Justice in Transition: A Case of Decentralized Renewables from India

by

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ABSTRACT

As India expanded its grid infrastructure, decentralized renewable energy technologies, such as off-grid solar, also emerged in parallel as an electrification solution. This dissertation critically examines the role of off-grid solar in facilitating rural electrification efforts in India. Specifically, it applies the frameworks of the multi-level perspective, capabilities approach, and energy justice to achieve three objectives: (1) trace the evolution of off-grid solar in India; (2) understand the role of solar micro-grids in improving household capabilities and well-being; (1) examine whether and how community-scale solar micro-grids can operate as just means of electrification. This research relies on qualitative case-study methods. The historical research in Paper 1 is based on published policy documents and interviews with energy experts in India. It finds that landscape-regime-niche actor relations and politics were crucial in shaping off-grid solar transition outcomes. There is also a narrative component, as the key narratives of energy security, environmental degradation, climate change and energy for development converged to create spaces for state and non-state interactions that could nurture the development of off-grid solar. The community-level research in Papers 2 and 3 analyze a local energy initiative of community operated solar micro-grid using semi-structured interviews and participant observations from three villages in Maharashtra. Solar micro-grids play an important part in expanding people's choices and opportunities. The benefits are not uniform across all people, however. Increases in energy-related capabilities vary by economic class and gender, and to some extent this means certain biases can get reinforced. In addition, the inability of solar micro-grids to keep up with the changing electrification landscape and daily practices means that the challenges of

affordability, reliability and community engagement emerged as important concerns over-time. Empirically, this dissertation finds that off-grid energy initiatives must be carefully designed to be in alignment with local values and realities. Theoretically, it adds to debates on justice in energy transitions by showcasing the regime-led innovations, and temporality elements of energy justice local energy initiatives.

DEDICATION

My grandmother Padmasani Ranganathan. And to the rural communities around the world struggling to escape energy poverty.

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CHAPTER 1

INTRODUCTION

"The provision of one light to poor people does nothing more than shine a light on poverty"

Kandeh Yumkella, Former Director-General of the UN Industrial Development Organization

The journey towards this dissertation started in the summer of 2013, almost three years before I joined the doctoral programme. As I travelled across various rural parts of India, there was a growing realization towards the extent of energy poverty in a country that was seen as one of the brightest emerging economies in the world (Tharoor 2007). I was sitting out in a small, thatched roof hut in a village in Madhya Pradesh, with a solar lantern shining as the primary lighting source while finishing my dinner with the host family. Even that solar lantern meant a lot to that household as they preferred having that over a kerosene lamp. That was my first introduction to the use of off-grid solar (OGS) systems in rural electrification context. This dissertation is built on such stories from the ground, which is used to ascribe meaning to the contribution of OGS in the energy poverty discourse. In doing so, I try to trace how OGS evolved in India over a period of almost four decades, identify how it affects human capabilities and finally ask the question about its suitability as a just means of electrification.

1.1. Energy and Development – What do we know?

Energy poverty has emerged as one of the biggest challenges in the last few decades within development discourse. Though significant progress has been made, almost a billion people in Asia and Africa lack access to electricity, thereby being trapped in energy poverty (IEA, 2012). The international momentum as a result of Sustainable Development Goals (SDGs) has therefore pushed the agenda of achieving universal energy access by 2030. The SDG 7 deals with energy access with the goal to 'ensure access to affordable, reliable, sustainable and modern energy for all'. Understanding repercussions of energy poverty and a strong commitment towards tackling this challenge, the United Nations declared 2012 as Sustainable Energy for All (SE4ALL) and 2014-2024 a decade for the same (Rogelj, Mccollum, and Riahi 2013).

Energy is critical for human development, and lack of it deprives individuals of various opportunities to fulfil basic needs. International focus on energy and development has been around for decades and primarily revolved around economics. Since the seminal paper by Kraft & Kraft (1978) which found causality running from GNP to energy consumption in the United States, many studies have tried to determine the income and energy relationship. With the use of Human Development Index (HDI) as a welfare measure gaining prominence, researchers tried to establish relationship between energy and HDI. For example, Ouedraogo (2013) in her study of 15 developing countries using data between 1988-2008 found that 1% increase in per capita electricity consumption increases the HDI by 0.22%. Thus, the linear relationship between energy and growth permeated the international development discourse for a long time.

At a micro-level, energy studies have tried to focus on the aspects of poverty such as health, education and livelihoods. Literature has focused on the health risks arising out of lack of electricity at household level through the exposure of fumes or risks of burning from the use of kerosene lighting (Lam, Smith, et al. 2012b). Similarly, electrification has important implications for livelihoods as well. Dinkelman (2011) found that employment, both male and female, grew in places that gained access to electricity in South Africa. Similarly, there is also a positive effect of electrification on children's education, as shown by Khandker et al. (2014) where they found that children in households with electricity spend more time studying than in households without electricity. While there is evidence towards micro-benefits, researchers have questioned the pathways to realize the benefits of electrification as it tends to more complex than direct ones established in previous studies (Lenz et al. 2017; Aklin et al. 2017). All of it points out that household access to electricity is critical for well-being, and documenting evidence becomes critical to provide decision makers with insights about energy policies for rural electrification.

1.2. Electrification in India

For decades, India struggled with massive energy poverty in the simplest of sense i.e. have v/s have not. At the beginning of the millennia, the household electrification rate in rural India stood at 43.5 percent, which left more than half a billion people to either rely on kerosene for lighting or live in the dark (Bhattacharyya 2006; IEA 2002). This was not just because of mere large population of India but also to the inadequate electrification

efforts. For example, the number of villages electrified in 1990's was just under 40,000 as compared to 2,20,000 in the decade of 1980 (Dubash and Bradley 2005).

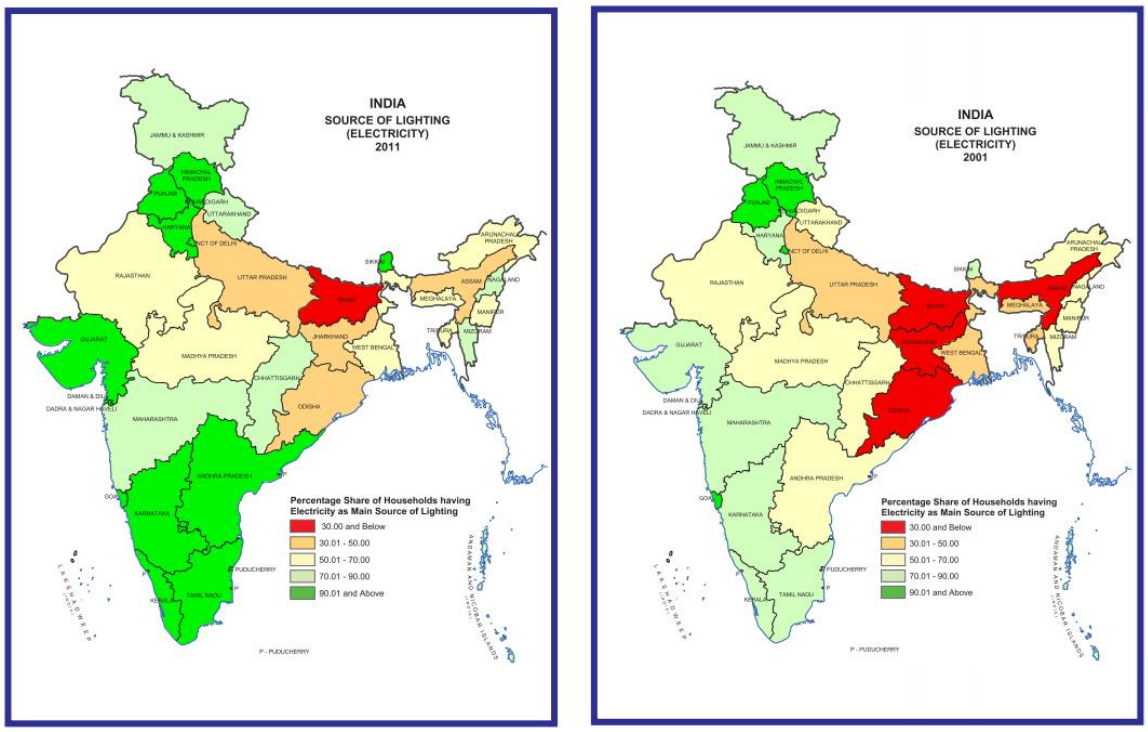


Figure 1: Electricity as the Main Source of Lighting in 2001 and 2011 (Source: *Census of India 2011)*

Rural electrification gained political attention during late 1990s and early 2000's as seen from the election slogans such as 'bijli, sadak, pani' (translated as electricity, roads and water) during the time (Suri 2004). Much of this also transformed into policy-oriented actions during mid 2000s as India introduced the Electricity Act (2003), followed by the flagship large scale rural electrification scheme called Rajiv Gandhi Grameen Viduyutikaran Yojana (RGGVY) to which aimed to electrify all household (Power for All) by 2012. The RGGVY predominantly focused on extending the grids to rural areas (Palit and Bandyopadhyay 2017). These changes did make the electrification rate grow

quicker during the decade; however, the goal of universal electrification did not materialize in the set time frame. The rural household electrification stood at mere 55.3 percent in 2011 (Census of India 2011b). The recent decade has seen a greater push towards bringing in all the people under electrification through Deen Dayal Gram Jyoti Yojana (DDUGJY) and the Saubhagya scheme. These efforts resulted in more than half a billion people in India gaining access to electricity since 2000, often cited as a success story of electrification efforts of past two decades (IEA 2017b).

1.2.1. 2020 – What is happening with electrification in India

India today shines as an example of global electrification efforts of this millennium. In the past two decades, India has provided electricity to over half a billion people. Towards the end of the decade, India achieved two symbolic milestones. First, the Government of India (GoI) announced total village electrification in 2018. And second, the GoI declared that it had all complete electrification of all households (except the ones who refused access) in 2019 (IEA 2020). Yet, various studies have indicated that energy poverty scenario is still worrying in India. A recent study indicates that almost 17 percent of rural households in India are still living without access to electricity (Agrawal, Kumar, and Rao 2019). While India has been successful in creating access, i.e. connecting households with access to electricity, it has been falling behind in reliability i.e. continuous power supply. In a large-scale survey of five states in India, it was found that households connected to grid received only 13 hours of supply on a typical day with almost four outage days per month (Thomas and Urpelainen 2018). There are important caveats to electrification in India. Traditionally, the energy poor in India are from rural areas with

por economic status. For example, 93 percent of those without electricity in 2011 resided in rural areas, while 40 percent were in poorest income quartile (Banerjee et al. 2015). The electrification progress also has highlighted the inequalities between various social groups in rural India. Acharya and Sadath (2019) highlight the energy poverty decline among marginalized groups like the tribal populations have been marginal as compared to communities like Hindus or Jains. Thus, studies like S. Gupta, Gupta, and Sarangi (2020) classified almost 65 percent of the households in India as either more or most energy poor. This underscores that energy poverty and related inequality is quite dominant in India despite its electrification efforts and leaves quite a gap for scholars to understand the reasons for such.

1.2.2. Decentralized Renewable Energy in India

The growing need to electrify rural areas and the inability of grids to expand to rural areas led to the saw emergence of decentralized renewable energy (DRE) as an alternative in India and around the world. The most dominant among DREs is the photovoltaic (PV) based energy systems (hereafter known as off-grid solar or OGS) i.e., solar home lighting systems and more recently, micro- and mini-grids. India has been at the forefront of its application for rural electrification, with early research and development starting in the early 1980's. The GoI recognized that DREs will be critical in achieving the last mile connection and started promoting OGS through schemes and initiatives starting in mid-1990s. Yet, it was clear that government's approach towards OGS was mainly subsidy driven and lacked reasonable support towards sustainability of such systems. Since 2000s, many initiatives from private and civil society were seen in

India promoting OGS. This growth was driven through various technological, financial, and business model innovations at niche level (K. Singh 2016).

Table below 1 provides an overview of different OGS service delivery models and their approach in India. Government organizes OGS through different programs like Remote Village Electrification Program (RVEP) or Decentralized Distributive Generation (DDG) in the case of India. Similarly, non-government organizations deploy decentralized solutions towards community development as part of energy access programmes. Private players like social enterprises or energy service companies (ESCO) deliver small load solutions for lighting (and household appliances like TV sets) through different delivery models to rural households. These enterprises eye the rural segment (or Bottom of Pyramid) for generating revenue while they meet the needs of this population following a customized market-based approach.

Table 1: Mapping of Different Off-grid Solar Models in India

		Actors		
		Government	**Non-government**	**Private**
Financial Model	**Subsidy**	• Subsidy towards deployment of technology under different schemes • 90 percent capital subsidy under rural electrification programme using renewable technology	-	• Partnering with government as channeled suppliers specified off-grid solar systems • Sells the subsidized solar systems and avails 30 percent subsidy as

		and 30-90 percent subsidy on installation of solar off-grid technology under National Solar Mission.		provided under National Solar Mission.
	Cash Sale	• Local shops called Akshay Urja Shop for selling of renewable energy products.	-	• Direct selling of products to the people on cash basis through established supply chain networks or retail marketing
	Credit	-	• Provisioning micro-finance to rural households	• Linkages with financial institutions (including rural banks) for credit
	Pay as you go	-	-	• Purchase of small credits, a part of which goes toward final payment of system.
	Fee for service	-	• Capital cost covered through grants/donations • Centralized of solar lantern at charging station and renting it at a fee determined in consultation with local communities	• Supply of power for basic lighting at nominal fee based on feasibility and economic cost of project
Type Based	**Community**	• Establishing micro/mini-grids in places having high	-	• Establishing micro-grid in communities to supply

		population density		small load power
	Individual	• Akshay Urja Shops sell different type of solar products including solar lanterns, solar home systems.	-	• Enterprise like SELCO, THRIVE promote and market individual system like solar lanterns and solar home systems of different capacities
Management and Operation	**Community**	• Manage the of the local systems through establishing Village Energy Committee (VEC) • Conflict resolution and overall management with the VEC	• Similar to the governments' approach with establishment of VEC • VEC manages the operation and looks at collection of fees.	-
	Local Entrepreneur	• Individual from local communities engage in selling of the product. • Complaints redressal and maintenance may the responsibility of the entrepreneur	• Manages the operation of the local systems • Collection of rent and deposit	-

1.3. Knowledge Gaps

The studies towards understanding DREs, specifically OGS have grown in the last decade. Yet, there are still some knowledge gaps within OGS and its application for achieving SDG 7. First, none have so far traced the development (or transitions) of OGS

in the Indian context despite its long presence and contribution to rural electrification. In a sector with which involves multiple actors, ranging from international organizations to local energy enterprises, we have little understanding of how OGS transitions have come about. As countries around the global south try to expand OGS to address rural electrification (Ma and Urpelainen 2018), it would be valuable to understand how the local-national-global actors interact to facilitate such a transition. The findings will be important for multiple reasons, including building crucial multi-stakeholder partnerships to not just create energy access, but also tackle various associated challenges such as climate change and renewable energy deployment.

