shamanism and the local perception of wind turbines. *Energy Research and Social Sciences, 46*, 262–273.
Gentle, P., Thwaites, R., Race, D., & Alexander, K. (2013). *Changing role of local institutions to enable individual and collective actions for adapting to climate change*. University of Wollongong, Australia.
Global Off-Grid Lighting Association (GOGLA). (2018). *Powering opportunity: The economic impact of off-grid solar*. www.gogla.org/sites/default/files/resource.docs/gogla_powering_opportunity_es.pdf
Gray-Anatki, M. (2016). Now we have equality: A feminist political ecology analysis of carbon markets in Oaxaca, Mexico. *Journal of Latin American Geography, 15*, 49–66.
Grimm, M., & Peters, J. (2016). Solar off grid markets in Africa. Recent dynamics and the rule of branded products. *Field Actions Research, 15*, 160–163.
Hirmer, S., & Guthrie, P. (2017). The benefits of energy appliances in the off-grid energy sector based on seven off-grid initiatives in rural Uganda. *Renewable and Sustainable Energy Review, 79*, 924–934.
Index mundi. (2019). *Nigeria—Access to electricity, rural (% of rural population)*. www.indexmundi.com/facts/Nigeria/access-to-electricity
International Finance Corporation (IFC). (2018). *Off-grid solar market trends report 2018*. International Finance Corporation.

IRENA. (2016). *Roadmap for a renewable energy future, 2016 Edition*. Abu Dhabi: International Renewable Energy Agency.

International Renewable Energy Agency (IRENA). (2018). *Renewable power generation costs in 2017*. IRENA. www.irena.org/media/files/IRENA/Agency/Publication/2018/Jan/IRENA/_2017_Power_costs_2018.pdf

International Renewable Energy Agency (IRENA). (2019). *Off-grid renewable energy solutions to expand electricity access: An opportunity not to be missed*. IRENA.

Johansen, K., & Emborg, J. (2018). Wind farm acceptance for sale? Evidence from the Danish wind farm co-ownership scheme. *Energy Policy, 117*, 413–422.

Jung, Y., Kim, Y. D., Moon, J., & Lim, S. (2018). A scenario analysis of solar photovoltaic grid parity in the Maldives: The case of Malihini resort. *Sustainability, 10*, 4045.

Kabir, E., Kumar, P., Kumar, S., Adelodun, A. A., & Kim, K. H. (2018). Solar energy: Potential and future prospects. *Renewable and Sustainable Energy Reviews, 82*, 894–900.

Komendatova, N., Yazadanpanah, M., & Schafiei, R. (2018). Studying young people's views on deployment of renewable energy sources in Iran through the lenses of social cognitive theory. *AIMS Energy, 6*(2), 216–228.

Lal, S., & Raturi, A. (2012). Techno economic analysis of a hybrid mini-grid system for Fiji Islands. *International Journal of Energy and Environmental Engineering, 3*, 1–10.

Laufer, D., & Schafer, M. (2011). The implementation of solar home systems as a poverty reduction strategy—A case study in Sri Lanka. *Energy and Sustainable Development, 15*, 330–336.

Meriggi, N. F., Bulte, E., & Mobarak, A. M. (2021). Subsidies for technology adoption: Experimental evidence from rural Cameroon. *Journal of Development Economics, 153*, 102710.

National Bureau of Statistics (NBS). (2006). *Annual abstract of statistics*. Abuja: NBS.

National Renewable Energy Laboratory (NREL). (2012). *U.S. renewable energy technical potentials: A GIS-based analysis*. NREL.

Newkirk, M. (2016, December 2). How solar power works—On-grid, off-grid and hybrid systems. *Clean Energy Reviews*. https://www.cleanenergyreviews.info/blog/2014/5/4/how-solar-works

Ojong, N. (2021a). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.

Ojong, N. (2021b). Solar home systems in South Asia: Examining adoption, energy consumption, and social practices. *Sustainability, 13*, 7754. https://doi.org/10.3390/su/3147754

Ojong, N. (2022). Energizing entrepreneurship. *Nature Energy*. https://doi.org/10.1038/s41560-022-01014-9

Rural Electrification Agency (REA). (2017). *The off-grid opportunity in Nigeria: Upscaling mini-grids for least cost and timely access to electricity*. https://rea.gov.ng

Samad, H. A., Khardker, S. R., Asaduzzaman, M., & Yunus, M. (2013). *The benefits of the solar home systems; An analysis from Bangladesh* (Policy Research Working Paper No. 6724). World Bank.

Shove, E., Partzar, M., & Watson, M. (2012). *The dynamics of social practice: Everyday life and how it changes*. Sage.

Sievert, M., & Steinbuks, J. (2020, April). Willingness to pay for electricity access in extreme poverty: Evidence from Sub-Saharan Africa. *World Development*, 128. https://doi.org/10.1016/j.worlddev.2019.104859

Sovacool, B., Hess, D., Amir, S., & Geels, F. (2020). Sociotechnical agendas: Reviewing future directions for energy and climate research. *Energy, Research, and Social Science, 70*, 1–35.

Sposato, R. G., & Hampl, N. (2018). Worldviews as predictors of wind and solar energy support in Austria: Bridging social acceptance and risk perception research. *Energy Research and Social Science, 42*, 237–246.

Stock, R., & Birkenholtz, T. (2020). Photons vs firewood: Female (dis) empowerment by solar power in India. *Gender, Place and Culture, 27*, 1628–1651.

Strauss, S., & Love, S. T. (2013). Cultures of energy in the twenty-first century. In *Cultures of energy: Power, practices, technologies* (pp. 10–38). Left Coast Press.

Trading Economics. (2022). *Nigeria—Rural population.* www.tradingeconomics.com

Warren, C. R., & McFadyen, M. (2010). Does community ownership affect public attitudes to wind energy? A case study from South-west Scotland. *Land Use Policy, 27*, 204–213.

Winther, T., Ulsrud, K., & Saini, A. (2018). Solar powered electricity access: Implications for women's empowerment in rural Kenya. *Energy Research and Social Science, 44*, 61–74.

Winther, T., Ulsrud, K., Matinga, M., Govindan, M., Gill, B., Anjali, S., Brahmachari, D.,Palit, D., & Murali, R. (2020). In the light of what we cannot see: Exploring the interconnections between gender and electricity access. *Energy Research and Social Science, 60*, 1–18.

World Bank. (2014). *For up to 800 million rural poor, a strong World Bank commitment to agriculture*. www.worldbank.org/en/news/feature/2014/11/12/for-up-to-800-million-rural-poor-a-strong-world-bank-commitment-to-agriculture

10

Assessing Enablers and Barriers to Off-Grid Solar Electrification in Urban Ghana

Wilson Kodwo McWilson and Gloria Mensah

10.1 Introduction

Central to realizing sustainable development is the sustainability of energy systems (Villavicencio Calzadilla & Mauger, 2018). The development trajectory of almost every country reveals the pivotal role of electricity and other forms of energy in promoting social and economic wellbeing. Energy remains a significant factor for economic prosperity and social wellbeing, yet the dynamics of population growth and higher energy demand and consumption pose an imminent energy shortage (Sun et al., 2021). Many basic needs of society, including lighting,

W. K. McWilson (✉)
Hong Kong Polytechnic University, Hung Hom, Hong Kong, China
e-mail: 20073348R@connect.polyu.hk

G. Mensah
Lingnan University, Tuen Mun, Hong Kong, China

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_10

cooking, phone charging, etc., require electricity (Ojong, 2021a; Yang et al., 2021).

Globally, an estimated 900 million people do not have electricity access (International Energy Agency, 2018). Approximately 621 million people in sub-Saharan Africa have no access to electricity, and several hundred million are likely to be without electricity by 2030, a phenomenon that counters the United Nations' Sustainable Development Goal 7—sustainable energy for all (Ojong, 2021b; Ulsrud, 2020; World Bank, 2015). Again, a significant proportion of the global population has unreliable and inadequate power supply despite being considered to have access to electricity. In sub-Saharan Africa (SSA), where more than half of the population lacks electricity access, most countries face a double tragedy in electrification. Indeed, not only are there low electricity access rates but erratic supply to those who have access.

Furthermore, the unfavourable energy systems in many developing countries have influenced the use of alternative energy sources that are consequential to human health. Ikejemba and Schuur (2016), for instance, note that the use of generators for electricity produces toxic fumes, which have wellbeing and environmental consequences. Again, the move from current unbalanced carbon-extensive systems to sustainable energy forms remains central to the Sustainable Development Goal 7, Target 7b, which seeks to 'expand infrastructure and upgrade technologies for supplying modern and sustainable energy services for all developing countries'.

Confronted with the pursuit of economic development through industrialization and ensuring the highest form of living standard for citizens, most governments in developing countries are unable to provide enough electricity to meet industrial needs and residential consumption (Baynes et al., 2011; Ye et al., 2018). Available methods of electricity provision in developing countries are often slanted towards fossil fuel and hydro generation mechanisms. Again, providing electricity through these means requires huge pecuniary investments and infrastructure. Not only do these electrification approaches require massive capital outlays, but they also have long gestation periods due to the bureaucracies and other processes involved in realizing them.

As energy challenges persist in the subregion, researchers and practitioners are grappling with finding sustainable solutions to these challenges. The need to transition to cleaner, cheaper and more reliable energy forms has tickled many innovations towards achieving this goal. Some of these include solar parks (SPs), wind electricity generators, and solar and wind-assisted parks (SWAPS) (Ikejemba & Schuur, 2016). Furthermore, in the wake of global warming concerns, the Intergovernmental Panel on Climate Change upheld at a 90% confidence level that this ecological crisis is human-induced by activities like burning fossil fuel (Obeng et al., 2008). Concurrently, there has been an upsurge in policies and research aiming to promote the adoption of renewable energy technologies in electricity provision (Mceachern & Hanson, 2008; Muchunku et al., 2018; Obeng et al., 2008). Baurzhan and Jenkins (2016) observe that about 30 countries in SSA seek to attain a significant share of electricity generated through renewable energy sources such as wind, geothermal, hydro and solar. Of these countries, nine intend to adopt grid-connected solar PV technology.

Many factors have been identified as critical to adopting and using renewable energy in Africa. Bugaje (2006) points out the need for a coalescence of appropriate resource management, social sustainability through equitable access and usage, institutional sustainability, and economic affordability to enable disadvantaged populations to access energy resources.

Pointing out that most African countries face fiscal constraints in the provision and, where existent, expansion of electrical power grid infrastructure, Bugaje (2006) suggests the need to develop and harness available renewable resources. More recently, studies have been skewed towards off-grid solar technologies for electrification in developing countries (Baurzhan & Jenkins, 2016; Mugisha et al., 2021; Urmee & Md, 2016).

Contrasting the various off-grid electrification options available in developing countries, Reiche et al. (n.d.) suggest that the solar-powered off-grid options remain the most economically feasible electrification option for many users. Yet, studies suggest that the capital cost of off-grid solar systems remains high (Baurzhan & Jenkins, 2016). For instance, a study conducted by the European Commission on electrification in

Africa found that the capital cost of PV systems costs approximately $6000–12,000 US per kWp (Baurzhan & Jenkins, 2016).

The literature on off-grid solar electrification has highlighted the benefits associated with it. Numerous studies have concluded that solar electrification reduce unsustainable energy forms such as kerosene in providing lighting; this goes to a large extent to reduce environmental pollution (Mahapatra et al., 2009). Furthermore, solar electrification, particularly in under electrified areas, has been noted to increase task efficiency. More importantly, in the wake of climate change concerns, solar electrification technologies provide environmentally sustainable energy for everyday life (Bisaga et al., 2021; Mishra & Behera, 2016; Sun et al., 2021).

The dynamics of energy demand, pricing, and ecological concerns in the wake of climate change challenges inform the use of renewable energy sources globally. While efforts continue to achieve the energy sustainability goals set in the Sustainable Development Goal 7, it is expedient for continuous efforts to identify plausible barriers and hindrances to adopting these systems. This is particularly important in reaching pivotal junctures that see these technologies adopted.

The energy justice framework has been used to address concerns within energy systems, from production to consumption (Mccauley & Jenkins, 2013). Drawing on the previous works on environmental justice (Bullard, 2005; Bullard et al., 1997), energy justice accentuates the need to consider social questions that bother on issues of access, affordability, distribution or the needs of people (Müller et al., 2021). Subjected to multiple conceptualizations, energy justice is often conceptualized as three overarching tenets; viz., distributive, recognition and procedural justice, or as principles connected to energy-related decisions such as availability and affordability. Jenkins (2018) suggested that such frameworks position energy justice as a functional tool for framing justice questions, thus enabling researchers to transcend the mere discussion of concepts to their application.

This chapter uses the energy justice framework to examine the enablers and barriers to adoption of off-grid solar technologies in urban Ghana. Targets have been set by the Ghanaian government to increase the adoption of renewable energy technologies, including off-grid solar technologies. The success of policies and programmes towards achieving this will call for a comprehensive understanding of the complexities of energy systems, alongside identifying the fundamental principles likely to influence their successful deployment. This is expedient, considering that off-grid solar technologies are relatively cheaper when compared to conventional electrification technologies. We further discuss plausible policy strategies that can be adopted to ensure the fair and equitable distribution of off-grid solar technologies in urban Ghana.