Second, as OGS becomes an important strategy for rural electrification, there is inadequate understanding of its pathways to achieve human capabilities. More recently, energy poverty is being redefined in terms of capabilities deprivation (Day, Walker, and Simcock 2016). Thus, any intervention to bring in electricity (grid or off-grid) will provide avenues for enabling new energy related capabilities within rural communities. However, interventions are still to center discussions around technologies such as OGS for rural electrification through lens of the capabilities. This opens up additional spaces for designing interventions through understanding the relationship between energy services and capabilities, thereby also highlighting alternative means to support capabilities (Day, Walker, and Simcock 2016). It will help develop program and policies sensitive to various aspects like gender or environment, which inherently become a part of OGS interventions in the long-term.

Third, the literature does not delve into OGS as just means of electrification. While there is no doubt that OGS has created energy access for millions across the global south in a rather quick time frame, there are issues with its integration into rural lives and livelihoods as a long-term solution. Electrification in global south countries is a dynamic process with the use of multiple fuels and technologies (Yadav, Davies, and Asumadu-Sarkodie 2021; Aziz and Chowdhury 2021) and a moving target (Harris, Collinson, and Wittenberg 2017). Energy access once created will be not necessarily be sufficient in itself for communities to sustain it. Thus, questions about factors such as technology appropriateness becomes central to the discussions of energy justice in global south (Munro, van der Horst, and Healy 2017). Similarly, learning about whether and why perspectives change regarding OGS as means of electrification is necessary to build effective programs and policies. Unless policymakers have insights into the issues that emerge from the experiences of being embedded in energy access through OGS, it will be unwise to assume that OGS is a just form of electrification, atleast from the perspective of rural communities.

1.4. Research Objectives

This dissertation examines the role of OGS in facilitating rural electrification efforts in India. This is guided by tracing the narratives which influences off-grid solar development in India, and further examining its ability to address energy justice issues at local level by looking at detailed case-study of community based solar micro-grids. The research questions guiding this thesis are:

- How did India's off-grid solar sector evolve for rural electrification, and what narratives influenced how various actors pursued off-grid solar?
- What and how capabilities are affected in rural communities from solar micro-grids?
- How successful are solar micro-grids as a just means of electrification?

These questions provide a broader understanding of the contribution of off-grid solar in the electrification efforts in global south countries. Not only does the study look at OGS as a solution and effectiveness in facilitating energy access, but also sheds light its implications on energy justice.

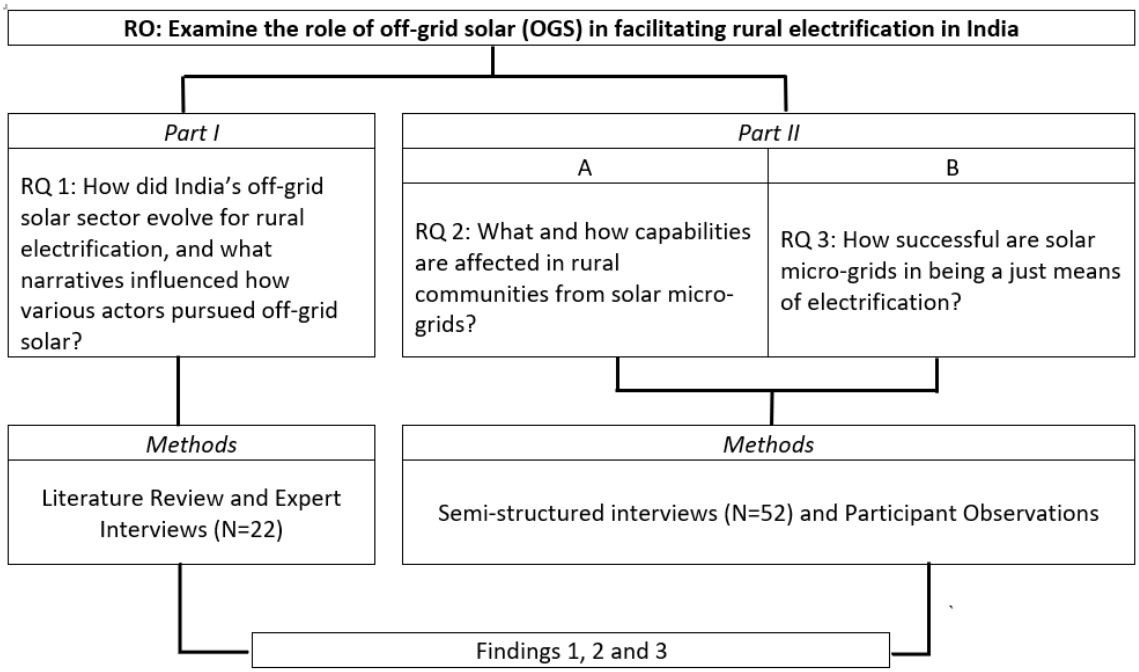


Figure 2: Research Design - Objective, Research Question and Methods

1.5. Theoretical Perspective

This dissertation is engrained in the main fields of socio-technical transitions and energy justice. While these two different strands are often separate within energy research, today we see scholars calling to embed justice approaches within socio-technical transitions to produce fair and equitable energy system (Jenkins, Sovacool, and McCauley 2018; Sareen and Haarstad 2018). This comes from the fact that energy decisions and planning for transitions often give rise to range of ethical and equity related dilemma (York 2015; B. K. Sovacool and Dworkin 2015). The first part of this section briefly explains socio-technical transition and the framework of multi-level perspective. Then, it moves on to the energy justice framework and the capabilities approach.

1.5.1. Socio-technical transition

A socio-technical transition is seen as a fundamental shift in the whole, interlocking system including technology, material, institutions, networked supply chains, regulations and belief systems, which over a long time periods, are replaced by new products, services and business models (Smith, Stirling, and Berkhout 2005; Frank W. Geels 2010; 2004). When referring to socio-technical transitions (STS) here, this dissertation explicitly deals with energy transitions, which in contemporary context often is discussed as shift from a fossil-fuel based economy to a more a low-carbon economy. The impact of such transitions will probably be comparable to other historic energy transitions, such as the transition from wood to coal or to a complex energy mix that exists today incorporating natural gas, coal power and nuclear power, among many other growing renewable energy sources such as hydropower and solar and wind power (B. Sovacool,

Sidortsov, and Jones 2013; Bickerstaff, Walker, and Bulkeley 2013). Low-carbon transition processes which utilize these low-carbon technologies cannot be envisaged as solely economic or technological challenges, but rather are also deeply entrenched in the dynamics of social change and social relations.

The Multi-Level Perspective (MLP), originally developed by Rip and Kemp (1998), is a branch of transition studies, which provides a framework to understand how any change (particularly transitions) within a socio-technical system occurs (Genus and Coles 2008; F. W. Geels 2005; Frank W. Geels 2002; Frank W. Geels and Schot 2007b; Smith, Stirling, and Berkhout 2005). According to Geels and Schot (2007), a transition occurs as a result of "alignment of these processes enables the breakthrough of novelties in mainstream markets where they compete with existing regime." Transition, often a non-linear process, is a result of interaction at different analytical levels. The MLP framework describes these levels in three societal systems – niche, wherein radical innovation emerges; the regime, consisting of dominant institutions and technologies; and the landscape representing the macro-level trends that describes contextual drivers and barriers to change.

Often conceptualized as specific territorial boundaries – niches occur at sub-national or have local features, regimes depicted with national features and landscape with international characteristics (Hansen and Nygaard 2013). The relationship between the three levels is a nested hierarchy, where regimes are embedded within landscapes and niches within regimes. It is also important to take note that transitions, as studied through

MLP, involve setbacks and a lot of back and forth between various sets of processes and actors.

Niches are regarded as the 'protected spaces' where innovation takes places. These protected spaces can be 'R&D laboratories, subsidized demonstration projects, or small market niches where users have special demands and are willing to support emerging innovations' (Frank W. Geels 2012). In simpler terms, the idea of niche is to provide opportunities to support innovations that so far has not proven viability (due to low performance of radical novelties is initially low), thus holding at bay certain selection pressures from mainstream environment (Smith and Raven 2012b). Regimes are the stable and dominant pathways established to achieve certain societal functions. Regimes are often conceptualized spatially at national levels of governance, and often consist of dominant institutions and technologies. Most often, change at the regime level is often seen as slow and incremental in nature as a result of 'sunk investments, vested interests, habits, bureaucracy and other factors which afford stability but at the same time constraints flexibility and opportunities for radical change' (Whitmarsh, 2012, pp. 483). Sociotechnical landscapes provide deep-structural 'gradients of force' which facilitates transitions by adding pressure or providing impetus to the socio-technical regime level (Frank W. Geels and Schot 2007b). Landscape processes include environmental and demographic change, new social movements, shifts in general political ideology, broad economic restructuring, emerging scientific paradigms, and cultural developments.

1.5.2. Energy Justice

Energy justice has evolved as a moral issue in academic and policy circles in recent years. There is no formalized definition of energy justice which is universally accepted; with researchers defining it many ways. According to McCauley et al. (2013), energy justice aims at providing 'all individuals, across all areas, with safe, affordable and sustainable energy.' Sovacool and Dworkin, (2015, pp. 436) 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.' However, one can see the evolution of the concept of energy justice to encompass spatial and temporal dimension of energy decisions since the term was started to be used. McCauley et al. (2018) expanded the idea of energy justice to add temporal perspective in the context of policy change by redefining as 'the adoption and subsequent reformation of an agreed plan of action or policy framework designed by multiple actors with the stated purpose of enhancing principles of fairness and equity in or between energy systems.' Energy justice allows us to evaluate the implication of decisions and choices through justice principles (Jenkins, McCauley, and Forman 2017; Jenkins et al. 2016).

Energy justice has three rooted principles: distribution, procedure and recognition. Rawls, in his seminal work 'Theory of Justice', argued that fairness in the distribution of goods and advantages should be the fundamental idea in social justice (Rawls 1971). He claims that fairness can be arrived at from the 'original position' i.e. if a person is unaware of his place in society, his class position or social status, nor does he know his fortune in the distribution of natural assets and abilities, his intelligence, strength (Rawls 1971). The

'original position' allows for the resultant outcome to be just and distribution to be fair. While Rawls provided the foundational work for theory of justice, many have criticized his thought. Sen argues for 'capabilities' as against the distribution of resources (of what Rawls calls 'primary goods') being object of concern. For example, people cannot convert primary good to outcome at same rate because of the inherent differences (A. Sen 1999). Thus, distributive justice represents both, physically unequal allocation of environmental benefits and ills, and the uneven distribution of their associated responsibilities (Walker 2009b). The capabilities approach, pioneered by Amartya Sen (A. Sen 1979), has been further expanded by eminent scholars like Martha Nussbaum. The capabilities approach, in simple terms, is an assessment of individuals quality of life based on opportunities available which he or she has reason to value. It is based on the idea of freedom being critical for social evaluation (Nussbaum and Sen 1993) and therefore forming a premise for critical arguments in development economics. Capabilities approach has two interlinked concepts: functioning and capabilities. Functioning refers to things a person values doing or being, with examples such as 'being adequately nourished' or 'being free from disease' or 'having self-respect' (A. Sen 1997). Functionings covers all different activities and situations people recognize to be important for themselves. Capability refers to actual freedom to achieve various alternative combinations of functionings, or doings and beings (A. Sen 1990). The difference between functioning and capabilities is that between what is realized and what can potentially be realized. In other words, capability is set of total functions available to a person. By this approach, Sen places a deep correlation between freedom and function. If a person has more freedom, thereby has more opportunities to fulfill one's function.

The capabilities approach could appreciate all changes in a person's quality of life: from knowledge to relationships to opportunities and inner peace, to self-confidence and the various valued activities made possible by access to new resources (Alkire 2005).

While the capabilities approach has been around for decades, only recently have the researchers started to explicitly explore its linkage with energy. The capabilities approach is gaining prominence in terms of understanding the outcomes of energy decisions as it becomes more people centered. An important piece here to mention is Day et al. (2016) which argues that energy is a material pre-requisite to achieve valued functioning. The article elucidates how energy and the services provided are necessary for achieving secondary capabilities that in turn affect basic capabilities. It builds on the premise of Sen's idea that the relationship between income (and other resources) and individual achievements and freedoms is not constant (A. Sen 1997). According to Sen, we can easily express the lack of or inability of energy access (in other terms energy poverty) to fulfill needs as a form of 'unfreedom', which can be detrimental to individual capabilities. This premise can also be translated to energy access and its benefits differing for different individuals. Let us take an example of young and an old person, who need different amounts of energy to keep themselves warm during cold winters. Possible reason could be the physical needs of warmth, as well as the disposable income available to spend on energy bills. This could easily affect the way both consume energy, thereby affecting their well-being. Hence energy may be valued differently by different groups based on their needs and ability, and which can further be shaped by values and experiences.

While the initial philosophy of justice revolved around distributional theories (for example Rawls, Sen), the work by Young, Fraser and others pushed its boundaries to supplement it with the ideas of procedure and recognition. Young (1990) proposes that the distributional injustice is an outcome of various interactions of social and institutional characteristics of the society. Procedural justice emphasizes on the procedures (for example underlying processes of implementation or decision making) which produce just or unjust outcomes (Walker and Day 2012). Outcomes, if to be accepted by the people, are to be based on fair processes, which then in turn lend legitimacy to the decisions. As put forward by Sovacool et al. (2016), procedural justice around energy decision revolved around 'who gets to decide and set rules and laws, and which parties and interests are recognized in decision-making? By what process do they make such decisions? And how impartial or fair are the institutions, instruments and objectives involved?' Within the environmental policy realm, AARHUS convention lays out important principles for interaction between public and authorities, through involvement in decision making. As per the convention, procedural justice has three pillars which are access to information, access to meaningful participation in decision-making and access to justice in case of environmental matters seeking redressal with regards first pillars (UNECE 2004). Procedural justice strongly speaks to democratizing the energy systems, wherein there is a possibility for the community members to be heard at every step. For example, in case of local energy renewable transitions in Europe, Mundaca et al. (2018) found that despite the problematic distributional (cost and benefits) outcomes, it was considered fair by local communities because the procedural mechanism was considered fair.

Justice as recognition which relates closely with procedural justice, can be seen as precursory to it. However, recognition is not the same as participation, instead it manifests as "the process of disrespect, insult and degradation that devalue some people and some places identities in comparison to others" (Walker, 2009, pp. 615). Idea of recognition is considered more as cultural or symbolic phenomena deeply rooted in the patterns of representation, interpretation, and communication, exemplifying cultural domination, non-recognition and disrespect (Fraser 1995). Fraser identifies (mis)recognition if 'individuals and groups are denied the status of full partners in social interaction simply as a consequence of institutionalized patterns of cultural value in whose construction they have not equally participated, and which disparage their distinctive characteristics, or the distinctive characteristics assigned to them' (Fraser, 1998, pp. 3). Recognition justice states that individuals must be fairly represented, that they must be free from physical threats and that they must be offered complete and equal political rights, thus being far more than just tolerance (Schlosberg 2003b). When voices of certain groups go unrecognized or unattended, the process of distribution even achieved through participation, cannot be considered fair. Within energy context, the existing fuel poverty approach has strongly voiced the need to understand the implications of recognition problem (Walker and Day 2012). For example, if the certain groups such as women are completely overlooked, it can lead to (mis)recognition within energy decisions.

1.5.3. Connection Transitions to Justice

While distinct in their own sense, the three frameworks have deep inter-linkages with each other. The socio-technical transition framework like MLP can provide understanding of the transitions across spatial and temporal boundaries, and adding justice and capabilities provides an avenue to bring in discussions of equity and fairness of associated processes of transitions. This theoretical foundation of this dissertation is guided by the emerging scholarship around bringing these frameworks together to discuss the implications of justice within energy transitions (Jenkins et al., 2018; Sareen and Haarstad, 2018). In doing so, the dissertation expands the current literature by adding a case-study of off-grid solar transitions in India, neither of which have gained any significant attention so far within the literature.

The figure 2 below visually showcases how energy justice and capabilities are embedded in transition processes from a multi-level perspective framework. The operationalization of the various framework together in this dissertation reflects the important discussions that needs to occur about larger topics of energy poverty, climate change and sustainable development. For example, the process of transition occurs at different levels with various factors affecting the pace of new innovations to becoming a dominant regime. At the same time, energy transitions which may create unequal benefits for various stakeholders means questions about equity and fairness becomes inherently a part of transition processes. In this dissertation, the idea of energy justice and capabilities with respect to larger off-grid solar transitions in India is only discussed from the perspective

of solar micro-grid initiative. Having said, it is understood that discussions of capabilities and justice have to necessarily become a part of each spatial levels of transitions.

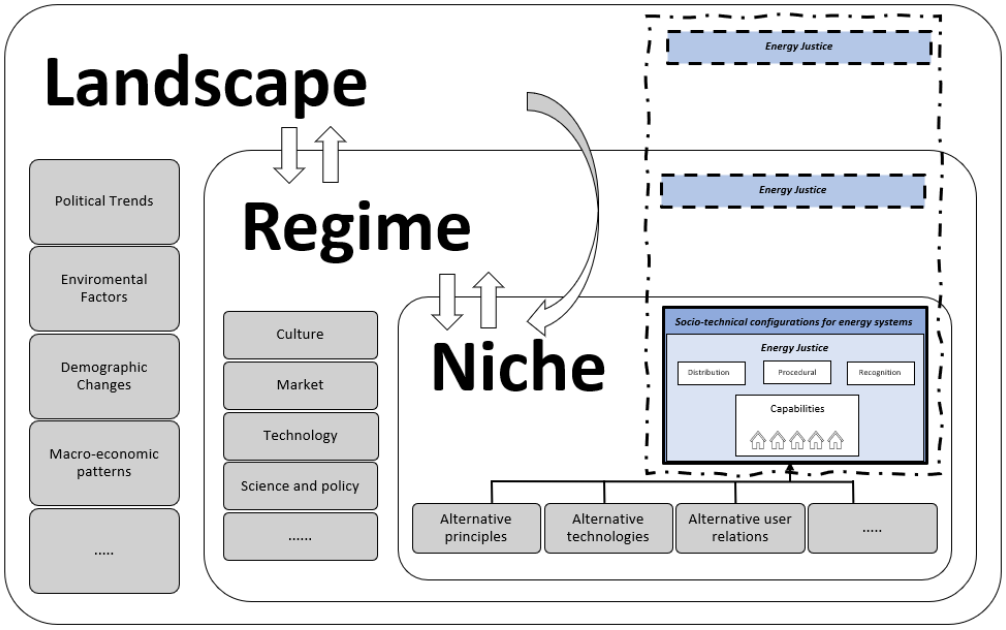


Figure 3: Conceptualization of Justice in Energy Transitions

1.6. Methods

This dissertation engages with case-study methodology as prescribed by Yin (2014). A case-study is described as empirical enquiry that investigates a contemporary phenomenon in a real-life context, where the investigator has little to no possibility to control the events (Yin, 1994). This approach is ideally suited for the objective of this dissertation as the intention is to seek detailed explanation of social phenomena of energy transition (which is off-grid solar in the current context) and consequent implication for energy justice. In the recent years, a large section of studies within social spectrum energy poverty, transition, and off-grid solar have relied on the case-study approach in

the global south countries (Bhamidipati, 2019; Bisaga, 2018; Kumar, 2015). This approach is particularly important where issues of colonization and other socio-political factors have created unique circumstances of poverty and deprivation that gets either directly or indirectly embedded in every aspect of lives of the people. These contextual conditions are important as these are inextricable from the subject matter itself (Yin 2014), making a case study approach more appropriate for this dissertation.

1.6.1. Case Selection

Analytically, the dissertation focuses on two unit of analysis: first, the national level and second, local community level comprising of solar micro-grid users. The case-study selection for India, and its subsequent subset of a smaller case-study in Maharashtra was based on the specific empirical observations made during the desk-research stage and the pilot field visit. The specific observation for the research question one is on the case-study of India. The section 1.2. details out the specifics of India's energy poverty situation with respect of electrification and evolving role of decentralized renewable energy within its policy fixture, making a unique case for analysis of off-grid solar transition. Similarly, the Maharashtra case-study which specifically answers research question two and three is based on study of community-operated solar micro-grids initiative in three villages in Maharashtra. There could have been other examples of such community operated models in India (for example solar micro-grids in Chhattisgarh or more so known as CREDA models), but the selection of Maharashtra based case-study was also influenced by the two other factors: one, type of solar micro-grid intervention and second, evolving electrification paradigms in India. The solar micro-grids went

beyond just household lighting paradigm to also include street-lightings and community water pumps. These additional dimensions of energy service help us understand energy capabilities in detail. Furthermore, during the pilot visit in December 2018, it was noticed that grid electrification was rapidly occurring this region as well as many other off-grid initiatives were dominantly present. In one of villages, the households infact had received solar home lighting systems under Saubhagya scheme (distribution occurred during the pilot visit) despite having grid poles within the village almost a year ago. This meant the intersectionality of various technological pathways could be observed as the energy transition relating to electrification, making it an idea case to be selected for this research question two and three of this dissertation.

1.6.2. Data Collection

Basing the approach on case-study methods, the data collection relied on multiple sources according to the research question examined. Often, multiple sources of information is suggested to improve the internal validity of the study through data triangulation (Crowe et al., 2011; Rouse and Harrison, 2015). For research question one, the primary methods employed were literature review and expert interviews. As the foundational piece of this dissertation, literature review provided the initial understanding of off-grid solar landscape in India. Other than the published academic literature in the form of published articles, the literature also consisted of policy documents, technical papers, reports and policy briefs from various organizations engaged in this space in various capacities. For example, international institutions such as World Bank, Asian Development Bank, and Sustainable Energy for ALL (SE4ALL) have published various reports on energy poverty

and decentralized renewable energy. Similarly, industry associations in India have started to publish yearly reports on the sector, while policy think tanks are generating policy-based information. In addition to the literature review, interviews were conducted with 22 experts representing various organizations at across spatial level (Annexure I). These experts were identified through the literature review as it had shed sufficient light on the important organizations within this space in India. The experts were from various sectors – government agencies dealing with renewable energy, national and international policy think-tanks, aid agencies, industry associations and entrepreneurs. The average experience of these actors working in this space ranged from five to thirty-two years. In addition, many of these interviewees also pointed out to any other additional materials (from different projects they were involved in) that were helpful to add to literature analysis. All the interviews were conducted via Zoom or Skype and generally lasted around 40-75 minutes.

For part II exploring research questions two and three, semi-structured interviews were primarily used for data collection (Annexure II). The information regarding the kind of energy appliances owned, and the primary users, energy services derived, and the aspirational needs were collected. In addition, the interviewees were asked to highlight the challenges with the energy use through solar micro-grids, and perception regarding their involvement with community-based energy systems and off-grid solar in general. Overall, 52 interviews were conducted, which represented almost one-third of total households in the three villages. In addition, field notes and participant observations became a key tool to add perspective to the findings, allowing to gain and present a sense

of reality of the households, communities and surrounding infrastructure (Creswell, 2014). For example, observation and capturing the usage of solar home systems at household level or the condition of the solar streetlamps in the villages shed light on the embeddedness of energy assemblages within rural societies.

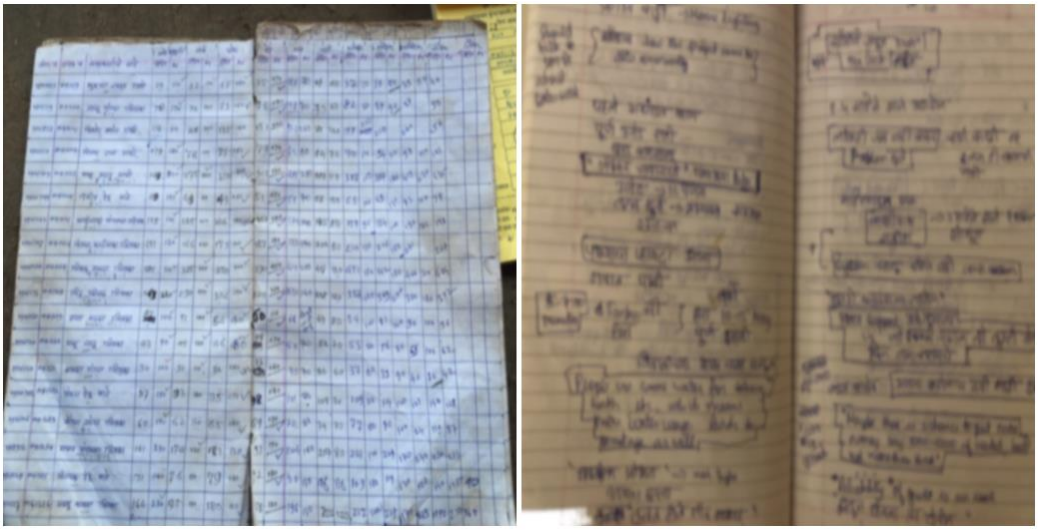


Figure 4: Example of Photographic Evidence and Field Notes

1.6.3. Analysis

The transcripts of the interviews (expert interviews in case of research question one, and semi-structured interviews in case of research question of two and three) were qualitatively analyzed through thematic analysis through open and axial coding process. There was a need for translation for the community level study as the interviews were conducted in the local language. Once transcribed, the coding was done through qualitative software MaxQDA using, both, inductive and deductive approaches. Given how frameworks were already established for data collection, certain codes were initially

looked for during this process. After initial compilation of transcripts in the qualitative software, a line-by-line coding process was followed creating various set of codes (Figure 4). The larger set of codes were further condensed into smaller set of codes. A prime example here would be women discussing various activities and tasks carried out by them. During the initial coding, each activity was separately coded and finally emergent theme of 'household activities' was derived (seen in chapter 3). The quotation, remarks and passages were coded into various themes and cross-checked with relevant literature for consistency and relevance. While some sets of final themes were consistent with literature (example education) highlighting degree of confidence in the procedures established, the newer ones added to existing knowledge around subject of investigation. The final analysis i.e., findings are reported presented in chapter two, three and four.

Figure 5: Example of Coding Strategy

1.7. Structure of the dissertation

This dissertation primarily is structured in different chapters focusing on each of the research question from section 1.4. The findings are reported in each of the chapter two, three and four along with detailed methodology used for data collection and analysis. The

final chapter discusses the key takeaways and policy implications that have emerged from learnings.

The second chapter looks traces the evolution of India's off-grid solar sector from the early 1980s through 2020. The chapter uses Multi-Level Perspective (MLP) to highlight interactions across local, national, and international actors and institutions, with additional attention to how these developments were influenced by evolving narratives around energy and development. Empirically, it was found that the development of off-grid solar required deliberate niche-building policies and resources from regime and landscape actors over multiple decades. Theoretically, this chapter also contributes to the MLP literature by showing how narrative analysis can shed light on the dynamics of energy transitions.

The third chapter focuses on understanding the role of solar micro-grids in improving the well-being of rural communities in India using the capabilities approach. The findings indicate that solar micro-grids play an important part in expanding people's choices and opportunities. Women appear to have benefited through assistance in household chores and reduced drudgery, while men seem to value entertainment and socialization aspects. However, these energy-related capabilities are, to an extent, defined by socio-economic identities such as gender roles, and certain biases can get reinforced due to the social norms and traditions of the society. The study thus recommends that energy interventions need to be designed keeping in touch with local values and realities, thus, helping policies to be more effective.

The fourth chapter, using the three tenets energy justice approach examines the community operated solar micro-grids as just form of electrification. The findings indicate that the challenges faced in terms of affordability, reliability and community engagement from community operated solar micro-grids create concerns about the energy justice within rural communities. The idea of development, particularly from perspective of electricity, is deeply connected to grids within these communities. In such cases, while solar micro-grids emerge as clean modern electrification option, it does not sufficiently get embedded within the local context in the long-term. The inability of these solar micro-grids to adapt to the changing electrification infrastructural and policy landscape as well as daily practices means communities always will have preference to grid. The study underscores the importance of incorporating energy justice principles within off-grid interventions, while emphasizing on the component of social infrastructure surrounding OGS to enable it to become just form of electrification.

The final chapter draws the conclusion, provides some important takeaways in terms for policy lessons and the theoretical contributions that has emerged from this dissertation work.

1.8. Audience of this research

This dissertation targets two distinct groups. The first is the growing set of transition and energy justice researchers who are looking at the relationship between the two. This dissertation responds to call to the bridge the knowledge gap between the two as the

global community strives to not just expand renewable energy as way to tackle climate change, but also do so in manner where we do not create additional moral, ethical and equity problems that current legacies have left the world with. The second is the energy practitioners who work with various organizations including governments, or development finance institutions (DFIs) who are actively striving to accelerate energy access in the global south countries. The hope is that the learning from this study can in some ways can help improve on current approaches of delivering decentralized solutions like off-grid solar to rural communities.

CHAPTER 2

NICHES, NARRATIVES, AND NATIONAL POLICY: HOW INDIA DEVELOPED OFF-GRID SOLAR FOR RURAL ELECTRIFICATION

2.1. Introduction

Decentralized Renewable Energy (DRE) is critical for addressing rural electrification in many parts of the world. Globally, at least 133 million people have gained access to electricity through DRE technologies, including off-grid solar such as solar lanterns, solar home lighting systems, and micro- and mini-grids (IRENA 2018). Furthermore, DREs are envisioned to be the most cost-effective solution for over 70 percent of those who will gain access to electricity in rural areas by 2030 (IEA 2002).

Despite the great potential offered by DREs, particularly off-grid solar, for providing low-carbon electricity for rural electrification and poverty reduction, it can be challenging for a country to develop a thriving DRE sector (Bertheau et al. 2020; Rathore, Chauhan, and Singh 2019). Developing effective policies, programs, and projects requires coordination across multiple types of actors, including local communities, civil society organizations, private enterprises, national governments, and international funding agencies (Haas 2019; Fudge, Peters, and Woodman 2016; Hansen and Nygaard 2013). The trajectory of off-grid solar is shaped by the interaction of these actors over long periods of time, as these actors develop capacities and adapt to changing economic, social, and technical circumstances. As countries around the world seek to expand off-grid solar to address rural electrification (Ma and Urpelainen 2018), it would be valuable

to understand how interactions among local-national-global actors facilitate this development. However, the energy transitions literature has not yet addressed the questions of how off-grid solar emerges in the global south and how actors across local, national and global scales interact to facilitate its transition.