10.2 The Dynamics of Electricity Supply and Consumption in Ghana

Ghana currently has a population of about 30.8 million and a GDP of about $72.35 billion US (Ghana Statistical Service, 2021; World Bank, 2020). In 2018, the country had installed 4889 megawatts (MW) of generation capacity, producing approximately 16 terawatt-hours (TWh) of electricity annually.

Ghana has relatively high electricity access in the Sub-Saharan region, yet only 42% of grid-connected households have reliable electricity supply, a phenomenon that ranks among the top five problems the country faces (Oyuke et al., 2016). Despite the strides made in electricity provision in Ghana since 1989 through the National Electrification Scheme, the country faces several energy challenges. The past few decades have been characterized by frequent power outages, load shedding and erratic supply, chiefly due to the country's overdependence on hydro-generated electricity (Asumadu-Sarkodie & Owusu, 2016). Despite Ghana's commitment to ensuring universal access to electricity by 2020, it could not meet this target nor ensure that electricity supply was reliable and affordable (Amankwaa & Gough, 2021). More precarious is the observation that electricity demand in Ghana increases at 10% per annum (Agyekum et al., 2020). Again, the dependence on conventional energy sources, juxtaposing the increasing cost of fuel for running those energy generation systems, has constrained the ability to provide enough electricity to meet this demand. Accordingly, renewable energy and nuclear options have been touted as sustainable alternatives (Agyekum et al., 2020; Asuamah et al., 2021; Asumadu-Sarkodie & Owusu, 2016; Gauri et al., 2015).

In Ghana, the renewable energy sector is plagued with limited investment, the inability of the government to attract private investments, regulatory uncertainty, and governance challenges (Adenle, 2020). All these challenges culminate to derail the effective uptake of solar energy technologies. Alongside these challenges, the country targets generating not less than 10% of electricity from renewable technologies by 2030 (Ghana Energy Commission, 2019).

The economic, social, cultural and environmental benefits of renewable energy sources have been emphasized in the literature. For instance, Marktanner and Salman (2011) highlight the economic cost benefits, geopolitical relevance and socio-economic ramifications of renewable energy. Asumadu-Sarkodie and Owusu (2016) also studied the economic viability of grid-connected PV development in Ghana, identifying suitable locations for their implementation. On the off-grid option, many studies in Ghana have focused on rural electrification considering the challenges of the national electricity grid reaching off-grid communities (Javadi et al., 2020; Obeng, 2013; Obeng & Evers, 2010). However, in the face of Ghana's energy crisis and the emergence and proliferation of off-grid solar electrification technologies, it is expedient to bring urban areas into focus in the adoption or otherwise of these technologies. This is premised on the energy distribution and access challenges that both the rural and urban are confronted with. Furthermore, with renewable energy options gaining prominence, the question remains what economic, social, cultural, and political factors can support the uptake or rejection of off-grid solar electrification technologies among urban households in Ghana.

10.3 Literature Review: Barriers and Enablers of Off-Grid Solar Technologies Adoption

The implementation of energy policies may pose a great hurdle to policymakers and all relevant stakeholders, considering the many operational aspects spanning across politics, environment, society and management among others (Wang et al., 2008). In the implementation of such policies, barriers are those factors that hinder the success of the policies whereas enablers are those that promote the success of such policies. This section reviews the enablers and drivers for the adoption of off-grid solar electrification technologies in the literature.

Off-grid solar electrification technologies may foster social inclusion or exclusion. This may be influenced by a number of factors which may be cultural and social (Karatayev et al., 2016). Focusing on India, Akter and Bagchi (2021) studied the inclusiveness of off-grid solar power and its implications for social inequality. The authors found that off-grid solar technologies were instrumental in poverty alleviation. Pointing out to factors that influence the adoption of these electrification technologies, they found that awareness was critical. Furthermore, they note that affordability plays a significant role in adopting off-grid solar electrification technologies; poorer households and those belonging to lower social classes (caste system) have low adoption rates. Furthermore, the dichotomy of social classes and the adoption of these technologies amplify the social prestige associated with using off-grid solar electrification systems. Oyuke et al. (2016) found that the possibility of these technologies to project images of affluence, which may draw the attention of vandals and armed robbers, influence the decision to adopt them or reject them. At the community level, studies have found that the inclusion of key stakeholders from the conception to implementation of off-grid solar electrification projects has positive effects on the adoption rate. In essence, participatory and collaborative initiatives founded on the principles of equity, transparency and accountability are very consequential to the adoption of off-grid solar electrification technologies.

Aklin et al. (2018) suggest that the economic cost of solar electrification technologies is consequential to their social acceptance. When new energy systems are perceived as expensive than conventional electrification options, end-users are more likely to reject them. Furthermore, the cost of setting up these technologies and maintaining them influences households' decision to adopt or reject them. For home-based enterprises (HBEs), households are often willing to adopt off-grid solar electrification technologies only when they are assured of such energy alternatives sustaining their business operations, thus generating additional income (Akter & Bagchi, 2021; Tong et al., 2015). Another factor important to adopting off-grid solar electrification technologies is the initial capital outlay. Numerous studies have noted that households with a higher propensity to spend are often willing to acquire these technologies; nevertheless, poorer households are often unwilling to adopt them due to the capital requirement. This manifests at the state level too, where many institutional agencies and government are often beset with the capital requirements of such solar electrification projects (Aklin et al., 2018; Simpson et al., 2021; Tong et al., 2015).

Several political factors influence the decision to adopt off-grid solar electrification systems. The availability of off-grid solar electrification systems on the market influences several factors from the price, based on the dynamics of demand and supply and the awareness of such technologies (Ondraczek, 2013; Williams & Sovacool, 2019). Government policies further influence the availability of these systems. For instance, Adenle (2020), studying solar technology opportunities and challenges in Africa, points out the need for clear policy directions to ensure availability of solar energy technologies and their adoption. Another political factor identified in the literature to influence the adoption of off-grid solar electrification technologies is the availability of incentives. These do not only influence the adoption of these technologies at the microlevel. Incentives taking the forms of tax holidays and duty-free imports, among others, attract investors and other business organizations as well as NGOs to embrace plausible pathways towards making off-grid solar electrification technologies available to end-users (Aklin et al., 2018; Girardeau et al., 2021; Schmidt et al., 2020; Simpson et al., 2021).

Furthermore, end-users of off-grid solar electrification systems are often keen on the quality of the technologies they adopt. This stems from the economic connotations of quality. Inferior or low-quality technologies are likely to increase maintenance costs and replacement costs which may deter the adoption of off-grid solar electrification technologies (Aklin et al., 2018).

10.4 Research Hypothesis

The research hypothesis is crucial to the completion of any research study. Through research hypothesis we learn all the critical elements of the research process that inform conclusions that are comprehensive in their reach (Toledo et al., 2011). A great point of departure for every research hypothesis is the research idea. Based on the research aim of identifying drivers and barriers to the adoption of off-grid solar electrification technologies using the energy justice framework, relevant justice principles were identified in the literature. These identified factors informed the hypotheses in this section. Based on the literature review, three broad principles, social, economic and political were identified and used in the hypotheses' formulation. The hypotheses are then illustrated in the conceptual framework in Fig. 10.1.

Hypothesis 1 Economic factors have a significant relationship with decision to adopt. This statement is true if the hypothesis is valid. Under other conditions, economic factors do not have any relations and are not consequential to the decision to adopt off-grid solar technologies.

Hypothesis 2 Political factors have a significant relationship with decision to adopt. This statement is true if the hypothesis is valid. Under other conditions, political factors do not have any relations and are not consequential to the decision to adopt off-grid solar technologies.

Hypothesis 3 Political factors have a significant relationship with economic factors since they are consequential to economic enablers for adopting off-grid solar electrification technologies. This statement is true if the hypothesis is valid. Under other conditions, political factors do not have any relations and are not consequential to economic factors for adopting off-grid solar technologies.

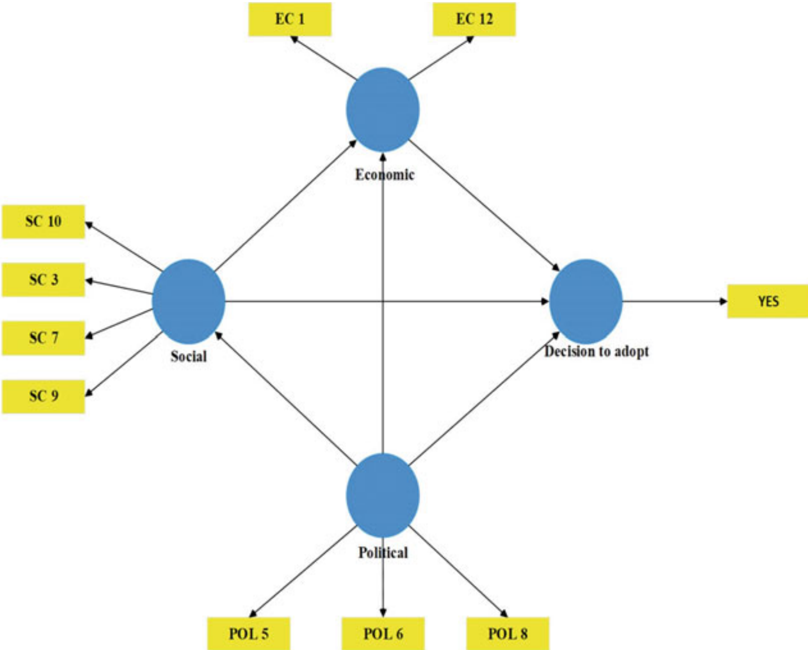

Fig. 10.1 Conceptual model: enablers and barriers of off-grid solar electrification

Hypothesis 4 Political factors have a significant relationship with social factors since they are consequential to social enablers for adopting off-grid solar electrification technologies. This statement is true if the hypothesis is valid. Under other conditions, social factors do not have any relations and are not consequential to economic factors for adopting off-grid solar technologies.

Hypothesis 5 Social factors have a significant relationship with decision to adopt. This statement is true if the hypothesis is valid. Under other conditions, social factors do not have any relations and are not consequential to the decision to adopt off-grid solar technologies.

Hypothesis 6 Social factors have a significant relationship with economic factors since they are consequential to economic enablers for adopting off-grid solar electrification technologies. This statement is true if the hypothesis is valid. Under other conditions, social factors do not have any relations and are not consequential to economic factors for adopting off-grid solar technologies.

10.5 Research Methodology

The research is epistemologically situated within the postpositivist philosophical and deductive reasoning. A cross-sectional research paradigm is adopted to achieve the objectives set out in this study. Cross-sectional research designs are ideal for obtaining empirical data from a defined population at a specific time. Furthermore, the lack of microlevel secondary data in Ghana on renewable energy technologies requires primary data collection. A mixed research approach is thus assumed for this study. Additionally, a mixed questionnaire survey was developed and used in data collection. The designed questionnaires were administered to consenting household heads in the study area.

The questionnaire for the study was designed based on the principles identified in the literature as vital to fostering energy justice. These factors were classified under economic, political, social and institutional themes. The questionnaire consisted of three parts. The first section surveyed respondents' demographic data, distribution and consumption the second, energy patterns. The last section invites research participants to rate the importance and criticality of a set of social, economic and institutional factors in influencing their adoption of off-grid solar technologies. A five-point Likert scale with (1 = extremely unlikely; 2 = somewhat likely; 3 = neither likely nor unlikely; 4 = somewhat likely; 5 = extremely likely) was adopted. Finally, the respondents were asked to explain their choice of influencing their adoption or otherwise of off-grid solar technologies.

10.5.1 Case Study, Sampling and Data Collection

The national capital of Ghana, Accra, was chosen as the geographical context for this study. This choice of is justified by the socio-economic fabric of this urban area. Being home to most of Ghana's industries and a high number of urbanites spanning a broad socioeconomic spectrum, Accra presents an ideal case for illuminating the ramifications of energy justice in the Ghanaian context. The Accra Metropolitan District was selected for the study through a multistage sampling approach.

The case study, Kaneshie, a suburb of Accra, is situated approximately 4 kilometres north of the city and located in the Accra Metropolitan District. Kaneshie represents an interesting case study considering it has focused on expanding national grid electrification in the past, signalling the electricity challenges they face (World Bank, 2019).

According to the 2010 population census, Kaneshie has a population of 31,140. This population size was used in determining the sample size for the study.

$$Sample\ size = \frac{Z^2 * (p) * (1 - p)}{c^2}$$

Z from the equation above is the confidence value which is 95%; the error margin is 5% which implies a confidence level of 1.960. Substituting these in the above formula, a sample size of 380 was required for the study. Due to the possibility of nonresponse from some research participants, 425 questionnaires were administered. However, only 239, representing 63% of the sample size of 380, were valid and therefore used in the data analysis.

The research participants were consenting household heads who were randomly sampled. Due to time and resource constraints, a convenient approach was adopted to ensure cost-efficiency. Data was collected during weekends as this is the time most people are home. Nevertheless, the possibility of missing out on households that could offer relevant information cannot be ruled out. During the fieldwork, respondents were first engaged to ensure they knew about off-grid solar technologies before the questionnaires were administered.

10.5.2 Data Analysis Technique—PLS-SEM

Limitations in other statistical techniques have rendered Structural Equation Modelling (SEM) a more convenient and rigorous analytical tool for this study (Ahmadabadi & Heravi, 2019; Eybpoosh et al., 2011). As a result, SEM is well suited to examining potential interacting effects among the three enabler constructs and developing a predictive model between enabler variables and off-grid solar electrification technology adoption. Therefore, either with the covariance-based structural equation modelling (CB-SEM) or partial least square structural equation modelling (PLS-SEM), thus the two types of SEM, the hypotheses put forward (Hypotheses 1–6) could be tested.

The CB-SEM is ideal for assessing existing hypotheses with a large sample size of data (i.e., > 200) that are usually distributed (Adabre et al., 2021). In contrast, the PLS-SEM is suitable for testing hypotheses with a relatively small non-normally distributed data sample size. Because this study aims to test hypotheses using data that is not normally distributed, the PLS-SEM is better for data analysis (Astrachan et al., 2014).

A sufficient sample for statistical testing was maintained, notwithstanding the PLS-SEM's relatively low sensitivity to sample size matched to the CB-SEM via achieving the basic requirements for statistical analysis. To fulfil the sample requirement of 30 subjects per the central limit theorem, 239 valid responses were obtained and deemed appropriate for statistical analyses. As a further requirement for employing the PLS-SEM, the estimated sample size should be more than ten times the maximum number of arrows pointing at a construct (Hair et al., 2012). From Fig. 10.1, a maximum number of three arrows point at the decision to adopt construct. Therefore, the required sample size should not be less than ten times the maximum number of arrows pointing at the decision to adopt the construct (i.e., $10 \times 3 = 30$). Since the sample size is 239 > 30, the data is considered more than suitable for statistical analysis using the PLS-SEM.

In the conduct of the PLS-SEM, two models are estimated, thus the measurement and the structural models. First and foremost, the measurement model was approximated by determining the relationships between the constructs (i.e., the enablers categories and decision to adopt) and their indicators. Reflective measurements by all constructs to their respective indicators were performed. Through validity and reliability checks, the measurement model was assessed. Composite reliability, Cronbach's alpha, and rho alpha were used for assessing how reliable the measurement model was. In assessing the validity of the measurement model, convergent validity (with the aid of factor loading and average variance extracted) and discriminant validity (through cross-loadings and Fornell and Lacker criterion) were employed. The structural model assessment followed the measurement model assessment, which established the potential relationships among the grouped enablers and the decision to adopt. The variance inflation factor (VIF) was used to check for the structural model's multicollinearity. Using bootstrapping analysis, a test of significance of the relationships (i.e., hypotheses) was conducted afterwards.

10.6 Results of Data Analysis

10.6.1 Demographic and Socio-Economic Characteristics

Demographic characteristics of households or research participants are vital to analyzing and understanding how these factors influence social, economic and cultural behaviour. Correspondingly, data was collected on the socio-economic characteristics of the survey respondents. The study, therefore, examined the households by gender, marital status, education level, household size, employment status, household income, electricity access and consumption patterns. These are presented discussed in this section.

In terms of gender composition, 165 of the 239 respondents, representing 69% of the respondents, were male, while 74 respondents, representing 31%, were female. This variable intends to observe the incongruities between household heads and the influence of the identified energy justice principles and adoption decisions. The low proportion of female-headed households corresponds with studies in many developing countries, including Ghana, highlighting the prevalence of male-headed households (Karakara & Osabuohien, 2020).

Table 10.1 Household income of respondents

Household Income	Frequency	Percent	Cumulative percent
Less than GHS 500	56	23.4	23.4
GHS 501–GHS 2000	150	62.8	86.2
GHS 2001–GH 3500	29	12.1	98.3
Above GH 3500	4	1.7	100.0
Total	**239**	**100.0**	

In terms of education, the majority of the respondents had at least primary education. The highest level of education attained by the respondents was a Ph.D. The level of education is expected to influence the adoption or rejection of off-grid solar electrification technologies. Some studies have found that higher levels of education have instigated the adoption of solar electrification technologies compared to lower education levels (Irfan et al., 2021; Mahalik et al., 2021; Malik & Ayop, 2020).

The choice of energy source adopted and consumed is influenced by household income. This variable was included to measure how income as an economic factor influences the adoption or rejection of off-grid solar electrification technologies. From Table 10.1, the majority of the respondents earn not more than GHS2000 per month (≈$325.07 US). This observation corresponds with the Living Standards index of household income for Ghana, considering the economy is mainly informal (Adusah-Poku & Takeuchi, 2019; Williams et al., 2020).

10.6.2 Access to Grid Electricity

When asked about access to electricity, 239 respondents, representing 100% of the respondents, indicated that they were connected to the national electricity grid. Yet when asked how often they experienced power outages daily, all respondents affirmed that they experienced not less than six power outages. In some instances, they spend as much as three days without electricity. These periods also marked other parts of the city having uninterrupted electricity supply. This observation further amplified the challenges that conventional electrification sources pose in the face of increasing population and demand.

When asked how much they spent monthly on electricity bills, three of the respondents noted that they spent less than GHS136 (≈$21.13 US) per month. According to Ghana Statistical Service (2019), the average monthly expenditure on electricity is GHS136. One hundred and twenty (120) of the respondents indicated that they spent between GHS137 and GHS250 (≈$38.85 US) on electricity monthly while the remaining 108 respondents spent between GHS251 and GHS500 (≈$81.47 US) on electricity while 8 respondents spent more than GHS500 (≈$81.47 US). Respondents with higher electricity were noted to use higher electricity consuming gadgets like microwaves, refrigerators and hotplates. Regarding household income and household size, 82% of the households were willing to immediately switch to off-grid solar technologies due to the prohibitive cost of grid electricity and unreliable energy supply. Based on the monthly expenditure of respondents, those in the lower income band spend approximately 28% of their household income on electricity. Combined with other household expenditures, which differ based on household size, this mounts pressure on households in the lower income bracket.

10.6.3 Descriptive and Reliability Analysis

The Cronbach's alpha values are used to assess the data validity in terms of how reliable the data is. For data to be deemed reliable, the estimated Cronbach's alpha values should be greater than 0.7 (the threshold for data validity). From the data gathered, the estimated Cronbach's alpha values are 0.734 and 0.778 for variables of enablers and indicators of the decision to adopt, respectively, signifying that the data is adequately valid for further analysis.

Subsequently, the standard deviations and mean values of both the decision to adopt construct and enablers were computed, giving rise to a prioritized ranking of the underlying indicators. Where two or more indicators had the same mean values, their respective standard deviation values served their differences. In that, the indicator with the lower or lowest standard deviation is ranked the highest or higher. The standard deviation and mean values of all the indicators are presented in Table 10.2.

Table 10.2 Statistical details of indicators

S/N	Construct	Enablers	Mean	Std. Deviation	Rank
12	**Economic**	Future income generation	4.64	0.646	1st
1		Low or no upfront cost	4.57	0.683	3rd
2		Expected reduction in electricity bill	4.51	0.655	4th
4		Reduced dependency on ECG	4.31	0.659	8th
13		Installation cost of technology	3.78	0.797	12th
14		Maintenance cost	3.03	1.053	13th
10	**Social**	Awareness of technology	4.63	0.615	2nd
3		Recommendations from other users	4.44	0.720	5th
9		Prestige of having off-grid solar electrification technology	4.10	0.718	9th
7		Community participation in implementing solar energy projects	4.07	0.710	10th
11		Drawing in thieves and vandals	2.26	0.848	14th
5	**Political**	Availability on market	4.32	0.734	7th
6		Government incentives or subsidies	4.42	0.747	6th
8		Installation quality of off-grid solar electrification technology	4.00	0.787	11th
		Cronbach's Alpha	0.734		

In reference to Table 10.2, the top five enablers revealed included 'future income generation', 'awareness of technology', 'low or no upfront cost', 'expected reduction in electricity bill' and 'recommendations from other users'. Among the enabler categories, three economic indicators were seen among the top 5.

10.6.4 Measurement Model Estimation

With the aid of Smart PLS version 3.3.3, the interactive effects were assessed among the variables under the three distinct enablers (political, social and economic) and the decision to adopt construct. Indicators with factor loadings below 0.50 were taken out in the measurement model estimation (Hair et al., 2012). Until all the retained indicators had factor loadings greater than or equal to 0.50, the analysis was performed over and over. The valid measurement model is shown in Table 10.3. For satisfactory reliability of the measurement model, four validity tests need to be conducted; thus, average variance extracted (AVE), factor loadings, composite reliability (CR) and rho alpha (Rho_A). For AVE and factor loadings of all indicators, data becomes valid if their values are above 0.50, whereas CR and Rho_A values need to be greater than 0.70 for data validity. Table 10.3 shows all the constructs with their respective factor loadings, AVE's, CR's and Rho_A satisfying the reliability of the measurement model.

Discriminant Validity

Three specific tests, thus Fornell and Larcker criterion, cross-loadings of the indicators and heterotrait–monotrait (HTMT) ratio of correlation, were employed to assess the measurement model (as seen in Tables 10.4, 10.5 and 10.6). With regards to Fornell and Larcker criterion, a condition of each construct having the highest correlation with itself needs to be fulfilled and as such correlations presented diagonally in Table 10.5 (Fornell & Larcker, 2018; Gefen et al., 2000; Hulland, 1999). On the cross-loadings, all variables of the construct decision to adopt, and enablers had loadings of the highest value to the construct they are

Table 10.3 Indicator loadings

	Items	Loadings[a]	AVE[b]	CR[c]	Rho A[d]
Economic	EC 1	0.502	0.511	0.784	0.743
	EC 12	0.553			
Social	SC 10	0.638	0.558	0.845	0.856
	SC 3	0.501			
	SC 7	0.537			
	SC 9	0.53			
Political	POL 5	0.645	0.576	0.798	0.824
	POL 6	0.501			
	POL 8	0.501			
Decision to adopt	DC1	0.624	0.564	0.723	0.728

Items deleted: indicators' factor loadings < 0.5: EC2, EC4, EC13, EC14, SC11
[a]All item loadings > 0.5 indicates indicator reliability (Hulland, 1999)
[b]All AVE > 0.5 indicates convergent reliability (Bagozzi & Yi, 1988)
[c]Composite reliability (CR) > 0.7 indicates internal consistency (Gefen et al., 2000)
[d]Cronbach's alpha > 0.7 indicates reliability (Nunnally, 1978)

Table 10.4 Validity and reliability measurements

Indicators/variable	Decision to adopt	Economic	Political	Social
EC1	0.172	**0.489**	0.348	0.353
SC10	0.043	0.528	0.572	**0.638**
EC12	−0.001	**0.553**	0.453	0.443
SC3	0.036	0.300	0.492	**0.493**
POL5	0.171	0.470	**0.645**	0.603
POL6	0.101	0.402	**0.501**	0.460
SC7	0.090	0.432	0.480	**0.537**
POL8	0.082	0.406	**0.501**	0.465
SC9	0.062	0.401	0.493	**0.530**
EC2	1.000	**0.254**	0.220	0.104

[a] All item loadings 0.5 shows indicator Reliability
[b] All Average Variance Extracted (AVE) > 0.5 suggests Convergent Reliability

hypothesized to measure as seen in Table 10.4. Finally, with regards to the HTMT ratio of correlations, a condition must be fulfilled that states all correlations should have to be compared to an established threshold of 0.9, below which the measurement model will look adequate for discriminant validity criteria. Table 10.6, presents that all the HTMT are below 0.90.

Table 10.5 Fornell-Larcker criterion

Construct	Decision to adopt	Economic	Political	Social
Decision to adopt	**1.000**			
Economic	0.154	**0.522**		
Political	0.220	0.553	**0.771**	
Social	0.104	0.549	0.767	**0.929**

The diagonal values are the square root of the AVE of the latent variables and indicate the highest in any column or row

Table 10.6 Heterotrait–monotrait ratio (HTMT)

Construct	Decision to adopt	Economic	Political	Social
Decision to adopt				
Economic	0.166			
Political	0.216	0.781		
Social	0.105	0.757	0.837	

Estimation of Structural Model

In assessing the influence of the various constructs among themselves, the structural model was estimated with the help of path analysis. This was used to assess the interactive influence of enablers and their respective impact on the decision to adopt. Figure 10.2 presents the outcome of the structural model.

Structural Model Assessment

Before the structural model assessment, with the help of variance inflation factor (VIF), the model was tested for multicollinearity. For multicollinearity to be accepted, the model should satisfy the condition of obtaining estimated values of VIF been lower than 5.00. For all values of VIF, minimum multicollinearity was observed. To determine the significance of the hypotheses, the structural model was estimated.