We address this gap by examining the case of India, which has been on the forefront of off-grid solar for rural electrification. India has made great strides in electrification: nearly 500 million people gained access to electricity in India between 2000 and 2016 (IEA 2017a), and more recently India achieved 100 percent village electrification. While these electrification efforts primarily focused on grid extension, India has also seen a vibrant off-grid solar sector, particularly for rural electrification. India has facilitated DRE diffusion in a variety of ways over the past three decades, including government-led subsidy-based models and private enterprise. Yet despite the prominence of this sector within India's rural electrification efforts, it has received relatively little scholarly attention. While there have been studies on the development of India's rural electrification policies (Palit and Bandyopadhyay 2017) and renewable energy sector (Mangotra 2016), few studies focus on off-grid solar within the context of rural electrification. Only a handful of publications have assessed the current state of off-grid solar in India, including the community acceptance of projects (Millinger et al., 2012; Ulsrud et al., 2011), policy environment (Comello et al. 2017) and viability against grid electrification (Bhattacharyya et al., 2019; Choragudi, 2013), but none provide a historical institutional analysis of how the sector evolved.

In this paper, we answer the two following questions: how did India's off-grid solar sector evolve for rural electrification, and what narratives influenced how various actors pursued off-grid solar? We answer these questions through a case study that traces the development of India's off-grid solar sector over three decades. The case study applies the framework of the Multi-Level Perspective (MLP) to draw attention to the interactions among local, national, and international actors and institutions. We further add to the MLP framework with a narrative lens, identifying and discussing the evolving narratives that shaped the off-grid solar development in India across these three levels. In addition to providing an important historical record for scholars and practitioners in Indian energy policy, this study provides valuable lessons about off-grid solar transitions for other nations that are striving to achieve universal electrification. Most broadly, India's experience with off-grid solar contributes to our theoretical understanding of energy transitions in the global south. It particularly sheds light on how local energy transitions can be shaped by the interaction between international and national actors.

2.2. Literature Review

This paper uses the Multi-Level Perspective (MLP) to guide the case study, as this framework highlights interactive developments at local, national, and international levels. The MLP, originally developed by Rip and Kemp (1998), has been further developed by various scholars (F. W. Geels 2005; Frank W. Geels 2002; Frank W. Geels and Schot 2007a; Smith, Voß, and Grin 2010; Genus and Coles 2008). The MLP was developed within transition studies as a framework to understand how change occurs within a socio-technical system. Transitions are complex processes that result from interactions at

different levels. The MLP describes three levels at increasing scales: niches, which are local or sub-national spaces of innovation; the regime, which consists of dominant institutions and technologies, often at the national level; and the landscape, consisting of macro-level or international features that present contextual drivers and barriers to change. The three levels are a nested hierarchy, where regimes are embedded within landscapes and niches within regimes. According to Geels and Schot (2007, pp.400), a transition occurs when "alignment of these processes enables the breakthrough of novelties in mainstream markets where they compete with existing regime." Transitions, as studied through MLP, involve feedback between various sets of processes and actors across all three levels.

Each level contributes distinctly to innovation and transition processes. Niches are regarded as the 'protected spaces' where innovation takes places. These protected spaces can be "R&D laboratories, subsidized demonstration projects, or small market niches where users have special demands and are willing to support emerging innovations" (Geels, 2012, pp.472). In simpler terms, the idea of niche is to provide protected opportunities to support innovations that have not proven viable (Smith and Raven 2012a).

Regimes are the stable and dominant systems established to achieve certain societal functions. Regimes are often conceptualized at national levels of governance, and often consist of dominant institutions and technologies. Most often, change at the regime level is seen as slow and incremental as a result of "sunk investments, vested interests, habits,

bureaucracy and other factors which afford stability but at the same time constraints flexibility and opportunities for radical change" (Whitmarsh, 2012, pp.483).

Sociotechnical landscapes provide deep-structural 'gradients of force' which facilitate transitions by adding pressure or providing impetus to the socio-technical regime level (Frank W. Geels and Schot 2007a). Landscape processes include environmental and demographic change, new social movements, shifts in general political ideology, broad economic restructuring, emerging scientific paradigms, and cultural developments.

The MLP provides a useful framework to simplify the analysis of complex multi-scalar structural transformations (Smith, Voß, and Grin 2010). It has been applied to numerous case studies of energy transitions, often tracing the long-term evolution of a sector or technology within a given country. Examples include studies of the Dutch electricity transition from 1960 to 2004 (Verbong and Geels 2007), the decline of the British coal regime from 1913 to 1967 (Turnheim and Geels 2013), low-carbon energy transitions in Germany and the UK from 1990 to 2014 (Geels et al. 2016), and the development of Ontario's electricity regime from 1885 to 2013 (Rosenbloom and Meadowcroft (2014). While the transition dynamics in these cases are complex, dependent on spatial and temporal specificities, many European and North American case studies emphasize how incumbent regimes are destabilized over time by niche developments, aided by landscape level shifts. This pattern is visually captured in the canonical MLP diagram developed by Geels (2002).

Two recent developments in the MLP literature are extending and enriching this depiction of energy transitions. First, although the literature initially had a European bias (Markard, Raven, and Truffer 2012), the MLP is now increasingly applied to developing countries (see Hansen et al. 2018 and Wieczorek, 2018 for recent reviews). These posit a larger role for transnational linkages of actors, knowledge, capital, institutions and technology (Wieczorek et al, 2015), including through North-South donor relationships (Marquardt et al., 2015) and South-South knowledge transfer (Ulsrud et al., 2018). Studies from the global south also suggest different processes of niche formation (Wieczorek 2018), including a larger role of national governments in fostering niches. Furthermore, they highlight how the challenges faced by developing countries, ranging from poverty to regime instability, additionally shape the barriers and opportunities for low-carbon energy transitions (Ramos-mejía et al., 2018 ; Yadav et al. 2019; Weng et al., 2020).

Second, scholars are incorporating greater attention to the role of narratives in energy transitions (Moezzi et al., 2017; Geels, 2019). Narratives are stories that describe and frame a problem, identify consequences, and possibly suggest solutions (Roe, 1994; Riessman, 2008). Narrative approaches have been used in energy research to understand how discursive power shapes international energy and climate governance (Phillips and Newell 2013), how emerging technologies are evaluated and portrayed (Mulvaney 2014) and how evidence is used in policy decisions (Levidow and Papaioannou 2016). In recent years, narrative approaches have been incorporated into the MLP, with case studies including nuclear policy in Japan, Germany, and the UK after Fukushima (Hermwille

2016); India's electricity sector (Moallemi et al. 2017); the UK transportation sector (Roberts and Geels 2018); biogas technology in Southern Israel (Pilloni et al. 2020); and the transition away from coal in Saskatchewan (Hurlbert et al. 2020). These studies have demonstrated how the stories told about societal challenges and energy technologies shape the trajectory of energy transitions.

This paper contributes to both emerging trends in the MLP literature. It applies the MLP to the development of off-grid solar in India from the 1980s to 2020, including how national and international narratives shaped the evolution of financial investments, institutional innovation, and project development. It makes both empirical and conceptual contributions to the energy transition literature. Empirically, a recent review found that India is understudied in the MLP literature (Wieczorek 2018), and only two studies apply the MLP to Indian off-grid solar (Yadav, Davies, and Abdullah 2018; Yadav, Malakar, and Davies 2019), both in a single state. Our study expands the scope to the larger off-grid solar transition over a long period of time. Since India has been a leader in developing off-grid solar for rural electrification, this is also a valuable case study that can provide comparisons for other developing countries.

Conceptually, this case study suggests that regime-level actors can play a key role in driving energy transitions in the global south by creating opportunities for niche experimentation and mediating financial investments from landscape-level actors. The role of the national government was especially important in initiating the development of the off-grid solar, though over time sector evolved to become more civil society and

private-led. The directionality of change was therefore different than is often depicted in the MLP. In addition, we show how national and international narratives about problems and policy solutions shaped actions at landscape, regime and niche levels.

2.3. Methodology

2.3.1. Longitudinal case study

This research is a longitudinal case study that traces the development of off-grid solar over three decades. This in-depth, qualitative approach is appropriate to capture process-related how questions with rich accounts of contextual details (Yin 2014). This research approach relies on multiple sources of data such as documents, archival records, interviews, etc. (Yin 2014). Studies pertaining to transitions are suited to longitudinal research design because of the long-term nature of transition processes (Zolfagharian et al. 2019). The frequent use of case-study approach to understand technology transitions (Zolfagharian et al. 2019), particularly related to energy systems (Frank W. Geels et al. 2017; Ulsrud et al. 2011), strengthen its choice for the current study.

The empirical case in this study is India. India struggled with rural electrification for decades and only recently made significant progress. As an alternative to grid expansion, off-grid solar emerged as one of the pathways for rural electrification in the country almost four decades ago. Given the long duration of its existence and multitude of actors involved in this space, the market for off-grid solar technology is institutionally rich (Harriss-White, Rohra, and Singh 2009), making the case of India ideal for a historical analysis of DREs, especially off-grid solar, within rural electrification. This study has

important implications as off-grid solar is expected to play an important role in achieving universal electrification around the world.

2.3.2. Data collection and analysis

Data for this analysis is drawn from a variety of primary and secondary data sources. Published public policy documents include reports from government agencies and think tanks as well as working papers and academic articles. Additionally, insights are drawn from reports of international agencies like the World Bank, Asian Development Bank, and Sustainable Energy for ALL (SE4ALL) who have actively promoted solar off-grids in India and around the world. We drew on a wide variety of reports as many pieces of information, such as the number of installations resulting from projects or programs during the 1980's and 1990's, were scarce or unavailable.

The document analysis was supplemented by twenty-two semi-structured interviews with experts on the off-grid solar sector in India (Annexure I). These experts were drawn from national and sub-national government agencies, national and international policy think-tanks, aid agencies, industry associations and entrepreneurs. They were identified from the literature and through snowball sampling based on their knowledge and expertise of off-grid solar in India. We particularly sought out experts who worked in this sector in government departments during different periods. The interviews took place between June 2019 and April 2020. The questions focused on the involvement and role of various actors in different projects, programs and policies, while also trying to understand the

broader contextual factors in off-grid solar. All interviews were conducted via telephone and lasted between 40 and 75 minutes.

The data from the literature review and semi-structured interviews was used to construct a timeline of how the off-grid solar developed in India. During the analysis, we categorized the evolution of off-grid solar into four distinct periods by identifying major developments like important projects, programs or policies at the levels of technological niches (micro), socio-technical regime (meso) and socio-technical landscape (macro) as described in the MLP. For each period, we identify the roles played by various actors as well as the larger contextual factors.

While the MLP guides the structure of the case study, our discussion also draws on a narrative perspective to highlight the motivations of different actors in shaping this energy transition. Narratives are used in this study to draw attention to the discourse, particularly how changing global, national and local priorities served as an impetus for developing off-grid solar during different periods in India.

2.4. Case study

This case study describes the growth of India's off-grid solar in four phases: experimentation and niche development (1980s), initial growth and public-private partnership development (1990s), scaling up and expanded private enterprise (2000-2015), and reconsideration in an era of universal electrification (since 2015). The overall

development of off-grid solar within rural energy spectrum in India is depicted in the figure 6.

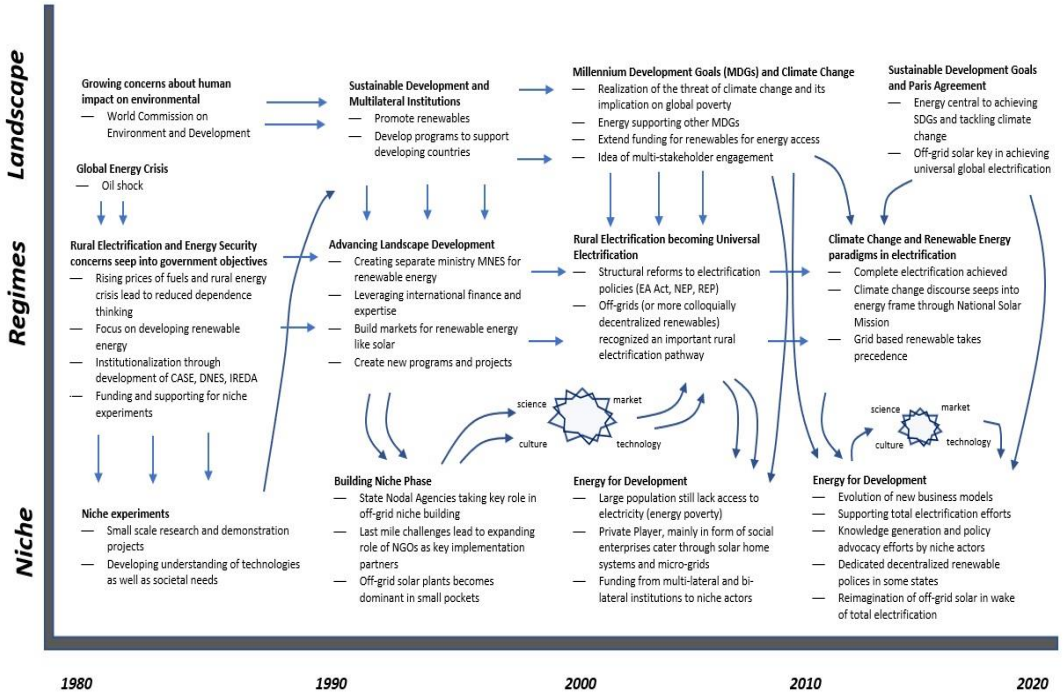


Figure 6: Off-grid Solar Development in India Using MLP Framework

2.4.1. Phase I (1980 – 1990) – Initial Experimentation and Niche Development

This first phase was government-led, with a focus on developing the institutional capacity for technology demonstration. The context was that in the 1970s India suffered from firewood shortages, electricity shortfalls, and capital scarcity (Moulik 1988). The oil shocks exacerbated these challenges of energy security. Household electrification rates were quite low, making almost three fourths of the population dependent upon kerosene for lighting. The scarcity was particularly acute in rural India, which suffered from sharp increase in the prices of kerosene (Interview 2, 5 and 6), with severe implications for

poverty eradication efforts (Ahluwalia 1986). India's internal energy crisis and vulnerability to external shock pushed it to focus on energy independence.

In the late 1970s, these mounting pressures led the Government of India to acknowledge decentralized energy as a viable alternative to satisfy various energy needs of rural communities (WGEP 1979). The sixth Five Year Plan (1980-85) identified decentralized renewable energy as an energy source for rural communities (Planning Commission 1980). This paved the way in March 1981 for the Government of India to establish the Commission for Additional Sources of Energy (CASE), a high-powered commission under the Department of Science and Technology. The primary aim of CASE was to draw up plans for achieving a transition from an economy based on hydrocarbons to one based on renewable energy resources (P. S. C. Rao et al. 2009). In an effort to take a more integrated approach towards non-conventional energy programs, the Government created the Department of Non-Conventional Energy (DNES) in 1982, which is the world's first government agency for renewable energy. CASE was subsumed into DNES. With the forming of DNES, renewables were envisioned to receive integrated support, including human resources development, design and development of products and technologies, and resource assessment studies.