Further analysis of the coefficient of determination (R^2) was employed to assess the variance and total effect size as expounded in the decision to adopt by the three constructs of the enablers. As a rule of thumb, the R^2 of the decision to adopt should be greater than or equal to 0.10

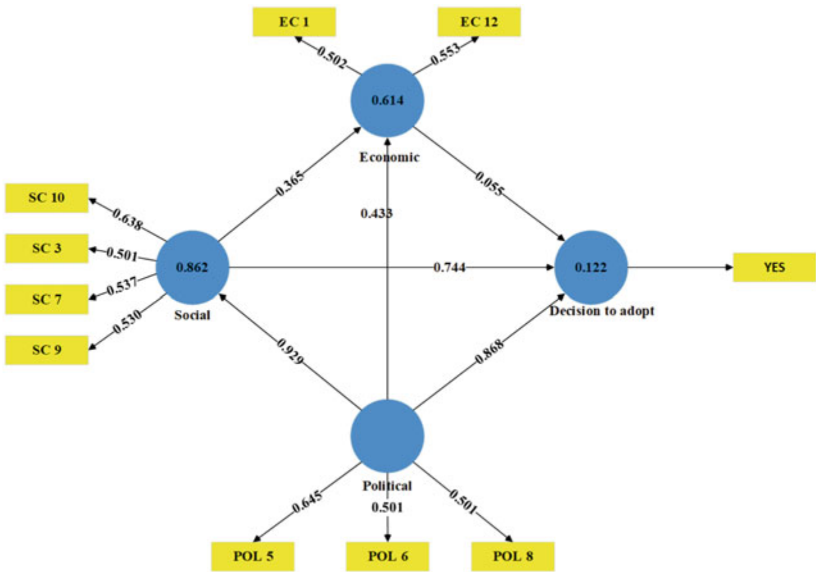

Fig. 10.2 Structural model

(Gorai et al., 2015), which was the case in this study. To normality of the data was performed, after which the test of significance of the path was also tested. For data normality, Mardia's multivariate skewness of 8.71 was seen as greater than the supposed cut-off of ±1 as well as kurtosis of 39.87 was also greater than the supposed cut-off of ±20. This, therefore, proved the data as not normally distributed and hence bootstrapping analysis was conducted using the test of significance of the paths identified as shown in Fig. 10.3. For the non-normally distributed data, bootstrapping analysis was conducted as it seemed suitable for the measurement of the direct impact of Hypotheses 1–6.

Validation of Hypotheses

The *t*-values in the Table 10.7 represent the bootstrapping analysis coefficients in the bootstrapping analysis (refer to Fig. 10.3) are the *t*-values for assessing the significance of the paths. According to Astrachan et al.

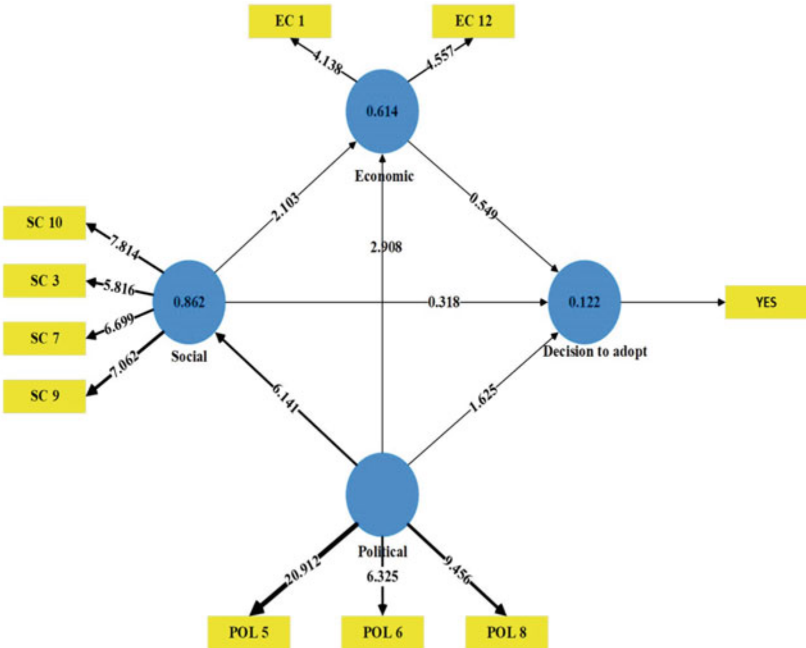

Fig. 10.3 Results of bootstrapping analysis of the three enabler categories and decision to adopt off-grid solar systems

(2014) the significant paths for a two-tailed test have three levels of *t*-values; *t*-values of 1.65 (for significance level = 10%), *t*-values of 1.96 (for significance level = 5%) and *t*-values of 2.58 (for significance level = 1%). Consequently, for the interactive effects among the enablers, the *t*-value of 2.908 for the political enabler to economic enabler path is supported at a significance level of $p < 0.05$ ($t0.05 > 1.96$). Correspondingly, the *t*-value of 6.141 for the institutional enabler to social enabler path is supported at a significance level of $p < 0.05$ ($t0.05 > 1.96$). With at-value of 2.130, the social enabler to economic enabler path is supported at a significance level of $p < 0.01$ ($t0.01 > 1.96$) (refer to Fig. 10.3). However, the economic enabler to decision to adopt path, the social enabler to decision to adopt path, and the political enabler to decision to adopt path are not supported at any of the conventional significance levels.

Table 10.7 Direct relationship with hypothesis testing

Hypothesis	Relationship	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	*T* statistics (|O/STDEV|)	*P* values	Decision
H1	Economic → Decision to adopt	0.05	0.05	0.091	0.549	0.583	Not supported
H2	Political → Decision to adopt	0.164	0.158	0.101	1.625	0.105	Not supported
H3	Political → Economic	0.231	0.225	0.08	2.908	0.004	Supported
H4	Political → Social	0.563	0.557	0.092	6.141	0.000	Supported
H5	Social → Decision to adopt	−0.029	−0.029	0.092	0.318	0.751	Not supported
H6	Social → Economic	0.271	0.259	0.129	2.103	0.036	Supported

10.6.5 Model Constructs and the Adoption of Off-Grid Solar Electrification Technologies

The economic construct has two significant loaders. These are low or no upfront cost—EC 1 (0.502) and future income generation EC 12 (0.553). EC 12 is the most important loader of the economic construct with the potential to influence the decision to adopt off-grid solar electrification technologies. Considering the informal nature of the economy in Ghana and the prominence of home-based enterprises, many households will be more likely to adopt technologies to support the subsistence of their enterprises. Low or no upfront cost ranks third of all the loaders used in the model. The significance of this loader implies the likelihood of households to adopt off-grid solar electrification technologies. This finding parallels that of studies that highlight the dynamics of pricing relative to household income as influential on affordability. Again, finding from the fieldwork that all respondents rely on the national grid while concurrently willing to adopt off-grid solar electrification, the inequitable distribution of electricity comes to bear. Over the past decades, the erratic supply of electricity highlights a classic case of energy poverty, which widens socioeconomic inequalities as those without the financial strength are unable to access electricity. Within the theoretical lens of energy justice, the affordability of sustainable energy systems has been highlighted as a plausible solution to energy poverty. These variables further consolidate the embeddedness of economic systems in society's energy justice (LaBelle, 2017).

The social construct has four significant loaders which include awareness of technology—SC 10 (0.638); 'recommendations from other users'—SC 3 (0.501); 'community participation in implementing solar energy projects'—SC 7 (0.537) and 'prestige of having off-grid solar electrification technologies'—SC 9 (0.530). The 'awareness of technology' loader was the second highest in the model. From this ranking, it can be inferred that when households are aware of innovative sustainable electrification alternatives like off-grid solar technologies, they are more likely to adopt them. The awareness of these technologies and their accompanying benefits, such as environmental justice as well as other economic benefits, are influential in adoption decision-making (Walker & Day, 2012). Similar to our finding, Lacey-Barnacle and Bird (2018) opine that energy justice can be achieved through energy campaigns to create awareness of emerging energy alternatives at the local level.

Furthermore, recommendations from other users is a social loader that has a high potential of influencing the decision to adopt off-grid solar electrification technologies. Social and community networks (Ojong, 2020) are influential to the adoption decision of off-grid solar systems. Nevertheless, this hinges on the quality of the technologies being used by the recommenders. The adoption of off-grid solar electrification technologies is a complex interaction among the market, institutions and the wider social fabric. Some studies have concluded that local social network recommendations often yield a positive result in adopting these technologies.

The political construct has three significant loaders, which are; availability on the market—POL 5 (0.645); government incentive or subsidies—POL 6 (0.501), and installation quality of off-grid solar electrification technology—POL 8 (0.501). The most significant of these political construct loaders is government incentives or subsidies. From a political or institutional perspective, when governments offer tax incentives and subsidies for importing or producing off-grid solar electrification technologies, this motivates potential investors and businesses to participate in this market. With the interaction of the invisible forces of demand and supply, the prices of these technologies, all things being equal, will reduce, thus ensuring affordability and empowering vulnerable social groups to consider adopting them. Through such initiatives, reduced pricing may contribute to equitable access to these technologies by all, thus closing the energy injustice gap.

10.7 Conclusion and Recommendations

Electricity plays a key role in all aspects of our everyday life as well as in ensuring economic growth, Yet the heavy reliance of conventional electrification sources has engendered many cross-cutting challenges that have social, economic and environmental implications. While the adoption of alternative electricity sources, particularly renewable energy have been central to the polies of national and international bodies as well as civil society and other stakeholders, their uptake remains dire. This study sought to identify key energy justice principles that may serve as enablers or barriers in the adoption of off-grid solar electrification technologies (Solar Home System [SHS]) in urban Ghana. Through the review of relevant literature, key enablers and barriers were identified. These were grouped under various themes which also informed the design of the research questionnaires for the study. From the preceding, the discussed high ranked loaders for economic, social and political constructs that influence the decision to adopt off-grid solar electrification technologies. Our findings and results indicate that the economic loader low or no upfront cost is the most influential factor for the decision to adopt off-grid solar electrification technologies. For that matter, it is expedient that relevant stakeholders, from global through national to the local level, formulate and implement pragmatic policies that enhance the update of these technologies. Considering that most households in developing countries have low household incomes, coupled with substantial household sizes and other sociocultural responsibilities, the current alternative electrification options remain out of their reach. This influences not only economic livelihoods, but also social and psychological wellbeing. Energy campaign coalitions are thus required to ensure the balanced interests of all actors in the energy web. Such balanced grounds are necessary for achieving energy justice through the adoption of off-grid solar electrification technologies.

Therefore, it is recommended that government policies on international trade and domestic production and trade focus on offering attractive incentives and subsidies to draw both producers and end-users of these electrification technologies. Furthermore, participatory and collaborative mechanisms should be adopted in the awareness creation of these technologies. However, these will require strategic navigation of today's society's numerous socio-political and economic complexities in the Global South. Achieving energy justice within the off-grid solar electrification system calls for strategies and actions that foster the fair and equitable distribution of these technologies while conscious efforts are made to account for the often divergent but relevant interests of all actors.

References

Adabre, M. A., Chan, A. P. C., Edwards, D. J., & Adinyira, E. (2021). Assessing critical risk factors (CRFs) to sustainable housing: The perspective of a sub-Saharan African country. *Journal of Building Engineering, 41*. https://doi.org/10.1016/j.jobe.2021.102385

Adenle, A. A. (2020). Assessment of solar energy technologies in Africa—Opportunities and challenges in meeting the 2030 agenda and sustainable development goals. *Energy Policy, 137*, 111180.

Adusah-Poku, F., & Takeuchi, K. (2019). Energy poverty in Ghana: Any progress so far? *Renewable and Sustainable Energy Reviews, 112*(July 2018), 853–864.

Agyekum, E. B., Velkin, V. I., & Hossain, I. (2020). Sustainable energy: Is it nuclear or solar for African Countries? Case study on Ghana. *Sustainable Energy Technologies and Assessments, 37*, 100630.

Ahmadabadi, A. A., & Heravi, G. (2019). The effect of critical success factors on project success in public–private partnership projects: A case study of highway projects in Iran. *Transport Policy, 73*, 152–161.

Aklin, M., Cheng, C. Y., & Urpelainen, J. (2018). Social acceptance of new energy technology in developing countries: A framing experiment in rural India. *Energy Policy, 113*, 466–477.

Akter, S., & Bagchi, K. (2021). Is off-grid residential solar power inclusive? Solar power adoption, energy poverty, and social inequality in India. *Energy Research & Social Science, 82*, 102314.

Amankwaa, E. F., & Gough, K. V. (2021). Everyday contours and politics of infrastructure: Informal governance of electricity access in urban Ghana. *Urban Studies*. https://doi.org/10.1177/00420980211030155

Astrachan, C. B., Patel, V. K., & Wanzenried, G. (2014). A comparative study of CB-SEM and PLS-SEM for theory development in family firm research. *Journal of Family Business Strategy, 5*(1), 116–128.