Solar was one of the earlier technologies supported by the government, but the support was primarily limited to research. The initial period of off-grid solar in India was an experimental phase, as the government had minimal technological experience in decentralized renewables for rural electrification (Interview 5 and 6). In the mid 1980's,

the government spent almost 13 times more money on research and development as on demonstration (Haum 2014). Nevertheless, the government did fund several prominent demonstration programmes in the 1980s. For example, a five-year National Solar Photovoltaic Energy Demonstration (NASPED) project was initiated in 1980 with one of the objectives being systems deployment and demonstration, majorly in rural areas (Bhattacharya 1982). Under the project, Bharat Heavy Electrical Limited (BHEL) started PV production in India in 1983 and small panels of 6, 12 and 15 Watts (W) were developed for demonstration projects. After NAPSED, a program called Rural Renewable Energy Systems was initiated in 1985, which installed almost 588 off-grid lighting systems in India by 1987 (R. Bhatia 1987). In a similar effort, the government initiated Urja Gram (Energy Village) in 1988 to showcase the viability of renewable energy through demonstration projects using locally available resources, leading to another 3500 solar photovoltaic lighting systems across India.

In addition to funding research, development, and demonstration, the government of India also made investments in developing institutional structures for project finance. During the 1980s, conventional financial institutions like banks showed little interest in financing renewables (Peter, Ramaseshan, and Nayar 2002). This was a major hindrance towards private sector participation in renewable energy development in India. Thus, the government established the Indian Renewable Energy Development Authority (IREDA) in 1987 to promote, develop and finance renewable energy projects (Peter, Ramaseshan, and Nayar 2002). Since its inception, IREDA has predominantly supported decentralized approaches for off-grid solar to reach rural communities by establishing channels with

different partners including state nodal agencies (SNA), rural cooperatives and banks, and non-government organizations (Peter, Ramaseshan, and Nayar 2002).

2.4.2. Phase II (1990 – 2000) – Initial growth and partnership development

After the initial phase of government-led experimentation, India's off-grid solar sector began a second phase characterized by two important factors: (a) growing international actor influence, especially in funding, indicating a strong landscape-regime interaction and (b) regime-led momentum towards scaling. Whereas the first phase was motivated by domestic concerns about energy poverty and rural electrification, this second phase was buoyed by international discourse about global environmental problems. India was able to rapidly tap into this growing attention because of its foundation of institutional capacity. India upgraded DNES from a department to a ministry in 1992, naming it Ministry of Non-Conventional Energy Sources (MNES). With it, India became the first country to have a dedicated ministry devoted to renewable energy.

As part of the rising global sustainability agenda, multilateral aid organizations, most notably the World Bank but also the Global Environment Facility (GEF), International Finance Corporation (IFC), and bilateral agencies like US Agency for International Development (USAID) and BMZ-GTZ Germany, made conscious efforts to promote decentralized renewables (Murthy 2001). While the World Bank initially focused on large utility scale-PV projects, it soon realized that rural electrification through DREs had the most potential (Miller and Hope 2000). This was primarily because pre-investment studies found utility-scale PV projects to be uneconomical and presented technological

challenges in developing countries. In searching for near commercial renewables, World Bank found solar home lighting systems for rural electrification as a viable alternative to grid electrification, particularly since other emerging economies, like Kenya, were beginning to see unsubsidized private sector-led diffusion by the late 1980's (Byrne, Mbeva, and Ockwell 2018; Miller and Hope 2000).

Starting in the early 1990's, the World Bank invested in initiatives like the Renewable Resources Development Loan to accelerate the diffusion of renewable energy technologies in India. GEF provided $26 million to promote renewable energy in India, of which $10 million was dedicated for solar (Miller and Hope 2000). Similarly, the Asia Alternative Energy (ASTAE) Program was launched by the World Bank to support sustainable energy transition in developing countries in Asia (Martinot, Cabraal, and Mathur 2001). ASTAE represented a multi-actor approach towards promoting renewable energy, as it was supported by Netherlands Directorate General for International Corporation (DGIS), US Department of Energy (USDOE), USAID, UNDP and others. India was seen as an easy ground for multi-lateral agencies given its immense potential for off-grid solar (Miller 2009), decade of research and demonstration, and its established institutional mechanisms (particularly a fully-fledged Ministry dedicated to renewable energy). India thus became one of the earliest and largest beneficiaries of the ASTAE, with both technological deployment and as well as policy support provided through the program. Similarly, UN agencies like United Nations Development Program (UNDP) engaged with MNRE in 1990's on DREs projects including off-grid solar for sustainable

development. In terms of flow of international finances, India received commitments for $52.6 million for off-grid electrification between 1999-2006 (World Bank 2016).

An early focus of these larger-scale deployment programs were solar lighting systems, which were disseminated as an alternative to kerosene-based lighting under a national program (Chaurey and Kandpal 2010). The government's approach also began to build local private sector capacity, as MNES adopted a market approach by launching Akshay Urja Shops (renewable energy shops) in 1995 to facilitate the sale, service and delivery of solar home systems through its programmes (Chaurey and Kandpal 2009). It encouraged state nodal agencies and non-governmental organizations to set up these shops by facilitating short-term loans and by supporting part of the annual recurring expenditure. As a result of its various efforts, the government distributed almost 10000 solar home systems by the end of the decade (Figure 7).

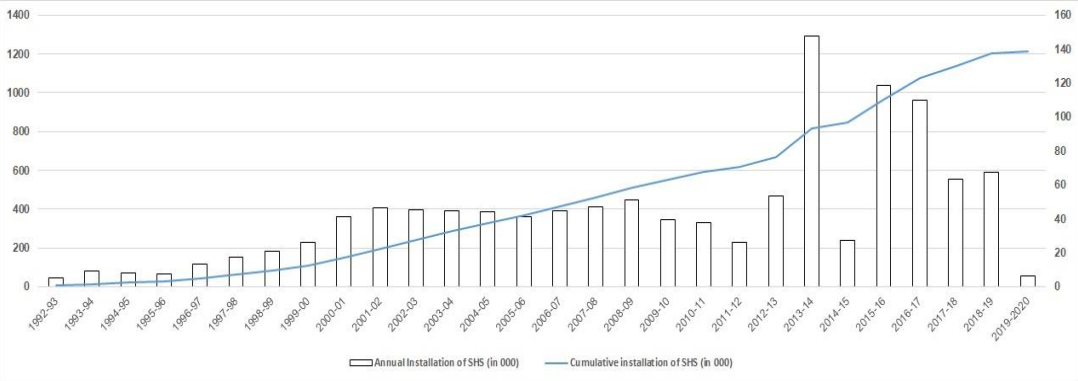


Figure 7: Time Variation of Solar Home Systems Installed in India (Source: Purohit, 2009; MNRE, 2019, 2018, 2010b, 2009, 2017, 2016, 2015, 2014, 2013, 2012a, 2011, 2010a)

As the sector started maturing, state-level actors along with other entities also started to experiment with community-based energy systems, such as solar mini-grids and micro-grids (Interview 6). After the initial success of solar lighting program in the Sagar islands of West Bengal during the early 1990's (Roy and Jana 1998), MNES and the West Bengal Renewable Energy Development Agency (WBREDA) sought to electrify the two islands through solar mini-grids. Their first demonstration was the electrification of Kamalpur village in Sagar Island in 1996 and then seven other plants were established in those areas by 2000 (Moharil and Kulkarni 2009). Similar projects followed on many other communities in the surrounding islands, and by 2001, India's largest solar PV plant, with an installed of capacity 55 kW, was operational in Moushuni island (Hiremath et al. 2009). The relative success of local initiatives, particularly at the state level provided a strong motive for a push at national scale to integrate DREs such as off-grid solar in electrification policies.

2.4.3. Phase III (2000 – 2015) – Institutionalization and Influence of Non-State Actors

As rural electrification and climate change became major national policy concerns in the 2000s, the government scaled up its initiatives in off-grid solar to meet these multiple policy objectives. At the same time, non-state actors, including both social and private off-grid enterprises, emerged with new business models to tap rural markets. This phase was thus characterized by both state and non-state development and niche-regime interactions.

2.4.3.1. State led development

Rural electrification became a prominent policy goal circa 2000, which added impetus to off-grid solar. India's energy consumption had grown significantly in the 1990's but was concentrated in urban regions. A large percentage of the population lived in the rural areas and continued to lack electricity. According to Census (2001), 56.5 percent of rural households lacked access to electricity, while only 12.4 urban households did so. Electrification began to become more of a political goal, which led to electrification reforms directed towards rural areas (Interview 10 and 12). As the government was stepping up its efforts for rural electrification, DREs expanded from a niche space into national policy discussions (Interview 4 and 15). The Rural Electricity Supply Technology Mission (REST) was launched in 2000 with the aim to electrify all villages and households by 2012 through both grid and off-grid options. This was important for two reasons: it was the first time that national policy identified household electrification (i.e. universal electrification) as a goal, and it identified DREs as a solution for rural electrification.

The government had experimented with off-grid as a potential alternative to grid electrification during the late 1990's, but now it sought to more systematically identify places where the grid could not reach (Interview 2). The Gokak Committee report on distributed decentralized generation in 2002 identified institutional pathways for DREs to become part of rural electrification plans. The Village Electrification Programme (VEP) was introduced in 2001-02 for provision of solar home systems in rural households. Using the census, the government identified around 18,000 villages that could not be

electrified by grid power by 2012, which was then designated to MNES (now MNRE) for electrification. In 2003-04, VEP was modified into the Remote Village Electrification Programme (RVEP), which intended to electrify all the unelectrified remote villages and hamlets by 2012 through DREs in order of preference: small/micro hydro power, biomass gasification, biogas engines or community solar power plants (Bhushan and Kumar 2012). In villages where such DREs were not feasible, solar home lighting was to be encouraged. Such measures led to off-grid solar diffusion including lanterns, solar home lights, streetlights and mini-grids reaching 27.5 percent of overall PV application by 2002-03 (Bhattacharyya and Jana 2009).

The Electricity Act (EA) of 2003 also outlined provisions for incorporating off-grids into India's electrification plans. Section 4 of the EA mandated the government to formulate policies for stand-alone systems for rural areas. The Rural Electrification Policy was subsequently established in 2006 with the objectives of providing access to electricity (reliable quality power supply) to all households by the year 2009 and to provide energy to all villages either through grid connected or through off-grid solutions, such as stand-alone systems. Other provisions of the EA, such as Section 13 and 14, authorized local institutions (panchayat institutions, users associations, non-governmental organizations, cooperative societies) and private persons to generate and distribute electricity in rural areas. Such provisions enabled more private participation in electrifying rural areas using renewable sources.

While efforts from the central government were key in pushing and funding off-grid solar, state-level agencies were also critical in implementation (Interview 6 and 14). State-level governments agencies such as Uttar Pradesh New and Renewable Energy Development Agency (UPNEDA), Assam Energy Development Agency (AEDA) and Chhattisgarh Renewable Energy Development Agency (CREDA) actively got involved in promoting off-grid solar solutions for rural electrification. For example, 17 solar mini-grid and solar hybrid mini-grid projects were implemented by WBREDA in Sundarbans island between 1996 and 2010 with an aggregate capacity of more than 1 MW capacity, supplying electricity to around 10,000 households (Palit 2013). Similarly, CREDA installed its first micro-grid in early 2003, and by 2012, the state's capacity increased to 3.5 MW of power serving around 58,000 families in the state (Bhushan and Kumar 2012). As a result of these efforts, more than one million households in India were reportedly using off-grid solar as the primary source of lighting, with rural households accounting for more than 95 percent of the total installations (Census of India 2011b).

Later in the decade, the government of India also began to act on climate change, as reflected in the National Action Plan for Climate Change (NAPCC) in 2008. This policy agenda brought further attention to solar energy, including both grid-scale and off-grid. During the launch of the National Solar Mission (NSM) in 2010, the PM of India announced plans to expand off-grid solar in rural regions (PIB 2011). One objective of the NSM was building 2000 MW of off-grid capacity, including 20 million solar lighting systems by 2022. The NSM's off-grid agenda subsumed many existing off-grid solar schemes, and implementation largely relied on the institutional legacies of the RVEP

(Siddiqui and Upadhyay 2011). For example, it was envisaged that 20,000 villages/hamlets/bastis/padas will be covered through DRE projects during the phase II of the NSM (MNRE 2012b). The RVEP, as result of efforts of decade and a half effort, had completed electrification of over 11,000 villages and hamlets by 2015.

2.4.3.2. Non-state actor developments

In the 1980s and 1990s, the government was the leading player in off-grid solar while non-state actors like private enterprises mostly served as technology suppliers. In the mid to late 2000s, the participation of non-state actors started to grow due to low barriers of entry to new entrepreneurs, lower technology costs due to innovation, and the new opportunities created by initiatives like NSM (Krithika and Palit 2011; TERI 2015). Given that a large percentage of rural households still relied on kerosene for lighting, many off-grids solar enterprises saw value in providing lighting devices like lanterns, solar home lighting systems and micro-grids (Interview 19 and 20). While government subsidies drove dissemination of off-grid solar during the initial years, social and private enterprises began experimenting with different business models to market based approach (K. Singh 2017). Innovations in delivery models and financial structures included rental, fee for service or pay-as-you-go (K. Singh 2016).

These local non-state actors also benefitted from many international organizations' commitment to universal energy access, which allowed them to leverage financing resources (Interview 10, 18 and 19). Many international initiatives such as UN Sustainable Energy for All, Power Africa and Lighting Global created more calls for

universal energy access (Doukas and Ballesteros 2015). Off-grid solar enterprises were able to secure investments and grants from various multilateral agencies who supported their market-led models of diffusion (Interview 9, 10, and 16). A BNEF survey of 22 off-grid companies in India reveals that $90 million were raised by organizations through various means of finances between 2013 and 2016 (BNEF 2016). For example, SIMPA Networks raised capital from Asian Development Bank, while Mera Gaon Power received enterprise support from USAID in 2012. As a result of growing financial institutions like RRBs, almost 250,000 solar home systems were sold by private players by 2013 (TGC 2014).

As the number of enterprises grew, they pushed for government reforms to create conducive environments for the off-grid solar sector. This advocacy occurred in various forms, including knowledge generation and direct engagement (Interview 1, 7, 11 and 15). Environmental policy think tanks and educational institutions were in the forefront of such efforts starting in the early 2000s, helping gain insights into best practices and impact assessments, which provided new policy direction (Interview 8, 9 and 12). Similarly, non-state actors strived to engage with the government to bring in sectoral changes to support the sector. For example, a group of enterprises consulted with Reserve Bank of India to include DRE in the list of priority sector in 2013 (Doukas and Ballesteros 2015). While the number of enterprises as well as other organizations increased, coalitions emerged to support engagement with government. For example, the Ashden India Collective (AIC) and Clean Energy Access Network (CLEAN) started to play a critical role in bridging the gap between the voices of key stakeholders outside and

within government (Interview 1 and 13). Similarly, industry associations such as Global Off-Grid Lighting Association (GOGLA) and Association for Rural Electrification (ARE) began to support off-grid solar enterprises in India in the 2010's as the sector became a more active participant in the overall electrification movement (Interview 3 and 7).

2.4.4. Phase IV (from 2015 – present) – recent developments

In recent years, India has pursued ambitious targets for both renewables and electrification. The role of off-grid solar is shifting from its contribution to energy access paradigms to augmenting or increasing the share of renewables in the energy systems (Interview 12). In 2016, Prime Minister Modi announced a goal of 175 GW of renewable energy by 2022, roughly doubling the country's renewable capacity in six years, and in 2018 he announced that India had achieved universal village electrification. In recent years, India has taken larger role in the global stage in solar energy through formation of International Solar Alliance (ISA). These policy goals have a grand scale, and to achieve them the government has emphasized large-scale, grid-tied systems rather than small, off-grid, decentralized renewables.