Asuamah, E. Y., Gyamfi, S., & Dagoumas, A. (2021). Potential of meeting electricity needs of off-grid community with mini-grid solar systems. *Scientific African, 11*, e00675.

Asumadu-Sarkodie, S., & Owusu, P. A. (2016). The potential and economic viability of solar photovoltaic power in Ghana. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 38*(5), 709–716. https://doi.org/10.1080/15567036.2015.1122682

Bagozzi, R. P., & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the academy of marketing science*, *16*(1), 74–94.

Baurzhan, S., & Jenkins, G. P. (2016). Off-grid solar PV: Is it an affordable or appropriate solution for rural electrification in sub-Saharan African countries? *Renewable and Sustainable Energy Reviews, 60*, 1405–1418. https://doi.org/10.1016/j.rser.2016.03.016

Baynes, T., Lenzen, M., Steinberger, J. K., & Bai, X. (2011). Comparison of household consumption and regional production approaches to assess urban energy use and implications for policy. *Energy Policy, 39*(11), 7298–7309. https://doi.org/10.1016/J.ENPOL.2011.08.053

Bisaga, I., Parikh, P., Tomei, J., & To, L. S. (2021). Mapping synergies and trade-offs between energy and the sustainable development goals: A case study of off-grid solar energy in Rwanda. *Energy Policy, 149*, 112028. https://doi.org/10.1016/J.ENPOL.2020.112028

Bugaje, I. M. (2006). Renewable energy for sustainable development in Africa: A review. *Renewable and Sustainable Energy Reviews, 10*(6), 603–612. https://doi.org/10.1016/J.RSER.2004.11.002

Bullard, R. D. (2005). *The quest for environmental justice: Human rights and the politics of pollution* (Vol. 19). Sierra Club Books.

Bullard, R. D., Johnson, G. S., & Wright, B. H. (1997). Confronting environmental injustice: It's the right thing to do. *Race, Gender & Class, 5*(1), 63–79.

Eybpoosh, M., Dikmen, I., & Talat Birgonul, M. (2011). Identification of risk paths in international construction projects using structural equation modeling. *Journal of Construction Engineering and Management, 137*(12), 1164–1175.

Fornell, C., & Larcker, D. F. (2018). Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of Marketing Research, 18*(3), 382–388. https://doi.org/10.1177/002224378101800313

Gauri, S., Safiatou, A. N., & Mohamed, Y. S. (2015). *Ghana renewables readiness assessment*. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RRA_Ghana_Nov_2015.pdf

Gefen, D., Straub, D., & Boudreau, M.-C. (2000). Structural equation modeling and regression: Guidelines for research practice. *Communications of the Association for Information Systems, 4*(1), 7.

Ghana Energy Commission. (2019). Ghana_Renewable_Map_Stanford. In *Ghana Renewable Energy Master Plan.*

Ghana Statistical Service. (2019). *Ghana Living Standards Survey (GLSS).* https://www.statsghana.gov.gh/gssmain/fileUpload/pressrelease/GLSS7/MAIN_REPORT_FINAL.pdf

Ghana Statistical Service. (2021). *Ghana 2021 Population and Housing Census (PHC).*

Girardeau, H., Oberholzer, A., & Pattanayak, S. K. (2021). The enabling environment for household solar adoption: A systematic review. *World Development Perspectives, 21*, 100290. https://doi.org/10.1016/J.WDP.2021.100290

Gorai, A. K., Tuluri, F., Tchounwou, P. B., & Ambinakudige, S. (2015). Influence of local meteorology and NO_2 conditions on ground-level ozone concentrations in the eastern part of Texas, USA. *Air Quality, Atmosphere and Health, 8*(1), 81–96. https://doi.org/10.1007/S11869-014-0276-5/FIGURES/8

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2012). Partial least squares: The better approach to structural equation modeling? *Long Range Planning, 45*(5–6), 312–319.

Hulland, J. (1999). Use of partial least squares (PLS) in strategic management research: A review of four recent studies. *Strategic Management Journal, 20*(2), 195–204.

Ikejemba, E. C. X., & Schuur, P. C. (2016). Designing a nation-wide network of solar and wind-assisted parks for Nigeria and for Ghana. *International Journal of Energy and Environmental Engineering, 7*(2), 177–198. https://doi.org/10.1007/s40095-016-0203-7

International Energy Agency. (2018). World energy outlook 2017 executive summary. *Energy Policy, 73*. https://doi.org/10.1016/0301-4215

Irfan, M., Elavarasan, R. M., Hao, Y., Feng, M., & Sailan, D. (2021). An assessment of consumers' willingness to utilize solar energy in China: End-users' perspective. *Journal of Cleaner Production, 292*, 126008. https://doi.org/10.1016/J.JCLEPRO.2021.126008

Javadi, D., Ssempebwa, J., Isunju, J. B., Yevoo, L., Amu, A., Nabiwemba, E., Pfeiffer, M., Agyepong, I., & Severi, L. (2020). Implementation research on sustainable electrification of rural primary care facilities in Ghana and Uganda. *Health Policy and Planning, 35*, II124–II136. https://doi.org/10.1093/HEAPOL/CZAA077

Jenkins, K. (2018). Setting energy justice apart from the crowd: Lessons from environmental and climate justice. *Energy Research & Social Science*, *39*, 117–121.

Karakara, A. A., & Osabuohien, E. S. (2020). Clean versus dirty energy: Empirical evidence from fuel adoption and usage by households in Ghana. *African Journal of Science, Technology, Innovation and Development, 13*(7), 785–795. https://doi.org/10.1080/20421338.2020.1816266

Karatayev, M., Hall, S., Kalyuzhnova, Y., & Clarke, M. L. (2016). Renewable energy technology uptake in Kazakhstan: Policy drivers and barriers in a transitional economy. *Renewable and Sustainable Energy Reviews, 66*, 120–136. https://doi.org/10.1016/j.rser.2016.07.057

LaBelle, M. C. (2017). In pursuit of energy justice. *Energy Policy, 107*, 615–620. https://doi.org/10.1016/J.ENPOL.2017.03.054

Lacey-Barnacle, M., & Bird, C. M. (2018). Intermediating energy justice? The role of intermediaries in the civic energy sector in a time of austerity. *Applied Energy, 226*, 71–81. https://doi.org/10.1016/J.APENERGY.2018.05.088

Mahalik, M. K., Mallick, H., & Padhan, H. (2021). Do educational levels influence the environmental quality? The role of renewable and non-renewable energy demand in selected BRICS countries with a new policy perspective. *Renewable Energy, 164*, 419–432. https://doi.org/10.1016/J.RENENE.2020.09.090

Mahapatra, S., Chanakya, H. N., & Dasappa, S. (2009). Evaluation of various energy devices for domestic lighting in India: Technology, economics and CO_2 emissions. *Energy for Sustainable Development, 13*(4), 271–279. https://doi.org/10.1016/J.ESD.2009.10.005

Malik, S. A., & Ayop, A. R. (2020). Solar energy technology: Knowledge, awareness, and acceptance of B40 households in one district of Malaysia towards government initiatives. *Technology in Society, 63*, 101416. https://doi.org/10.1016/J.TECHSOC.2020.101416

Marktanner, M., & Salman, L. (2011). Economic and geopolitical dimensions of renewable vs. nuclear energy in North Africa. *Energy Policy, 39*(8), 4479–4489. https://doi.org/10.1016/J.ENPOL.2010.12.047

Mccauley, D., & Jenkins, K. (2013). Advancing energy justice: The triumvirate of tenets. *International Energy Law Review, 32*(3), 107–110.

Mceachern, M., & Hanson, S. (2008). Socio-geographic perception in the diffusion of innovation: Solar energy technology in Sri Lanka. *Energy Policy, 33*(7), 2578–2590. https://doi.org/10.1016/j.enpol.2008.03.020

Mishra, P., & Behera, B. (2016). Socio-economic and environmental implications of solar electrification: Experience of rural Odisha. *Renewable and Sustainable Energy Reviews, 56*, 953–964. https://doi.org/10.1016/J.RSER.2015.11.075

Muchunku, C., Ulsrud, K., Palit, D., & Jonker-Klunne, W. (2018). Diffusion of solar PV in East Africa: What can be learned from private sector delivery models? *Wiley Interdisciplinary Reviews: Energy and Environment, 7*(3), 1–15. https://doi.org/10.1002/wene.282

Mugisha, J., Ratemo, M. A., Bunani Keza, B. C., & Kahveci, H. (2021). Assessing the opportunities and challenges facing the development of off-grid solar systems in Eastern Africa: The cases of Kenya, Ethiopia, and Rwanda. *Energy Policy, 150*, 112131. https://doi.org/10.1016/J.ENPOL.2020.112131

Müller, F., Neumann, M., Elsner, C., & Claar, S. (2021). Assessing African energy transitions: Renewable energy policies, energy justice, and SDG 7. *Politics and Governance, 9*(1), 119–130. https://doi.org/10.17645/pag.v9i1.3615

Nunnally, J. C. (1978). *Psychometric theory*. 2nd ed. Mcgraw-Hill.

Obeng, G. Y. (2013). Solar PV lighting and studying after sunset: Analysis of micro-benefits in off-grid rural Ghana. *International Journal of Renewable Energy Development, 2*(1), 45–51. https://doi.org/10.14710/ijred.2.1.45-51

Obeng, G. Y., & Evers, H. D. (2010). Impacts of public solar PV electrification on rural micro-enterprises: The case of Ghana. *Energy for Sustainable Development, 14*(3), 223–231. https://doi.org/10.1016/J.ESD.2010.07.005

Obeng, G. Y., Evers, H. D., Akuffo, F. O., Braimah, I., & Brew-Hammond, A. (2008). Solar photovoltaic electrification and rural energy-poverty in Ghana. *Energy for Sustainable Development, 12*(1), 43–54.

Ojong, N. (2020). *The everyday life of the poor in Cameroon: The role of social networks in meeting needs*. Routledge.

Ojong, N. (2021a). Solar home systems in South Asia: Examining adoption, energy consumption, and social practices. *Sustainability, 13*(14), 7754.

Ojong, N. (2021b). The rise of solar home systems in sub-Saharan Africa: Examining gender, class, and sustainability. *Energy Research & Social Science, 75*, 102011.

Ondraczek, J. (2013). The sun rises in the east (of Africa): A comparison of the development and status of solar energy markets in Kenya and

Tanzania. *Energy Policy, 56*, 407–417. https://doi.org/10.1016/J.ENPOL.2013.01.007

Oyuke, A., Penar, P. H., & Howard, B. (2016). Off-grid or 'off-on': Lack of access, unreliable electricity supply still plague majority of Africans. In *Dispatch, Afrobarometer 75*. http://afrobarometer.org/countries/results-round

Reiche, K., Grüner, R., Attigah, B., Hellpap, C., Brüderle, A., Wolff, R., Ziegler, F., Dietz, R., Schmitz, T. D., Zymla, B., Enskat, M., Lux, S., Pfanner, N., Bopp, G., Harsdorff, M., Heising, K., Goda, S., Sologuren, J., Birhuett, E., & Bernhard, E. (n.d.). *What difference can a PicoPV system make? Early findings on small photovoltaic systems—An emerging low-cost energy technology for developing countries*. Retrieved November 25, 2021, from www.gtz.de/energie

Schmidt, R., Martínez, M., Allende, M., & Potter, W. (2020). Field experiences and lessons learned with photovoltaic off-grid and on-grid applications in Northern Chile. *Proceedings of the ISES Solar World Congress 2019 and IEA SHC International Conference on Solar Heating and Cooling for Buildings and Industry 2019*, 1726–1737. https://doi.org/10.18086/swc.2019.34.04

Simpson, N. P., Rabenold, C. J., Sowman, M., & Shearing, C. D. (2021). Adoption rationales and effects of off-grid renewable energy access for African youth: A case study from Tanzania. *Renewable and Sustainable Energy Reviews, 141*(April 2020), 110793. https://doi.org/10.1016/j.rser.2021.110793

Sun, H., Awan, R. U., Nawaz, M. A., Mohsin, M., Rasheed, A. K., & Iqbal, N. (2021). Assessing the socio-economic viability of solar commercialization and electrification in south Asian countries. *Environment, Development and Sustainability, 23*(7), 9875–9897. https://doi.org/10.1007/s10668-020-01038-9/FIGURES/9

Toledo, A. H., Flikkema, R., & Toledo-Pereyra, L. H. (2011). Developing the research hypothesis. *Journal of Investigative Surgery, 24*(5), 191–194. https://doi.org/10.3109/08941939.2011.609449

Tong, T. M., Asare, J., Rwenyagila, E. R., Anye, V., Oyewole, O. K., Fashina, A. A., & Soboyejo, W. O. (2015). A study of factors that influence the adoption of solar powered lanterns in a rural village in Kenya. *Perspectives on Global Development and Technology, 14*(4), 448–491. https://doi.org/10.1163/15691497-12341356

Ulsrud, K. (2020). Access to electricity for all and the role of decentralized solar power in sub-Saharan Africa. *Geografisk Tidsskrift-Norwegian Journal* *of Geography, 74*(1), 54–63. https://doi.org/10.1080/00291951.2020.1736145

Urmee, T., & Md, A. (2016). Social, cultural and political dimensions of off-grid renewable energy programs in developing countries. *Renewable Energy, 93*, 159–167. https://doi.org/10.1016/J.RENENE.2016.02.040

Villavicencio Calzadilla, P., & Mauger, R. (2018). The UN's new sustainable development agenda and renewable energy: The challenge to reach SDG7 while achieving energy justice. *Journal of Energy and Natural Resources Law, 36*(2), 233–254. https://doi.org/10.1080/02646811.2017.1377951

Walker, G., & Day, R. (2012). Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. *Energy Policy, 49*, 69–75. https://doi.org/10.1016/J.ENPOL.2012.01.044

Wang, G. H., Wang, Y. X., & Zhao, T. (2008). Analysis of interactions among the barriers to energy saving in China. *Energy Policy, 36*(6), 1879–1889. https://doi.org/10.1016/J.ENPOL.2008.02.006

Williams, C. C., Adom, K., & Horodnic, I. A. (2020). Determinants of the level of informalization of enterprises: Some evidence from Accra, Ghana. *Journal of Developmental Entrepreneurship, 25*(1). https://doi.org/10.1142/S1084946720500041

Williams, L., & Sovacool, B. K. (2019). The discursive politics of 'fracking': Frames, storylines, and the anticipatory contestation of shale gas development in the United Kingdom. *Global Environmental Change, 58*. https://doi.org/10.1016/j.gloenvcha.2019.101935

World Bank. (2015). *Open data*.