This does not mean that decentralized renewables were completely dropped from the agenda. MNRE included decentralized renewables in its draft National Renewable Energy Act in 2015 and its draft National Policy for Renewable Energy based Micro and Mini Grids in 2016. However, neither of these drafts generated enough 'buzz' to be finalized. With the focus on large-scale deployment, off-grid solar lost some of its

urgency among policymakers as can be seen from a response from an interviewee from government institution, ‘once government itself is trying for total electrification through conventional grid approach, the lifetime of the DRE per se when you invest is at question.’

Although the government turned its attention away from off grid solutions, the private sector has continued with substantial growth in these technologies. One survey estimated that the private sector deployed 3.6 million solar lanterns, 92,000 solar home systems and 206 mini-grids use projects during the period during 2016-2017 (CLEAN, 2017). Similarly, the estimated deployment of off-grid solar products (pico-solar and solar home systems) in 2017-2018 was 5.29 million (CLEAN, 2018). The market growth attracted large utility players, either investing on their own or through existing organizations (Interview 7 and 11). The European utility ENGIE recently invested in SIMPA Networks and Husk Power Systems, two important players in the off-grid sector in India. The Shell Corporation similarly invested in Orb Energy, one the earliest players in this space. In 2019, Tata Power (a large independent power producer) created a partnership with the Rockefeller Foundation with an aim to install 10,000 micro-grids and power 5 million households in India.

The emerging trend in off-grid solar is that non-state actors are now seeking new opportunities beyond household or village electrification. Universal electrification pushed these actors to innovate and find new avenues for their technology, particularly applications to manufacturing and other income-generating activities (Interview 13, 15,

17 and 18). The potential for such innovations to support rural livelihoods in India is estimated to be more than $50 billion (Waray et al., 2018). According to recent survey of 42 DRE enterprises conducted by CLEAN, 36 have started new type of operation in productive application in 2018-19 (CLEAN, 2019). In lines with such developments, MNRE released a draft policy framework in late 2020 to develop and promote DRE livelihood applications in rural areas. However, what remains to be seen is the coordination with number of ministries and institutions involved in rural development, which could create additional barriers and costs towards effective implementation (Interview 17).

2.5. Discussion

This paper examined the evolution of off-grid solar in India during the last four decades, particularly in the context of rural electrification. Historical analysis shows that the transitions in India have been shaped by actors from different sectors (public and private) and different levels (niche, regime, landscape). Here we synthesize findings across the four phases of development and especially highlight the role of policy narratives.

2.5.1. Initiatory role of regime and national policy objectives

Over the last four decades, the national government played an important role in off-grid solar development in India. Energy security concerns pushed India to consider renewable energy in the late 1970s, in the context of an internal energy crisis and vulnerability of the fossil fuel-based economy. The niche building efforts for DREs were facilitated by creating dedicated institutions at the national level, which became a key source of

expertise and administrative capacity during the early years. The establishment of a separate ministry and financing arm thus helped renewable energy development. The private participation was minimal during the first two decades.

After niche experimentation in the 1980s and initial scale-up in the 1990s, off-grid solar projects seeped more prominently into national policy objectives in the 2000 due to India's commitment to universal electrification. The 'power for all' narrative became a key driver in framing all programs, policies and legislation related to electrification at the regime level. Learning through experimentation and demonstrations over many years helped build confidence in off-grid solar technology, which meant that it was ripe to take a leading role when total and rural electrification became prominent political issues. Similarly, DREs gained further momentum when climate change become a major policy concern. India's transition to solar in its national policies is also attributed to global pressures and partnerships focusing on climate change commitments (Shidore and Busby 2019). Off-grid solar benefitted from the fact that it served multiple domestic and international political narratives over time, from energy security to total electrification to climate change.

2.5.2. Supporting role of landscape actors and global narratives

Environmental concerns became a dominant concern of landscape-level actors during the 1980s and 1990s. Calls for sustainable development shaped the funding priorities of global aid organizations, and this funding became an important avenue to pursue more projects and build local capacities for renewable energy development in India. Landscape

actors thereby helped nurture the off-grid solar transition in India by supporting niche-friendly approaches the government had been undertaking. Investments from multilateral and bilateral agencies played a critical role during the period of the 1990's in off-grid solar space as it helped exhibit its viability for years to come. Programs sponsored by aid agencies helped improve the financial capacity for experimenting with off-grid solar and engaging in building awareness and institutional capacity.

The Millennium Development Goals also drew attention to the catalytic role that energy plays in poverty alleviation (Venema and Rehman 2007). This narrative shaped the policy and funding priorities of various actors, including India's national government during the early 2000s, which further played into the push for 'power for all'. This created windows of opportunity for DREs to be mainstreamed into the national energy regime, as seen in major energy legislation of the 2000s. These landscape-regime interactions were more co-evolutionary rather than a result of 'regime destabilization' (Frank W. Geels 2014).

The role of international agencies evolved over time. More recently, landscape-level actors have facilitated off-grid solar experiments in India through not just capital transfer, but also through knowledge and technology that complements local capabilities and resources (Wieczorek, Raven, and Berkhout 2015). Supporting experimentation with new business models, or co-initiating coalitions for policy advocacy to create a support environment for DREs, showcase how landscape level actors have evolved beyond simple funding. Thus, the Indian case study also showcases not only the dynamics of

such landscape-regime interactions, but also highlights landscape-niche relationships that co-produce developmental strategies.

2.5.3. Evolving role of private actors and emerging innovations and coalitions

The historical analysis shows that non-state actors can play a critical role in facilitating energy transitions under the right conditions. During the initial period, low participation from the private sector can be potentially attributed to immature technology and lack of adequate finance. As support from Indian government and international donors began to shape the domestic environment, a handful of private players began gaining a foothold into solar panel manufacturing which until now was driven by public sector companies. These enterprises primarily played the role of equipment suppliers to government efforts, without any direct involvement in rural energy space.

However, a different type of socially-oriented private enterprise emerged in the late 1990s and 2000s, influenced by the "energy for all" narrative (Mohan and Topp 2018). The slow pace of rural electrification and associated challenges in expanding grids opened up a window of opportunity to realize the potential of off-grid solar in Indian context. The need to expand energy access produced sufficient internal momentum in the 2000s, allowing for adaptations and transformations within for off-grid solar which subsequently led for novelties to develop.

The novel arrangements, which ranged from partnerships, financing, or technology provisioning (or in many cases amalgamation of all), thus became critical in tapping the

market potential of off-grid solar. The ability of social enterprises to identify market needs and contextualize solutions became a critical factor in developing business models for rural energy needs. With the government's prioritization of grid electrification and utility-scale renewable energy development in the last decade and a half, we observe that the locus of innovation shifted to these social enterprises which led the domination of off-grid solar in terms of number of installations.

As a result, social enterprises also played a role in shaping niche-regime interactions during the third phase. The emergence of coalitions during this period, suggest deliberate actions from non-state private actors promoting off-grid solar (DREs in general) within overall energy policy. These coalitions help in collective action and reduce the barriers in engaging with government, which is particularly perceived as difficult by enterprises in this space (Plutshack et al. 2019). Some policies, such as the national mini-grid policy and UP mini-grid regulations, were co-created with the help of non-state actors. In more recent times, significant activity is seen across the off-grid space despite the success of electrification, particularly from large investors and donors. This indicates a shifting paradigm for DREs to focus not just on lighting needs of the households, but larger development outcomes as well. While it may be unclear on what future holds in the total rural electrification phase for off-grid non-state actors like social enterprises which have primarily built their business models to cater to rural energy needs, however, coalitions might facilitate better knowledge flow within this sector by engaging with different actors. The Indian case study helps us understand how narratives of energy and poverty

contributed to the emergence of non-state actors and are now shifting the focus of off-grid solar from basic access to economic development.

2.6. Conclusion

The paper outlines the historical evolution of off-grids and major local and global narratives that pushed for its integration with rural electrification efforts in India. It shows that off-grid solar development was initiated by the government, later supported by international agencies, and in later stages led by innovations from non-state players. These actors were motivated by different narratives during different phases of off-grid evolution. Initially, India's problem of energy security provided sufficient internal momentum to experiment with off-grid solar (or DREs more generally). Landscape-level attention to sustainable development later provided conditions for global aid agencies to support renewables for electrification, including through off-grids solar. When these concerns merged with issues of poverty and climate change, the focus on innovative approaches led to emergence of non-state actors like private enterprises to build business models for rural electrification.

This case study provides several broader contributions to our understanding of the dynamics of energy transitions, particularly in the global south. First, whereas the MLP tends to portray niches as the realm of experimentation and regimes as the ossified configuration is ultimately destabilized, in this case the national government (a regime-level actor) took the lead in innovation, experimentation, and niche creation. We observe that regime-level actors can act as innovators, which can be a lesson to other countries

aiming to integrate off-grid solar into electrification policies. Given that off-grid solar will play a major role in achieving universal electrification by 2030 (IEA 2002), governments across the globe may need to have a larger role in facilitating niche-building.

Second, off-grid solar development was built on strong linkages across actors. Since the 1990s, actors from national and sub-national governments, international aid agencies, and private enterprises often worked together to facilitate off-grid transitions. Linkages between niche-regime-landscape actors indicate that off-grids are built on the strength of each of the actors. As we move forward with the agenda of universal electrification, it is clear each of these actors will have a role to play. Local and global engagement has evolved in India to facilitate flows of technology, knowledge and financing. Identifying these linkages and how they work will be critical for successful off-grid solar transitions.

Third, the role that a technology plays in energy provisioning may change over time, as both the technology matures, and social needs evolve. In India, off-grid solar started for household electrification, which in rural areas of developing countries particularly address lighting needs. As countries move forward with electrification, it will be wise to consider how off-grid solar can provide services beyond lighting. Private off-grids solar enterprises in India that built business models for lighting are now looking for larger opportunities that support livelihoods or micro-enterprises. A longer-term outlook will help go beyond universal electrification and contribute to other developmental outcomes envisioned in narratives of SDGs.

Off-grid solar will increasingly contribute to rural electrification across the globe. India's experience highlights not only how different actors contributed to the sector's development, but also how their actions were embedded within global and national narratives related to energy, climate, and development. While it appears to be a convoluted and complex process, it demonstrates the multiplicity of actors and resource mobilization strategies that can contribute to a vibrant off-grid solar sector.

CHAPTER 3

WHO BENEFITS AND HOW: A CAPABILITIES PERSPECTIVE ON SOLAR MICRO-GRIDS IN INDIA

3.1. Introduction

Energy access is fundamentally important to enabling sustainable development and human wellbeing. A high correlation between electricity consumption and Human Development Index (HDI) indicate its necessity for a better standard of living (Alstone, Gershenson, and Kammen 2015). In accordance, the Goal 7 of 2030 Agenda for Sustainable Development (known as SDGs) aspires to 'ensure access to affordable, reliable, sustainable and modern energy for all.' However, over a billion people worldwide lack electricity (IEA 2002). Especially in rural areas where it is expensive to extend the grid, off-grids such as mini and micro-grids are likely to be a pathway of electrification. In the vein of such development and reliance on off-grid pathways, it is important to recognize and address fundamental questions of energy justice around such a decentralized approach to rural energy access. Taking such discourse forward, this paper, using a case-study of solar micro-grid (SMG) users from India tries to study the role of solar micro-grids in capabilities enhancement. In the process, we identify what and how capabilities are affected in rural communities as a result of SMG, and lessons that can be learned to address justice dilemmas within energy initiatives.

In India alone, over 1.2 million rural households are currently electrified through off-grid solar (MNRE 2017). In recent years, there has been increasing emphasis on solar mini

and micro-grids due to their potential viability to move beyond just provide lighting solutions. As against individual systems like solar home lights, community-scale solutions such as solar microgrids have the possibility to supply reliable 24/7 electricity as well as support productive loads which makes them a viable substitute for grid-based electrification. Currently, it is estimated that there are over 2800 mini and micro-grids operating in India (ESMAP 2019). Despite all the developments, issues surrounding acceptability (A. Sharma 2020), reliability (Numminen and Lund 2019), financial viability (Subhes C. Bhattacharyya 2014), sustainability (Katre, Tozzi, and Bhattacharyya 2019) have implications for energy justice of decentralized renewables like off-grid solar. Yet, given the focus on large utility scale energy systems (Yenneti and Day 2016; Kruger and McCauley 2020), small-scale community-based systems are often not a part of discussions around energy justice dilemmas (Damgaard, McCauley, and Long 2017).

The capability approach has become an important framework in understanding energy justice by focusing on distributional inequalities. The benefits and risks can often be localized in cases of off-grid like SMGs, thereby calling for greater attention towards identifying the justice implication. This paper moves forward with this agenda in examining the role of SMGs on peoples' well-being and capabilities in rural India. In the process, we highlight different factors such as local norms and gender identities, other than just energy services from SMGs that matter in capabilities development. The study will be important in understanding the pathways of energy capabilities and their linkages to solar micro-grids, which can also provide lessons for countries on similar pathways.

The paper is organized as follows. Section 3.2 delves into the capability approach and its linkages to energy services within the energy justice context. Section 3.3 describes the methodology used in this study. The results from the study follow in section 3.4, while section 3.5 discusses the implications of the study from a theoretical perspective. Section 3.6 offers the concluding remarks.

3.2. Theoretical Framing

3.2.1. Capability approach

The capability approach, developed by economist and philosopher Amartya Sen and later expanded by Martha Nussbaum, is a centrally important approach in development studies. Initially articulated in the 1979 Tanner Lecture, 'Equality of What?', Sen critiqued the utilitarian approach of well-being as being too myopic due to its tendency to identify a person's well-being with their command over goods and services (A. Sen 1979). The sole focus on resources cannot fully capture individuals' valued ends, and there is a need to understand what individuals are able to do and be with those resources (Byskov, 2018 pp. 16). Sen while introducing his idea of capabilities writes, "what is missing in all of this is some notion of "basic capabilities": a person being able to do certain basic things [...] the ability to meet one's nutritional requirements, the wherewithal to be clothed and sheltered, the power to participate in the social life of the community" (Sen, 1979, pp. 218).

The capability approach is described as an "intellectual discipline that gives a central role to the evaluation of a person's achievements and freedoms in terms of his or her actual

ability to do the different things a person has reason to value doing or being" (Sen, 2009b pp. 16). In operational terms, it revolves around two main concepts – capabilities and functionings. Capabilities are a person's freedom to achieve valued functionings, whereas functionings are the achievements of the person i.e. 'what he or she manages to do or be' (Basu 1987) or alternatively put as 'beings or doings' (Sen, 1999, pp. 75). Examples of functionings are being nourished, being educated, being healthy, or doing the work, voting in elections, associating with others, participating in political life. The difference between capability and functioning is that functioning is achievement, whereas capability is freedom to achieve functionings (Robeyns 2017). In other words, functionings are the outgrowths or realization of capabilities (Nussbaum 2011), and all the functionings taken together form a capabilities set. The capability approach puts emphasis on increasing access to wider set of functionings which in turn will enhance capabilities and thus welfare.