World Bank. (2019). *Ghana—Access to electricity*.

World Bank. (2020). *GDP (current US$)—Ghana | Data*. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=GH

Yang, L., Danwana, S. B., & Yassaanah, I. F. (2021). *An empirical study of renewable energy technology acceptance in Ghana using an extended technology acceptance model*.

Ye, Y., Koch, S. F., & Zhang, J. (2018). Determinants of household electricity consumption in South Africa. *Energy Economics, 75*, 120–133. https://doi.org/10.1016/J.ENECO.2018.08.005

11

Off-Grid Solar Electrification on the Rise in Africa, but Where to?

Nathanael Ojong

11.1 Introduction

This volume set out to take stock of off-grid solar electrification in Africa by examining how political, economic, institutional and social forces shape the adoption of off-grid solar technologies, including how issues of energy injustice are manifested at different levels and spaces. In the Introduction (Chapter 1), I noted that injustices as they related to off-grid solar electrification in low-income non-Western communities (including pre- and ongoing electrification communities) have not received significant scholarly attention. Most studies using the energy justice framework tend to focus on Western countries. This volume addresses this gap by examining real-world experiences in pre- and ongoing electrification communities in Africa.

N. Ojong (✉)
York University, Toronto, ON, Canada
e-mail: nojong@yorku.ca

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment,
https://doi.org/10.1007/978-3-031-13825-6_11

The purpose of this concluding chapter is twofold. First, I compare and contrast the various case studies examined in this volume by analyzing topics such as renewable energy policy diffusion and application of energy justice theorizing. Second, the final segment reflects on the renewable energy sector in general, including off-grid solar electrification. I critically interrogate the notion that the ascendance of off-grid solar electrification in Africa is transformative.

11.2 Understanding Country-Level Comparisons of Off-Grid Solar Electrification

As shown in the various chapters in this volume, the scale of the diffusion of off-grid solar technologies in Africa is unprecedented. A closer look at the different chapters, especially Chapters 2–4, bring to the fore a similarity in terms of mechanisms of off-grid solar energy policy diffusion. By 'policy diffusion', I refer to the movement of policy ideas, designs, systems, instruments, etc. from one environment to another (Kuhlmann et al., 2020; Obinger et al., 2013; Shipan & Volden, 2009).

11.2.1 Renewable Energy Policy Diffusion

Extant scholarship notes four main policy diffusion processes: learning, competition, imitation or emulation, and coercion (Evans, 2004; Shipan & Volden, 2009). In learning, the focus of policymakers is on the policy itself; in other words, how it was designed and whether it was effective (Shipan & Volden, 2009). Unlike learning, imitation as a mechanism of policy diffusion is not related to the objective of a policy. Instead, the symbolic and socially constructed characteristics are vital (Greenhill, 2010). While learning focuses on the policy, imitation focuses on the actor, copying the actions of another state to look like them (Shipan & Volden, 2009). Thus, some policies will be highly viewed and accepted regardless of whether they work, while others will not enjoy high acceptance even if these policies could be beneficial (Maggetti & Gilardi, 2016). That said, the distinction between the learning and imitation transmission mechanisms is not always clear cut. This is precisely because an experience in a country may allow learning and induce imitation (Shipan & Volden, 2009). The third transmission mechanism—competition—involves countries keeping track of the policies of others in order to attract or retain resources (Dobbin et al., 2007; Maggetti & Gilardi, 2016). The fourth transmission mechanism—coercion—entails exerting pressure on countries to adopt policies they did not freely choose (Dobbin et al., 2007; Gilardi, 2012). This pressure often comes from other states or international organizations (e.g., World Bank, International Monetary Fund) (Gilardi, 2012). Notably, coercion can be seen to include 'softer' variants such as policy conditionalities, changes in incentives, and imposition of hegemonic ideas (Dobbin et al., 2007).

Coercion as a policy transmission mechanism is of particular importance to the discussion of off-grid solar electrification in Africa. Chapter 3 in this volume notes that the Senegalese government's embrace of off-grid solar energy as part of the country's energy landscape, occurred after reforming (i.e., partially deregulating) the electricity sector at the end of the 1990s, following pressure from the World Bank. Reforms of the electricity sector in Senegal, as in other African countries, paved the way for market-based approaches to promoting off-grid solar in the continent.

As noted earlier, powerful actors such as the World Bank play a crucial role in exerting pressure on states with regards to adopting policies. Unsurprisingly, this institution played a vital role in the diffusion of policy related to off-grid solar technologies in Africa. The coercion mechanism could not be effective without laying the groundwork. Hence, as noted in Chapter 2, the World Bank established the Lighting Africa programme in 2007, with the goal of promoting the development of the off-grid solar sector. This programme would ensure that the off-grid solar sector flourishes in various African countries. In a similar vein, in June 2016, influential organizations such as the Power Africa, United States Agency for International Development (USAID), Department for International Development (DFID), now Foreign, Commonwealth &

Development Office (FCDO), and the Shell Foundation launched the 'Scaling Off-grid Energy' initiative to 'to accelerate growth in Africa's off-grid energy market and bring clean, modern, affordable electricity to 20 million households' (USAID, 2017).

Promoting the adoption of off-grid solar technologies by various states, as part of their energy mix is also done through regular high-profile events. For instance, the Global Off-grid Solar Forum and Expo, which is organized on a regular basis, with the aim of accelerating the development of the off-grid solar market.[1] As mentioned in Chapter 2, in February 2020, the World Bank Group's Lighting Global programme and Global Off-Grid Lighting Association (GOGLA) hosted the Global Off-grid Solar Forum and Expo in Kenya. The event was officially opened by the President of the Republic of Kenya Uhuru Kenyatta, and recorded over 1250 participants from 75 countries and over 80 government officials attending. The 7th edition of this same high-profile biennial event will be organized in Kigali, Rwanda, from 18 to 20 October 2022. The fact that the 6th and 7th editions of the Global Off-grid Solar Forum and Expo took place in Africa is revealing—it is important to cement the position of off-grid solar in the energy landscape in various countries in the continent.

Having a successful case study was essential to the diffusion of energy policy promoting off-grid solar electrification. Therefore, as shown in Chapter 2, Lighting Africa used Kenya as its main case-study country in 2009. Having a success story is important for policy diffusion as it shows that the policy works, hence other countries would be encouraged to emulate the shining example. As noted in Chapter 1, Kenya is regarded by the Lighting Africa programme and other international actors as a good student, as about 10 million Kenyans have adopted off-grid solar technologies. Arguably, the success of this energy policy in Kenya facilitated the diffusion of off-grid solar technologies into other countries in East Africa. Today, East Africa is regarded as a leader for off-grid solar energy in the continent.

International actors, including the World Bank have used the 'softer' variants of coercion to promote the development of the off-grid solar

[1] https://www.offgridsolarforum.org/.

sector. These softer variants take the form of incentives such as financial and technical assistance. Chapter 8 posits that the World Bank financed the Kenya Off-Grid Solar Access Project (KOSAP), a flagship project of the Ministry of Energy aimed at providing electricity and clean cooking solutions in the remote, low density and traditionally underserved areas of the country. Similarly, Chapter 4 notes that the off-grid solar sector in Rwanda has received financial and technical support from the World Bank. In September 2020, the World Bank Board of Directors approved $150 million in financing to 'improve access to modern energy for households, enterprises, and public institutions in Rwanda and to enhance the efficiency of electricity services' (World Bank, 2020a). The funds will support the Rwanda Energy Access and Quality Improvement Project (EAQIP) which aims to expand 'grid connections for residential, commercial, industrial and public sector consumers, as well as by providing grants to reduce the costs of *off-grid solar home systems*' (World Bank, 2020a). Here, I lay emphasis on the provision of an incentive to enhance the adoption of solar home systems in Rwandan project. In West Africa, Ghana's Energy and Development Access Project (GEDAP) launched with a goal of ensuring access to renewable energy through off-grid solar services and products, was also financed by the World Bank (World Bank, 2020b). To support the push by the World Bank and other donors for the development of the off-grid solar sector, the government of Ghana enacted the Renewable Energy Law.

The emulation and coercion transmission mechanisms have been quite successful in ensuring that governments in various countries in the continent include off-grid solar in their energy policy. World Bank-supported solar projects and programmes have been launched in several countries, including Benin, Burkina Faso, Cabo Verde, Cameroon, Central African Republic, Chad, Cote d'Ivoire, The Gambia, Guinea, Guinea-Bissau, Liberia Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo.

11.2.2 Application of Energy Justice Theorizing

Beyond policy diffusion, there are similarities and differences with respect to how the various chapters in this book apply the energy justice framework to off-grid solar energy technologies.

In the midst of different historical, social, economic and political contexts, Chapters 4, 5, 6, 8 and 9 all note that off-grid solar technologies still remain unaffordable to a significant segment of the population. In other words, these chapters are highlighting distributional injustices related to access to solar energy. However, Chapter 6 adds another layer to the issue of affordability. According to that chapter, affordability is associated with the inability of certain people to cover the cost of installing a solar home system. In other words, affordability as a distributional justice issue goes beyond the inability to pay for a solar home system, it also includes the inability of households to cover the cost of installing the system after purchase.

Chapter 6 shows that distribution, recognition and procedural tenets of energy justice reinforce one another. The chapter shows how trying to tackle the issue of affordability of off-grid solar services and products through public subsidies brought to the fore the issues related to distribution, recognition and procedural justice. Using the case of Malawi, Chapter 6 notes that distributor-end subsidies were provided to encourage market-entry into the country's solar home systems market, but consumer-end subsidies were not provided to tackle the problem of affordability. Put differently, distributional injustice here intersects with recognition injustice and procedural injustice, as solar home systems remain unaffordable for certain segments of the population even after the implementation of a subsidies programme because they were not consulted in the decision-making process related to subsidies programmes and their exclusion in the decision-making process indicates that a lack of recognition of the needs of this segment of the population.

Chapter 5, unlike the others, engages with energy justice in certain spaces, e.g., in households. The chapter shows how distribution, recognition and procedural justice are intertwined in households. Distributional injustice is perceived in women's inability of women to have access to certain energy services. This is due to their exclusion in the decision-making process (procedural justice) regarding how energy generated by solar home systems are to be used. The exclusion of women in the decision-making process indicates that their needs are not recognized (recognition justice). This chapter articulates energy justice at the micro level, and links energy injustices to the *Ubuntu* philosophy. For instance, it argues that women's inability to have access to some energy services in the household is contrary to the *Ubuntu* philosophy.

Unlike the other chapters in this volume, Chapter 4 utilizes the energy justice framework of distributional, recognition and procedural justice to examine energy policy in Rwanda. The chapter shows procedural injustices with respect to how the country's National Electrification Plan (NEP) was drafted. Key stakeholders, especially those who were directly affected by the policy were excluded from the policy formulation process. This exclusion brings to the fore the failure to take into account the needs and wellbeing of certain groups (recognition justice). Their exclusion in policy formulation and non-recognition of their needs led to their inability to access electricity (distributional justice).

11.3 Concluding Reflections: Renewable Energy Transformation or Renewable Energy Injustice?

Globally, the off-grid solar sector has grown rapidly over the past decade and serves over 420 million users (World Bank, 2020c). While ostensibly global in scope, a significant proportion of these users are in sub-Saharan Africa. As noted in the Introduction (Chapter 1), sub-Saharan Africa accounts for 70% of the total global sales of solar home systems. Between 2013 and 2018, over 8 million people had pay-as-you-go contracts with off-grid solar companies in sub-Saharan Africa (Sotiriou et al., 2018). Africa has also witnessed an increase in mini-grids powered by an energy source—e.g., solar panels—combined with battery storage and a local distribution system, which then supply power to homes, small businesses and industry—particularly in areas beyond the reach of the centralized grids. Over 4000 mini-grids are being planned for development in the continent, representing more than 54% of the total 7507 planned mini-grids globally (World Bank, 2019). Clearly, off-grid solar technologies are now part of Africa's energy landscape. It enables millions of people to have access to electricity, which is used for basic energy services such as powering a light bulb, charging a mobile phone and powering a television and radio.

That said, keeping solar panels clean is essential to their proper functioning and this is challenging in several contexts in Africa. As Ozzie Zehner (2012: 21) puts it:

> When it comes to cleanliness, solar cells are prone to the same vulnerability as clean, white dress shirts; small blotches reduce their value dramatically. Due to wiring characteristics, solar output can drop disproportionately if even tiny fragments of the array are blocked, making it essential to keep the entire surface clear of the smallest obstruction, according to manufacturers. Bird droppings, shade, leaves, traffic dust, pollution, hail, ice and snow all induce headaches for solar cells owners as they attempt to keep the entirety of their arrays in constant contact with the sunlight that powers them.

The consequences of obstructing objects are rarely mentioned in the mobilizing narrative related to solar energy in Africa. Yet studies have shown that these obstructions can considerably reduce the effectiveness of the photovoltaic panel (Azimoh et al., 2014; Ghazi et al., 2014; Mustafa et al., 2020).

Additionally, although the off-grid solar sector is quite diverse, in practice, as has been shown in this volume, the sector is currently dominated by solar lanterns and solar home systems. This is problematic as the most affordable solar home systems generate electricity just for lighting and mobile phone charging. As has been shown in this book, the limitations of these systems in terms of electricity generation explains why people prefer grid electrification. Yet, there is an intense drive for countries to adopt low electricity generation systems. For instance, the Africa Clean Energy Technical Assistance Facility, funded by the UK Government recently published a report where it posits that Kenya will need at least 2.2 million solar home systems (SHSs) to achieve universal access by 2022 (ACE, 2021). Here again, emphasis is placed on these systems, despite their limitations in terms of electricity generation, and not on connecting customers to the existing grid through grid extension or localized distribution systems such as mini-grids.

The energy inequality gap cannot be closed by relying on systems which barely generate electricity just for lighting and mobile phone charging. As Nigeria's Vice-President, Professor Yemi Osinbajo recently noted in a piece published in *The Economist*, 'Africans need more than just lights at home. We want abundant energy at scale so as to create industrial and commercial jobs' (*The Economist*, 2022). Energy plays a key role in fostering economic progress (Toman & Jemelkova, 2003), and countries in the Global North would not have attained the level of economic development with limited levels of energy. Thus, the push for the adoption of solar lanterns or SHSs is akin to Friedrich List's memorable phrase—'kicking away the ladder'. The renewable energy narrative, or more precisely the push for the adoption of systems which generate low electricity simply reinforces Africa's marginalization in the global economy. According to estimates, 10 million medium-sized enterprises across the continent are without access to electricity (IRENA, 2020). Efforts should be channelled to generation electricity to be used by these enterprises, especially due to the critical role that these medium-size enterprises play in the economy in terms of job creation and generation of tax revenue. The so-called 'solar boom' in Africa is driven by pico-solar and small SHSs. These systems are not what medium-size enterprises are calling for.

It is worth pointing out that Africa's renewable energy economies are integrated into the global renewable energy economy in ways that are generally unfavourable to the continent. As shown in Table 11.1, Africa is a major producer and exporter of metals needed by the renewable energy sector, including aluminium, copper, manganese, iron and cobalt. The Democratic Republic of Congo has the largest reserves of cobalt in the world (3.4 million tonnes) (UNCTAD, 2020). The largest resources of land-based manganese are in South Africa, accounting for about 74% of the world total (UNCTAD, 2020). Moreover, refining and processing key metals takes place outside Africa. To be more precise, refining and processing of key metals used in the clean energy revolution takes place

Table 11.1 Production of minerals needed for renewable energy sector (in metric tonnes)

Iron (Fe-Content)		Cobalt		Manganese		Aluminium		Copper	
Country	2019	Country	2019	Country	2019	Country	2019	Country	2019
Algeria	409,900	Botswana	5746	Congo, D.R	1780	11, 970	51,700	Congo, D.R	1,461,124
Congo, Rep	20,200	Congo, D.R	78,664	Cote d'Ivoire	472,700	Egypt	290,000	Congo, Rep	18,760
Egypt	270,000	Madagascar	2947	Gabon	3,158,100	Ghana	45,150	Eritrea	16,008
Liberia	2,674,800	Morocco	2347	Ghana	1,884,050	Mozambique	564,756	Mauritania	29,620
Malawi	1800	South Africa	1027	Kenya	16,600	South Africa	717,000	Morocco	30,720
Mauritania	7,927,700	Zambia	1271	Morocco	35,600			Namibia	14,940
Morocco	7150	Zimbabwe	402	Namibia	14,660			South Africa	52,501
Namibia	8400			Nigeria	1000			Tanzania	14,187
Nigeria	1000			Senegal	1880			Zambia	789,942
South Africa	47,064,410			South Africa	6,456,400			Zimbabwe	8731
Tunisia	100,700			Sudan	1000				
				Zambia	11,970				

Source World Mining Data 2021

predominantly in China (Searcey et al., 2021). While there are enterprises in the continent involved in production, varying from assembly of batteries and PV panels to simpler component manufacturing (Mama, 2018), the continent is a net importer of finished renewable energy products such as SHSs, whose constitutive elements are solar panels, charger controller, inverter and the battery bank. The past decade witnessed the importation of millions of these systems and each year Africa imports thousands of them. For example, GOGLA, an industry association with over 200 members, reported that 2.43 million units of certified off-grid solar products, such as solar lanterns and SHSs, were sold in East Africa in the second half of 2019 (GOGLA, 2019). Similarly, Africa imports uncertified solar products from Asia (Samarakoon, 2020; Samarakoon et al., 2021). The point that I am emphasizing here is that Africa's renewable energy economies are integrated into the global renewable energy economy in a manner that (re)produces structural dependence, rather than fostering structural transformation. When discussing the narrative surrounding the 'solar boom' in Africa, it is necessary to differentiate between impressive numbers related to the adoption of solar energy and the structural features of the solar economies in the continent. The discussion about the structural dependence of Africa's renewable energy economies mirrors the broader economies of various African countries (see, Obeng-Odoom, 2015, 2022; Taylor, 2016). Arguably, the structural dependence of Africa's renewable energy economies could be framed as renewable energy injustice.

To the issue of structural dependency, we add those of child labour and precarious working conditions at mines sites in the continent. It is no secret that child labour is used in mining activities in Africa. With respect to cobalt mines in the Democratic Republic of Congo, Sovacool et al. (2021: 9) posit that 'child labor is widely used, with many orphans and ex-child soldiers seeking the livelihood opportunities offered by ASM cobalt mining'. Regarding working conditions, the authors note that '[o]ccupational health and safety is non-existent, with frequent injuries, mine collapses and accidents, as well as chronic exposure to mercury, dust, fumes, rock falls, landslides, and other environmental risk factors' (Sovacool et al., 2021: 9).

Furthermore, people have experienced multiple forms of dispossession due to mining activities. Here, I highlight two forms of dispossession: land dispossession and dispossession by contamination. In Kolwezi, located in the Democratic Republic of Congo, thousands of inhabitants were forcibly relocated in order to allow extraction of an estimated '£75 billion of cobalt' (Baker, 2019). In short, thousands of people in Kolwezi were dispossessed of their ancestral land, which has profound livelihood implications.

Other inhabitants of Kolwezi are victims of dispossession by contamination. Dispossession by contamination, denotes cases in which users are not directly hindered from accessing land and other natural resources but are, instead, indirectly affected by processes of industrial production which produce contamination (Hogan, 2015; Perreault, 2013). Put differently, dispossession by contamination occurs due to the deterioration of water and land quality, and other natural resources (Leifsen, 2017; Murrey, 2015a, 2015b). People in the cobalt mining communities in the Democratic Republic of Congo are also being victims of dispossession by contamination. With respect to the cobalt mining communities in the Democratic Republic of Congo, Sovacool et al. (2021: 9) note that '[e]nvironmental degradation is severe, with little regard for local environmental protection or ecosystems, with direct dumping of waste and tailings, effluents discharged into rivers and alluvial areas, soil erosion, deforestation and the loss of biodiversity'. Farmland which once was fertile has become less productive or even barren due to environmental degradation caused by cobalt mining activities, which is detrimental to a significant segment of the population that depends on farming for their livelihoods. Also, the contamination of surface waters, polluting rivers and streams which are water sources for the local inhabitants leads to the deterioration of water quality, which leads to several diseases. The point stressed here is that dispossession by contamination takes the form of deterioration of water quality. Clearly, even those who were not directly dispossessed of their land were victims of dispossession by contamination. For some people in Kolwezi, instead of displacing them from their land, the cobalt mining activities 'transformed the landscape, leaving them displaced-at-home with contaminated water sources…' (Murrey, 2015b: 19).

The discussion has, so far, focused on dispossession by contamination as it relates to humans, but the concept can be applied to non-human entities. This is based on the argument that the survival of non-human entities is shaped by their habitat. The copper and cobalt mining activities, which are crucial to the clean energy revolution, are a source of contamination to the natural habitat of non-human entities. The pollution of lakes and rivers due to effluents from metallurgical and mining plants contributes to a destruction of the habitat of different species of fish, contamination of fish stock and a reduction in fish stock for fishers in these communities. This has implications for humans. For instance, the local inhabitants' consumption of heavily contaminated fish from Lake Tshangalele, Katanga province, Democratic Republic of Congo largely contributes to intake of cobalt and other metals which is of great concern due to the health risks (Squadrone et al., 2016).

The animal community has equally been affected by the copper and cobalt mining activities in the Democratic Republic of Congo. The displacement of animals has been due to the destruction of the natural habitat: the forest. Also, the anthropogenic noise pollution caused by mining activities led to the relocation of animals. Studies show that noise pollution affects a range of animals across multiple habitats (Francis et al., 2012; Potocnik & Poje, 2010). The severity of noise pollution is perfectly framed by Parris and McCauley (2016: 1):

> When we start to add artificial, unfamiliar noises to natural soundscapes, it can alter the acoustic environment of these marine and terrestrial habitats. This can cause a range of problems. It can affect an animal's ability to hear or make it difficult for it to find food, locate mates and avoid predators. It can also impair its ability to navigate, communicate, reproduce and participate in normal behaviours.

In other words, the artificial sounds caused by the mining activities degraded the natural habitat of animals. Deforestation and noise pollution left the animals with no option than to move further to the forest, where the habitat was more conducive to their survival. But their movement further into the forest affects hunters who rely on them for their livelihoods.

The discussion here about child labour, precarious working conditions and multiple forms of dispossession is important as the clean energy industry depends on metals from these mines. The drive for the adoption of renewable energy systems and an increase in demand for these systems contributes to a significant increase in demand for various metals. This increase in demand contributes to the intensification of mining activities. Thus, any discussion of renewable energy transformation must consider the multiple injustices suffered by local inhabitants and non-human entities in the mining communities. Said differently, I am expanding the concept of energy justice to include extractive activities associated with the clean energy sector. There are distributional, recognition and procedural injustices linked to the extraction of metals used by the renewable energy industry. For example, recognition injustice is quite visible in the case of mining activities in the Democratic Republic of Congo, as the views and needs of marginalized or disadvantaged segments of the population were not taken into account. Also, marginalized segments of the population were disproportionately affected by the harms caused by the extraction of copper and cobalt (distribution injustice). Issues such as child labour, dispossession, environmental degradation and precarious working conditions are far too important to be overlooked in the renewable/clean energy debate, including the energy justice literature. It is precisely because of the intimate connection of these disturbing issues to the renewable energy debate that I frame them as renewable energy injustices.

Furthermore, the discourse surrounding off-grid solar electrification has highlighted its job creation potential. In fact, GOGLA, produced a report entitled 'Off-Grid Solar: A Growth Engine for Jobs'. According to the report, in East Africa, employment across the value chain in the off-grid solar sector was projected to rise from 75,000 in 2018 to 350,000 in 2022 (GOGLA, 2018). In West Africa, the report projected that the number of jobs will increase from 25,000 in 2018 to 150,000 in 2022 (GOGLA, 2018). To put this into perspective, East Africa had a total population of 177 million in 2019,[2] while West Africa had a total

[2] https://www.eac.int/eac-quick-facts.

population of about 391 million inhabitants in 2019 (United Nations, 2019). According to World Bank estimates, Nigeria has a labour force of 64 million while Kenya has a labour force of 24 million. Based on this context, the total number of jobs created (as noted in the GOGLA report) even if taken at face value, is modest to label off-grid solar as 'a growth engine for jobs'. This of course is not to say that the off-grid solar sector is devoid of any value in terms of job creation.