The capability approach also recognizes that the conversion of resources by individuals into valued functioning depends upon certain factors. These conversion factors are identified as personal characteristics, social characteristics and environmental factors (A. Sen 1999). According to Robeyns (2017, pp. 46):

Personal conversion factors are internal to the person, such as metabolism, physical condition, sex, reading skills, or intelligence... Social conversion factors are factors stemming from the society in which one lives, such as public policies, social norms, practices that unfairly discriminate, societal hierarchies, or power relations related to

class, gender, race, or caste. Environmental conversion factors emerge from the physical or built environment in which a person lives. Among aspects of one's geographical location are climate, pollution, the likelihood of earthquakes, and the presence or absence of seas and oceans.

Identifying the role of conversion factors helps distinguish between notionally available opportunities and actual opportunities. For example, although polling booths may be available in a village during elections, if social institutions discriminate against certain caste members in exercising their voting rights, the functioning of voting (there by political participation) will not be available to many members of the communities (an example of social conversion factors).

While the capability approach has been influential in academic disciplines, it also has been used by non-governmental organizations, governments, and large institutions. It has played a critical role in international development discourse, particularly influencing various parameters like the HDI (Stanton 2007). It has been extensively used in studies relating to basic human services like health (Venkatpuram 2011), water (Jepson et al. 2017), or addressing gender inequalities (Robeyns 2003). Similarly, it has proved particularly useful in discussion of inequities in the global environmental and climate justice literature (Schlosberg and Carruthers 2010; Schlosberg 2012).

3.2.2. Energy Justice and Capabilities

In the past few years, the capability approach has also been applied to understand energy justice and poverty. Energy poverty is conceived as a fundamentally distributional injustice issue (Walker and Day 2012). The discourse of energy justice provides avenues for deeper understanding of questions such as ‘what constitutes energy poverty’, ‘how does it manifests itself and what are its implications for different socio-economic groups’, ‘what role does energy access play in alleviating energy poverty’, and ‘what external factors other than access itself determine alleviation from energy poverty’.

Adding in the capability approach takes the discussion of energy poverty and justice beyond the narrow focus on economic improvements, as it can examine how local contextual factors such as social relations, local norms, or gender issues influence the ability to benefit from energy access. In recent years, scholars have used the capability approach to understand energy poverty through the lens of services they avail from energy rather than actual numeric consumption (Groh 2014). Day et al., (2016) proposed using the capabilities approach in understanding the context of energy poverty, emphasizing on the services that household needs to satisfy their needs, and enhancing capabilities. Fell (2017) defines these energy services as “functions performed using energy which are means to obtain or facilitate desired end services or states.” Sadath and Acharya (2017) using the capabilities approach, studied the multidimensionality of energy poverty in India. Their study highlights higher energy deprivation in socially backward groups like Dalits (Lower Caste) and Adivasis (Tribals) compared to others, indicating the social embeddedness of energy poverty. Similarly, Malakar (2018), using

the capabilities approach, looked at the role of electricity in understanding the well-being of rural communities in India, underlining its importance in improving people's lives. There is also recent emergence of literature on the role of energy and associated services generated through decentralized renewables. Cole (2018) studied the impact of renewable energy in Afghanistan using the capabilities approach, while Arnaiz et al., (2018) analyzed the livelihood implications of a micro-hydro project in Bolivia. These studies underline the growing application of the capabilities approach in deepening the understanding of energy poverty, including the contribution of decentralized renewables in expanding opportunities in rural communities. However, studies so far have not sufficiently shed light on the role of energy services through solar micro-grids in India and this current paper extends the discussion of its importance on such lines to provide implications for energy justice discourse.

3.3. Study Areas and Methods

The primary objective of this paper is to understand the impact of solar micro-grids on peoples' well-being and capabilities in rural India. This study is based on the case of solar micro-grid users from three villages in the district of Palghar from the state of Maharashtra (Figure 8). The three villages selected were part of a cluster of seven villages that had SMGs installed for their power supply. SMGs in this case are solar photovoltaic based community-based systems, primarily operated and managed by the villagers, supplying power to all the connected households and few local shops. Maharashtra, situated on the western coast, is the seventh largest state in India and one of the more economically developed regions. Palghar district has a population of over 2.9

million people (Census 2011) and consists of 8 blocks (or talukas) dominated by tribal populations: Jawhar, Mokhada, Vikramgad and Palghar talukas have a tribal population of more than 90 percent. The Palghar district has low HDI due to its low life expectancy and inadequate education infrastructure. The tribal population, who often fall under the lowest ranking of the Indian traditional caste system, are one of the most economically and socially disadvantaged groups in India. Thus, this case offers the particular advantage of understanding the implications of SMGs on households in resource constrained communities.

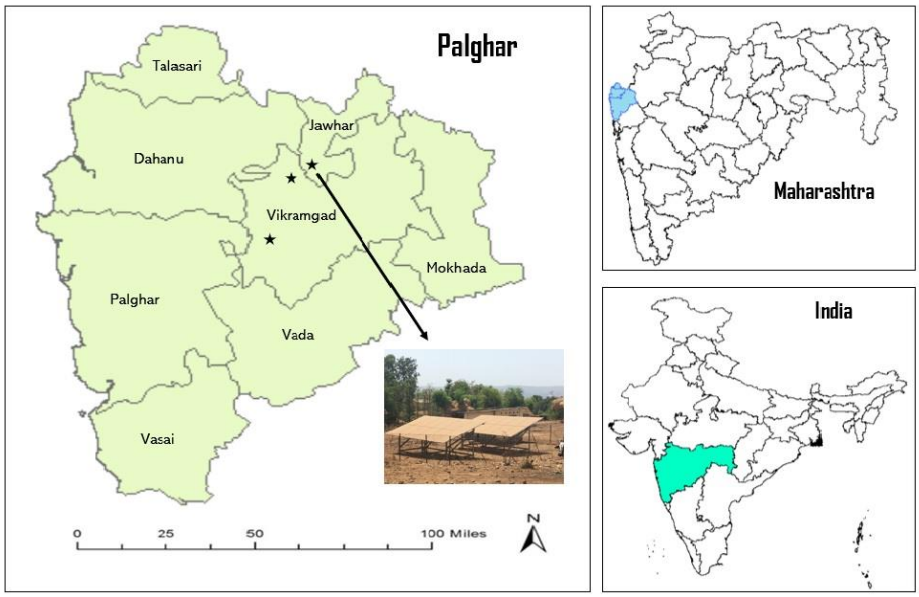


Figure 8: Study Area Map Indicating the Three Study Villages

The data collection spanned April-June 2019 and consisted largely of in-depth semi-structured interviews. The capability approach was operationalized in this study using both open-ended and close-ended questions, which focused on gathering information

regarding electrical appliance used by the households and the influence of SMG-related services on the day-to-day lives of the people. The open-ended questions such as “What do think has changed in your day-to-day life since arrival of solar power?” enabled participants to describe their own frames of energy usage. A few close-ended questions, such as “Has solar power affected ability to be autonomous in the activities you conduct?” provided a baseline of comparable data from each household. Field observation and desktop research supplemented the primary data from the household interviews.

The interviews were carried out in Marathi, the official state language of Maharashtra. The author’s fluency in the local language helped to accurately conduct the interviews and translation of other research materials. To assist with the discussion, the author was accompanied by a facilitator. The facilitator was associated with the organization that had installed the SMGs in the study villages and also was a resident of one of the nearby villages, and thus had an intricate knowledge about the communities, their practices and beliefs. It was ensured that the facilitator had never worked in the study villages and interviewees were unaware of his role with the SMG organization so as to eliminate any biases or pressure to provide positive responses. The role of the facilitator was to help navigate the villages, identify households and build rapport with the local people.

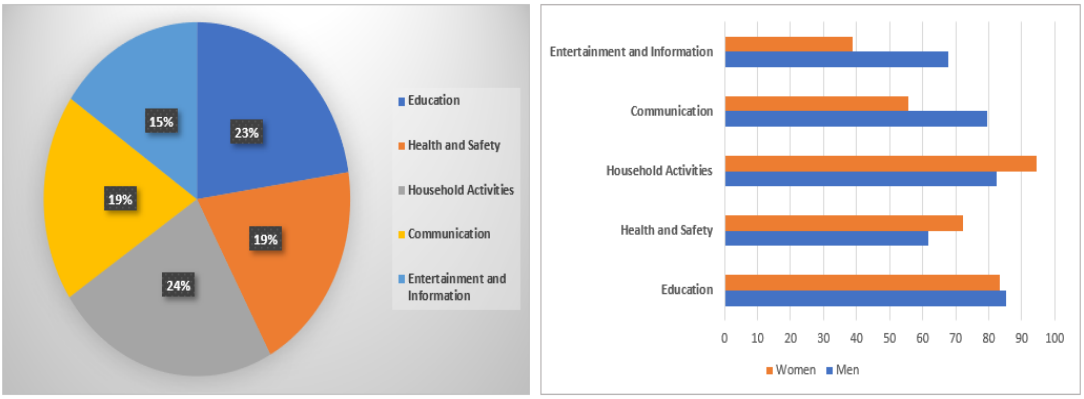
A snowballing method was used to identify the interviewees. Firstly, a preliminary discussion with the operator of each of three micro-grids from different villages allowed us to familiarize with most of connected households. All the three villages were

homogenous in terms of their social (caste) structure, however, economic conditions of the households varied. Hence, efforts were made to include households with different economic conditions to gain perspective about the capability development of different groups. Overall, 52 interviews were conducted during the course of the fieldwork, of which 34 were men and 18 were women. The interviews were conducted one-to-one in most cases and avoided speaking with men and women together to reduce any undue influence. On average, almost half of the respondents were considered households below the poverty line as per the ration cards they held and were living in semi-pucca (made with brick and mud) or kutcha (implies mud walls and a temporary roof of thatch) houses.

The principle of theoretical saturation was followed to determine adequacy of sample size (Morse 1995). A similar sampling strategy has been used in other qualitative energy studies (Müggenburg et al., 2012; Muhoza and Johnson, 2018). Interviews were conducted during the daytime as well as during evening hours to observe firsthand the energy practices of the rural households. The duration of each of the interviews ranged from thirty minutes to little over an hour, depending upon the willingness of the participants to share their lived experiences. All the interviews were transcribed, and a combination of open coding, axial coding and selective coding was applied to data collected through the interviews (Blair 2015). Furthermore, all such themes were also identified as per the perception and value addition to different groups, i.e. gender or age specific identities. NVIVO, a qualitative software was used for the coding and analysis of the data.

3.4. Results

In this section, the change in household ownership of electrical appliances as a result of SMGs is highlighted. Furthermore, five major energy related capabilities, namely – education, health and safety, household activities, communication, and entertainment and information are explained in detail. Overall, the 52 interviewees mentioned these five energy related capabilities 190 times and gender-wise differences show that certain capabilities like household activities were mentioned more by women, while entertainment and information by men (Figure 9).



(a) Percentage of individual capabilities within overall mentions (n=190)

(b) Percentage of capabilities mentioned as per gender

Figure 9: Energy-related Capabilities from Solar Micro-grids

3.4.1. Household Appliances Ownership

All households used lighting as the basic service enabled by the SMGs. Almost 70 percent of the households had at least 3 lighting connections, while the rest had 4 connections, with most using LED bulbs. In addition, 96 percent of the households purchased mobile phones, 27 percent purchased fans, 24 percent of the households purchased television sets, and 7 percent purchased refrigerators. The increase in

appliance ownership indicates the aspirations of the households to gain better energy services beyond lighting. As seen in Table 2, mobile phones, followed by fans and televisions were the electronic appliances most often owned by households.

Table 2: Change in ownership of household appliances

Household appliances	*Before Solar Micro-Grid*		*Post Solar Micro-Grid*		
	Number	*% HH Owns*	*Number*	*% HH Owns*	*Change in Ownership*
Fans	3	5.56	20	33.33	27.78
Laptops	0	0.00	2	3.70	3.70
Mobile Phones	5	9.26	55	96.30*	87.04
Refrigerators	0	0.00	4	7.41	7.41
Televisions	2	3.70	15	27.78	24.07

Note – Despite various studies that capture appliances like LED bulbs, CFLs or Incandescent bulbs in household ownership, this study does not take that into account because most of the households which were connected to micro-grids were provided with 3 or 4 lighting connections along LEDs, depending upon their need and initial payment.

While the ownership pattern of appliances reveals insights into what people value, there are two caveats to a purely functional valuation. First, while individual ownership cannot be established in this case-study, it is clear that important household decisions about expenditures on electrical appliances were controlled by men. On probing why such is the case, one interviewee explained, "*they (women) have less knowledge about what (brand or type) might work or what is the right price*." Such gender based decision-making asymmetry is an established norm within rural Indian society and it can subsequently shape how the appliances are purchased, used and valued at the household level.

Second, while households certainly valued the services gained through new appliances, material ownership is also often a status symbol, particularly in rural parts of India, which

boosts the importance of individuals or households in their communities. Given how modern appliances are considered 'highly desirable' (Winther 2015), and the prestige value associated with such ownership, there is relatively faster adoption of certain appliances.

3.4.2. Education

One most identified functioning as a result of lighting was the possibility for children to study during evening hours. Education is perceived as an important capability by the rural people as it is seen as key to further opportunities. As one interviewee elucidated, '*education gives us tools to find better jobs. To find jobs, we need some sort of higher education*.' Interviewees also stated that the quality of education in rural areas is often not at par with urban areas, especially from government run schools. This poses a great challenge to learning for children, further compounded by the fact they cannot come home and practice what is being taught to them in schools.

According to interviewees, the availability of lighting service through SMGs had led to improved studying conditions in the household which had contributed to increased studying hours amongst children. Most of the children spend their day hours in school, and evenings were the only available time to complete any schoolwork they have. As one of the interviewees responded, '*lighting helps children study during evening hours. They have assignments and homework from school, which they could do now with ease*.' Many other interviewees echoed the same sentiment indicating the importance lighting services had for education at household level.

While the importance of education was recognized as a pathway to a better life for children, the defined gendered role did play an integral part in the ways such impacts manifest themselves. Interviews revealed that the boys had more time to study as compared to girls. Sharma et al., (2019) had a similar observation where they found girls in general had less studying time than boys in rural parts of India. While household chores were mainly considered the duty of the female head, young girls were expected to help in accomplishing such tasks. As one female participant noted, '*our eldest daughter has to help me to take care of the household chores in the evening. She can't dedicate too much time to her studies*.' Others studies have also confirmed that the time spent by girls on household activities in rural areas in India were much higher as compared to boys (Raskind et al. 2020; Lin and Adserà 2013). This potentially reduced the time available to girls to conduct their academic activities at their home. The biases in the education of male and female children can be attributed to established social norms within rural communities. A general perception is that a daughter will eventually get married, and it is believed to be important for her to be proficient in accomplishing household chores. This highlights that while energy services do offer the benefit to children with respect to education, contextual factors like household conditions and social norms also play an important role in realizing the capabilities between the genders.