Moreover, jobs particularly related to the solar home system sector also depend on government policy. In other words, the sector would be severely affected if a government changes its policy related to low-energy generation systems such as solar lanterns and SHSs. Bangladesh is a glaring example where the solar home system programme came to a near collapse, when from 2015, the government worked towards greater energy access through grid expansion in SHSs areas and also introduced a free off-grid solar system initiative (Cabraal et al., 2021; Hellqvist & Heubaum, 2022).

With respect to the quality of the jobs, the GOGLA report acknowledges that at least 60% of these jobs will be in areas such as customer relations, sales and retail. Connecting people to systems which can generate enough power to meet their household needs (not just most basic energy services such as lighting and mobile phone charging) as well as engage in productive activities will make a meaningful and long-term impact in terms of job creation.

Also, the discourse surrounding off-grid solar electrification asserts that the adoption of solar systems contributes to home-based income-generation activities, especially in rural communities. Since SHSs account for a significant proportion of off-grid solar electrification in the continent, it is important to examine their income-generation potential. Studies have shown that SHSs adopters started income-generating activities such as mobile phone charging, giving private school lessons in the evenings, and operating barber shops and hair salons (Gustavsson, 2007; Kizilcec et al., 2021; Opiyo, 2020; Wassie & Adaramola, 2021). For those who used SHSs for income generation such as by charging mobile phones, the question which arises is over how sustainable these new income-generating activities are. Of course, early adopters of SHSs would generate considerable incomes by charging the phones of people in their communities, but this income stream is expected to decrease significantly or even come to an end as more people in these rural communities adopt SHSs and start offering similar services. Therefore, it is hard to argue that phone charging as a home-based incoming-generating activity can contribute towards increased household income in the medium and long terms.

In sum, off-grid solar technologies are currently part of Africa's energy landscape. Off-grid solar electrification has transformed the lives of millions of people in the continent, in the sense that they can have access to electricity needed for basic energy services such as lighting, mobile phone charging and powering a television. These technologies will continue to play a role in Africa's energy landscape in the foreseeable future due to limited access to and uncertainties related to centralized grid energy for a significant segment of the population, but there are numerous injustices (some of which are structural in nature) which are often kept out of view in the celebratory narrative of off-grid solar electrification in the continent. These injustices cannot be ignored, especially as they have implications for human wellbeing.

References

ACE. (2021). *Stand alone solar: Kenya*. Africa Clean Energy. https://www.ace-taf.org/wp-content/uploads/2021/04/Stand-Alone-Solar-Kenya-Market-Update.pdf. Accessed 21 May 2022.

Azimoh, C., Wallin, F., Klintenberg, P., & Karlsson, B. (2014). An assessment of unforeseen losses resulting from inappropriate use of solar home systems in South Africa. *Applied Energy, 136*, 336–346.

Baker, G. (2019, December 19). Thousands to lose homes after £75bn cobalt discovery in Democratic Republic of Congo. *The Times*. https://www.thetimes.co.uk/article/thousands-to-lose-homes-after-75bn-cobalt-discovery-in-democratic-republic-of-congo-0t58pn6h7. Accessed 1 June 2022.

Cabraal, A., Ward, W. A., Bogach, S. V., & Jain, A. (2021). *Living in the light: The Bangladesh Solar Home systems story*. World Bank. https://openknowledge.worldbank.org/handle/10986/35311

Dobbin, F., Simmons, B., & Garrett, G. (2007). The global diffusion of public policies: Social construction, coercion, competition, or learning? *Annual Review of Sociology, 33*(1), 449–472.

Evans, M. (Ed.). (2004). *Policy transfer in global perspective*. Ashgate.

Francis, C. D., Kleist, N. J., Ortega, C. P., & Cruz, A. (2012). Noise pollution alters ecological services: Enhanced pollination and disrupted seed dispersal. *Proceedings of the Royal Society of London B: Biological Sciences, 279*, 2727–2735.

Ghazi, S., Sayigh, A., & Ip, K. (2014). Dust effect on flat surfaces—A review paper. *Renewable and Sustainable Energy Reviews, 33*, 742–751.

Gilardi, F. (2012). Transnational diffusion: Norms, ideas, and policies. In W. Carlsnaes, T. Rise, & B. Simmons (Eds.), *Handbook of international relations* (2nd ed., pp. 453–477). Sage.

GOGLA. (2018). *Off-Grid Solar*. A Growth Engine for Jobs. Netherlands: Utrecht, Retrieved from https://www.gogla.org/sites/default/files/resource_docs/gogla_off_grid_solar_a_growth_engine_for_jobs_web_opt.pdf. Accessed 8 April 2022.

GOGLA. (2019). *Global off-grid solar market report semi-annual sales and impact data*. https://www.gogla.org/sites/default/files/resource_docs/global_offgrid_solar_market_report_h1_2019.pdf. Accessed 9 Nov 2020.

Greenhill, B. (2010). The company you keep: International socialization and the diffusion of human rights norms. *International Studies Quarterly, 54*, 127–145.

Gustavsson, M. (2007). Educational benefits from solar technology—Access to solar electric services and changes in children's study routines, experiences from eastern province Zambia. *Energy Policy, 35*, 1292–1299.

Hellqvist, L., & Heubaum, H. (2022). Setting the sun on off-grid solar? Policy lessons from the Bangladesh solar home systems (SHS) programme. *Climate Policy*. https://doi.org/10.1080/14693062.2022.2056118

Hogan, E. B. (2015). *On the edge of an open pit: Access to land & natural resources in Tundayme, Ecuador* [MSc thesis in International Development Studies, Noragric-NMBU, Aas].

IRENA. (2020). *Scaling up renewable energy deployment in Africa*. https://www.irena.org//media/Files/IRENA/Agency/Publication/2020/Feb/IRENA_Africa_Impact_Report_2020.pdf?la=en&hash=B1AD828DFD77D6430B93185EC90A0D1B72D452CC

Kizilcec, V., Parikh, P., & Bisaga, I. (2021). Examining the Journey of a Pay-as-You-Go Solar Home System Customer: *A Case Study of Rwanda. Energies, 14*, 330.

Kuhlmann, J., González de Reufels, D., Schlichte, K., & Nullmeier, F. (2020). How social policy travels: A refined model of diffusion. *Global Social Policy, 20*(1), 80–96.

Leifsen, E. (2017). Wasteland by design: Dispossession by contamination and the struggle for water justice in the Ecuadorian Amazon. *Extracting Industries and Society, 4*, 344–435.

Maggetti, M., & Gilardi, F. (2016). Problems (and solutions) in the measurement of policy diffusion mechanisms. *Journal of Public Policy, 36*, 87–107.

Mama, C. (2018). What's the current state of solar equipment import trade in Africa? *Solar Magazine*. https://solarmagazine.com/state-of-solar-equipment-import-trade-in-africa/. Accessed 21 May 2022.

Murrey, A. (2015a). *Lifescapes of a pipedream: A decolonial mixtape of structural violence and resistance in two towns along the Chad-Cameroon oil pipeline* [PhD dissertation]. Geography and the Environment, University of Oxford.

Murrey, A. (2015b). Narratives of life and violence along the Chad-Cameroon Oil Pipeline. *Human Geography—A New Radical Journal, 8*(1): 15–39.

Mustafa, R. J., Gomaa, M. R., Al-Dhaifallah, M., & Rezk, H. (2020). Environmental impacts on the performance of solar photovoltaic systems. *Sustainability, 12*(2), 608.

Obeng-Odoom, F. (2015). Africa: On the rise, but to where? *Forum for Social Economics, 44*(3), 234–250.

Obeng-Odoom, F. (2022). *Global migration beyond limits: Ecology, economics, and political economy*. Oxford University Press.

Obinger, H., Schmitt, C., & Starke, P. (2013). Policy diffusion and policy transfer in comparative welfare state research. *Social Policy and Administration, 47*(1), 111–129.

Opiyo, N. (2020). How basic access to electricity stimulates temporally increasing load demands by households in rural developing communities. *Energy for Sustainable Development, 59*, 97–106.

Parris, K., & McCauley, R. (2016). *Noise pollution and the environment*. Australian Academy of Science. https://www.science.org.au/curious/earth-environment/noise-pollution-and-environment. Accessed 2 June 2022.

Perreault, T. (2013). Dispossession by accumulation? Mining, water and the nature of enclosure on the Bolivian Altiplano. *Antipode, 45*(5), 1050–1069.

Potocnik, I., & Poje, A. (2010). Noise pollution in forest environment due to forest operations. *Croatian Journal of Forest Engineering, 31*(2), 137–148.

Samarakoon, S. (2020). The troubled path to ending darkness: Energy injustice encounters in Malawi's offgrid solar market. *Energy Research & Social Science, 69*, 101712.

Samarakoon, S., Bartlett, A., & Munro, P. (2021). Somewhat original: Energy ethics in Malawi's off-grid solar market. *Environmental Sociology, 7*(3), 164–175.

Searcey, D., Forsythe, M., & Eric Lipton, E. (2021, November 20). A power struggle over cobalt rattles the clean energy revolution. *The New York Times*. https://www.nytimes.com/2021/11/20/world/china-congo-cobalt.html. Accessed 1 June 2022.

Shipan, C. R., & Volden, C. (2009). The mechanisms of policy diffusion. *American Journal of Political Science, 52*(4), 840–857.

Sotiriou, A. G., Bardouille, P., Waldron, D., & Vanzulli, G. (2018). *Strange beasts: Making sense of PAYGo solar business models, Forum 14, Consultative Group to Assist the Poor*. www.cgap.org/sites/default/files/Forum-Strange-Beasts-Jan-2018.pdf. accessed 20 May 2022.

Sovacool, B. K., Turnheim, B., Hook, A., Brock, A., & Martiskainen, M. (2021). Dispossessed by decarbonisation: Reducing vulnerability, injustice, and inequality in the lived experience of low-carbon pathways. *World Development, 137*, 105116.

Squadrone, S., Burioli, E., Monaco, G., Koya, M. K., Prearo, M., Gennero, S., Dominici, A., & A and Abete, M. C. (2016). Human exposure to metals due to consumption of fish from an artificial lake basin close to an active mining area in Katanga (D.R. Congo). *Science of the Total Environment, 568*, 679–684.

The Economist. (2022, May 5). Yemi Osinbajo on the hypocrisy of rich countries' climate policies. *The Economist*.

Taylor, I. (2016). Dependency redux: Why Africa is not rising. *Review of African Political Economy, 43*(147), 8–25.

Toman, M., & Jemelkova, B. (2003). Energy and economie development: An assessment of the state of knowledge. *The Energy Journal, 24*(4), 93–112.

UNCTAD. (2020). *Commodities at a glance: Special issue on strategic battery raw materials*.

United Nations. (2019). *World population prospects: The 2019 revision*. United Nations, Department of Economic and Social Affairs, Population Division.

USAID. (2017). *Scaling access to energy in Africa*. USAID. https://pdf.usaid.gov/pdf_docs/PA00WJN1.pdf. Accessed 19 May 2022.

Wassie, Y., & Adaramola, M. (2021). Socio-economic and environmental impacts of rural electrification with Solar Photovoltaic systems: Evidence from southern Ethiopia. *Energy for Sustainable Development, 60*, 52–66.

World Bank. (2019). *Mini grids for half a billion people: Market outlook and handbook for decision makers*. Executive Summary. Energy Sector Management Assistance Program (ESMAP) Technical Report 014/19. World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/31926/Mini-Grids-for-Half-a-Billion-People-Market-Outlook-and-Handbook-for-Decision-Makers-Executive-Summary.pdf?sequence=1&isAllowed=y. Accessed 20 May 2022.

World Bank. (2020a). *World Bank project to boost household access to affordable energy*. World Bank. https://www.worldbank.org/en/news/press-release/2020a/09/17/world-bank-project-to-boost-household-access-to-affordable-energy#:~:text=Rwanda%20EAQIP%20aims%20to%20improve,off%2Dgrid%20solar%20home%20systems. Accessed 19 May 2022.

World Bank. (2020b). *Lighting up Africa: Bringing renewable, off-grid energy to communities*. World Bank. https://www.worldbank.org/en/news/feature/2020b/08/13/lighting-up-africa-bringing-renewable-off-grid-energy-to-communities. Accessed 19 May 2022.

World Bank. (2020c). *Off-grid solar: Market trends report 2020c*. World Bank. https://www.lightingglobal.org/wp-content/uploads/2020c/03/VIVID%20OCA_2020_Off_Grid_Solar_Market_Trends_Report_Summary_High%20res.pdf. Accessed 20 May 2020.

Zehner, O. (2012). *Green illusions: The dirty secrets of clean energy and the future of environmentalism*. University of Nebraska Press.

Index

N. Ojong (ed.), *Off-Grid Solar Electrification in Africa*, Energy, Climate and the Environment, https://doi.org/10.1007/978-3-031-13825-6