3.4.3. Health and Safety

Interviews suggested that community members perceived that arrival of SMGs led to improved health and safety. Household kerosene usage has been associated with harmful

pollutants (Lam, Smith, et al. 2012a) and associated health risks such as tuberculosis (Pokhrel et al., 2009; Lam et al., 2012a). A study found that households relying on kerosene wick lamps homes had higher indoor PM2.5 and black carbon levels compared with those using modern source of lighting (Muyanja et al. 2017). Households interviewed in this study confirmed that there was less exposure to black soot from kerosene wick lamps. In addition, as one interviewee commented, '*we can switch-on light bulbs or fan without any problem. With kerosene wick-lamp, there is always a risk of spilling, or getting fire-burns etc.*'

Lighting services also reduced the risks associated with nighttime theft or animal attack. In remote villages, there are always risks of snake and scorpion bites, which are especially concerning for children or toddlers, and also pose a risk to cattle that are a primary component of rural livelihoods. Most households reported keeping at least a single light on in the house during night hours for this reason, and many households also reported keeping a lighting connection in their cattle shed. Similarly, street-lights installed within the villages had increased a sense of security and enabled intra-village mobility during evening hours, which according to interviewees also helped with socialization as well.

3.4.4. Household Activities – Gendered Role

The nexus of gender and energy is under-researched in rural settings, including the impacts of electricity access on women's capabilities. A consensus emerged out of the interviews that women, in general, had benefited more out of SMGs. This is primarily

because of the different roles between men and women in rural Indian societies, particularly when it comes tending to household needs. Women work the hardest in rural settings, managing all the household chores, engaging in farm activities, and generating additional income during labor season if needed. In such a scenario, being un-electrified restricts a woman's ability to carry out household chores, which consumes their major part of the daily activities. Gender division is seen to be strictly observed norm in rural India, especially when it comes to division of labor (N. Rao 2012). As one interviewee noted, '*women generally won't sit and talk when men generally gather to have discussions*', while another participant mentioned, '*while menstruating, females are not allowed to do household chores like cooking or fetching water*.' Such deeply entrenched traditional beliefs are seen to restrict the freedom of women to make their own decisions in the rural settings of Maharashtra (Chorghade et al. 2006).

Reliable electricity supply after sunset had made household chores easier for women. Women engaged in a range of activities including cleaning (clothes, utensils, house, animal sheds), cooking, pounding and husking, drying grains and seeds, collection of firewood, caring for children and elderly, fetching water and feeding domestic animals as a part of their daily lives. Interviews indicated that women gained more control over how and when they could accomplish household tasks, which they considered an important value attached to SMGs in the community. For example, tasks such as cooking and cleaning used to be carried out predominantly during day since there was no lighting at night. But as a result of improved lighting conditions, these tasks were possible to accomplish after sunset. Furthermore, it is recognized by the interviewees that women

were able manage their household related workload better and have free time on their hands. The free time available to women was used to rest, take care of children or elders and socialize.

SMGs also facilitated access to water in these three villages. The labor of water collection often leads to negative health outcomes as women either have to fetch water from open wells or nearby rivers. Drudgery is quite often discussed as a result of lack of energy access, mostly from the perspective of collecting firewood for cooking. However, drudgery related to lack of access to water as a result of energy poverty does not often gain as much attention. Often, women in these communities had to take either multiple trips or carry multiple water containers at a single time to get needed water for the households, making water-bearing the highest energy cost amongst all of women's daily tasks. Research indicates that the energy cost of carrying two water containers on individual heads is highest amongst all the daily activities women engage in (S. Rao, Gokhale, and Kanade 2008). All interviewed households had to fetch water from the community well, and respondents mentioned that water fetching activities took at least half an hour of their daily time with almost all participants agreeing that summer was the most difficult period due to decreased water availability and increased physical difficulty due to hot weather.

As a result of SMGs, all three villages installed pumps near their community well which drew water to the storage tank built at a central point. As a result, most women no longer had to walk more than few minutes to fetch water, and it also significantly reduced the

labor of water collection, since water pots could be filled from taps in the water tank rather than pulled from the wells. Also, this provided flexibility of fetching water anytime from morning to evening, thereby, enabling improved access to water. The time and energy saved allowed women to engage in various activities including domestic, productive and personal activities.

Nevertheless, access to water (within walking distance) was not constant throughout the year as the communities restrict the use of water tanks during the summer because of water shortage. The primary reason given was that the availability of water through tanks increased the usage of water leading to overuse. Thus, as the water availability reduced during summer, the communities restricted the use of water tanks and reverted to the practice of fetching water from wells or other nearby source. This was predominantly highlighted as a concern because summer season is the most difficult time, and water needs are high while availability is low. Although water access had improved lives of women, it is not constant throughout the year.

3.4.5. Communication

One important aspect generally less understood is the impact of energy access on communication. More than 95 percent of the households previously lacked information services from modern technology such as television and mobile phones. Mobile phones, in particular, have seen a revolution in India due to cheaper handsets and affordable connections and have become ubiquitous even in some of the remotest villages. The cost of cell phone talktime and mobile data in India are amongst the lowest in the world.

However, without power to charge the cellphones, it was difficult for rural households to acquire and use the technology as consistently as their urban counterparts. As a female participant pointed out, '*we had to go to the main village to get our phones charged*.' This was severely limiting many of the benefits that households perceive important as a result of SMGs.

As a result, communication was an important functioning that had been realized for people, which in turn affected various aspects of their lives. Faster medical response, a resultant of mobile technology usage enabled by SMGs, was highlighted as one important benefit. As one female respondent mentions, '*medical emergencies can arise any time, day or night, especially when there are pregnant women or old people. Since we don't have any health clinics nearby, now it has become easier to call an ambulance if need arises*.' Similarly, respondents perceived social aspects of communication such keeping in touch with family to share good and bad news more important. As another interviewee elucidated, '*we can now know immediately if someone dies. Without mobile phones how will we know if our families need us?*' Similarly, a male respondent further explained, '*I work in towns for months at a stretch when our farming season is over. Only way to know what is happening in our village is through mobile phones. We now can at least connect to our homes and family while we are away*.'

3.4.6. Entertainment and information via television

In rural areas, there are not multiple avenues of entertainment, except watching television or gathering together to have a chat. SMGs enabled the adoption of television in rural

households, which allowed televised entertainment to emerge as an important leisure activity for the community. Movies and television shows were widely reported, although cricket matches were preferred by the male members of the communities. While only one fourth of respondents owned television sets (see Table 2), the benefits were not limited to them. Many households who could not afford one would visit other households to watch television. Such shared practices induce a sense of socialization, which was evident from the interviews. Prior to SMGs, interviewees mentioned that there was limited active social life after sunset. However, there was observable change in ways people conducted social life during evening hours, especially through activities like watching television. Different members of the households liked to get together during evening hours, watch television and catch-up on their daily conversation.

In addition to entertainment, television provided a new information source that seemed especially relevant to political discussions. News channels, especially during major electoral events like the general elections in 2019, became important sources of information. As one interviewee responded, '*we like to watch news during the evening hours and many times we even have our other members just drop by. Lately, only thing on news channels are about the ongoing elections. We discuss topics like how the government has performed, who will be the ideal candidate, etc.*' From this study, it can at least be inferred that there was an increased secondary capability of access to information, which could possibly lead to other capabilities such higher political participation through informed decision making.

3.5. Discussion

This paper deals with the question of what SMGs can enable individuals to do. The objective was not to quantify impacts, but to showcase the complex nature of how SMGs enhance capabilities in rural settings. The capability approach provides an effective framework to understand pathways associated with opportunities and choices, as it reflects what people value and how energy access can affect individual's well-being. In simpler words, this paper sought to identify not only the outcomes, but also how and why they mattered to people in the villages. The gendered aspects of capabilities also shed light on the role of external factors, highlighting potential implications for justice dilemmas.

In section 3.3, the paper discussed how the energy services enabled through SMGs affected different capabilities. First, they provided basic benefits to all households and enabled greater control over their environment. Lighting services enabled households to stay active after sunset, which in turn helped enable new capabilities. As a result, some household chores became easier for women and household surroundings (indoors and outdoors) became safer for all individuals. In particular, improved water access helped reduced drudgery and labor, which positively impacted women's physical well-being. Furthermore, electrification created new opportunities to communicate with friends and relatives, access televised entertainment and information, and increase leisure and recreation. These energy services from SMGs were perceived as an important part of well-being by the community.

While the findings presented here are consistent with some aspects observed in the literature (see Cole, 2018; Fernández-Baldor Martínez et al., 2014; Malakar, 2018 for more information), this study goes further in highlighting the contextual factors. The extent to which SMGs affect capabilities with respect to energy services varies depending on other factors including social, environmental, and economic positions.

Social conditions particularly have important implications for understanding energy related capabilities. Differentiation by gender is one of the most visible examples in this case study. The findings from this study suggest that women have benefited as a result of lighting services, particularly in terms of household chores that are designated by gender. Yet this does not confer higher order capabilities, such as an increase in power position within decision making. The interviews found that decisions about appliance purchases are not made by women, indicating relatively less power in economic decision-making within households. In addition, this study did not find any purchases of electric cooking appliances that may also aid women in household activities. Similarly, Rosenberg et al. (2020) identified higher ownership of male-dominated appliances in the rural households, whereas Moniruzzaman and Day (2020) highlight the degree of energy poverty being higher among women than men despite being part of the same households in rural Bangladesh. Thus, while energy services from SMGs in this case benefitted the day-to-day tasks and capabilities of women, they did not alter the traditional norms of the rural society. This pattern is also observed in different attitude towards girls' and boys' education, which highlights a gender-related bias that needs more attention in electrification studies. It is worth noting that gender biases start from a young age, as

studies like Azam and Kingdon (2013) find higher educational expenditure on male child as against females in rural India. This research identified that gender-related biases were reinforced through SMGs, despite the improvement in energy-related capabilities. Technologies such as SMGs improving energy access will not be sufficient to overcome such norms embedded within rural societies. Malakar and Day (2020) found that women relying on traditional energy sources like fuelwood perceived no enabling relationship between use of clean energy like LPG and their well-being. Similarly, their study found contradicting evidence where LPG users perceived that its use enabled well-being. This indicates that the gendered perceptions of energy-related capabilities also emerge from their lived experiences. Thus, we argue that there is also a need for sensitization and education to improve the possibilities of enabling new capabilities through energy access, particularly from a gender perspective. Additionally, this study also calls for further investigation into how power dynamics within rural societies shape SMGs effectiveness in terms of gender relations.

Furthermore, the results point to the fact that some capabilities enabled through energy services vary throughout the year. In this case, the environmental conditions restricted the enhancement of capabilities that are tied to the availability of resources like water. While time and effort needed to collect water was reduced, the reduced water availability during summers (and drought months) meant that communities reverted to pre-SMG water collection practices. Local vulnerabilities shape uneven exposure to energy poverty, highlighting deeper socio-material inequalities (Bouzarovski 2017, pp. 27), and in this case the lived experience of SMG users highlight that such vulnerabilities keep

manifesting despite energy access. Suggestions are made to deploy solar technologies for rural areas to improve water access, however, this study emphasizes that such solutions are strongly dependent on availability of local resources and calls for appropriate considerations while designing energy systems.

As a result of SMGs, we observe some sort of reconfiguration of existing social relations between different households. One of the understudied aspects is the relationship between energy poverty and social dynamics of rural communities (Middlemiss et al. 2019). Two specific capabilities found in this study to be enhanced are socialization and entertainment, both as a result energy services from SMGs. In resource-poor and close-knit communities, households tend to show social cohesion as they depend on one another for economic or moral support during times of need. For example, interviewees mentioned that socialization in the community improved as a result of energy services simply because now they have more opportunity to interact after sunset. Households don't just share tangible resources, but also share the intangible benefits that arise out of energy services. As seen in the results, households that did not own a television also gained value from visiting with their neighbors to watch movies or cricket matches. This practice shows that energy capabilities also depend upon existing social ties. The results provide insights into possible (energy) exchanges by means of social ties in off-grid interventions (A. Singh et al. 2017), which often are built on the idea of strong community relations as means of sustainability principles. Again, understanding off-grid solar like SMGs from the lens of social constructs might add additional insights into such local interplay between energy services and capabilities.

3.5.1. Lessons for Energy Justice

While this study builds on the understanding of capability enhancements from SMGs, it provides important implications for off-grid technology for rural areas in general. Developing energy systems for poverty alleviation will benefit from incorporation of considerations of capabilities and justice. Identifying who is impacted and how, including differences across gender, can provide insights into advancing the empowerment envisioned through energy access. This study strongly argues that addressing energy poverty through SMGs require understanding local norms, customs, and economic and environmental conditions. It doesn't support the magic bullet argument that eradicating energy poverty will in itself solve critical challenges. Instead, it suggests that focusing on specific capabilities and their differential effects will enable energy access to make meaningful contribution to global commitments like SDGs (Hillerbrand 2018). Using the capability approach to address fundamental questions about equality and justice will allow solar microgrids to contribute to low-carbon electrification while observing the principles of social justice.

3.6. Conclusion

It is often taken for granted that energy access will lead to benefits universally. However, many factors play an important in the realization of the benefits of electrification. This paper shows how the capabilities approach helps us understand what individuals value, how they achieve it, and what factors restrict or enhances their valued capabilities, thus providing important insights into the differential benefits of energy access from SMGs. Such an approach needs to be part of energy discourse, especially in nations across the

global south that still face impediments in achieving universal energy access. While SMGs can act as effective ways to tackle energy poverty in rural areas, there is a need to embed the understanding of local situation and social setting into off-grid solar programs, as well as incorporation of gender dynamics. The lessons arising from studies such as this will provide meaningful insights into the contribution of SMGs in universal electrification, which is expected to play an important role in achieving SDG 7. While grid expansion may be the dominant approach in some electrification schemes, understanding the role of SMGs will help build integrated strategies for universal energy access.

CHAPTER 4

SHEDDING LIGHT ON THE INVISIBLE – A PERSPECTIVE OF RURAL COMMUNITIES EMBEDDED IN ELECTRIFICATION PATHWAY

4.1. Introduction

The goal 7 of Sustainable Development Goals (SDG) guides the international development community to 'ensure access to affordable, reliable, sustainable and modern energy for all' by 2030. However, the last mile connectivity through grids to the rural areas of the global south remains a challenge due to the geographical constraints and low energy demand. In such cases, the decentralized renewable energy approaches such as off-grid solar (OGS) have been promoted as a sustainable solution to the problem (Levin and Thomas 2016). Despite capturing the attention of the international development community, the decentralized approaches to rural electrification such as the OGS have often met with mixed results and skepticism at the community level in global south countries (B. Sovacool 2013; Baurzhan and Jenkins 2016). A comparative assessment of 29 off-grid projects in Sub-Saharan Africa found that 17 became inoperable within first six months of operation (Ikejemba et al. 2017). This reflects on the unsuitable design of the OGS interventions in terms of the technological deficiencies (Yaqoot, Diwan, and Kandpal 2016) or adaptability to local contexts and its needs (Brooks and Urmee 2014). While such outcomes may not necessarily inspire confidence in OGS, it also indicative of justice related issues like lack of community participation or inclusive planning plaguing in the decentralized approaches to rural electrification in global south countries (Pandey and Sharma 2021; Fathoni, Setyowati, and Prest 2021). Apart from the risks of

reproducing marginalities in energy access efforts (Sanusi and Spahn 2020), OGS interventions are also giving rise to new kind of problems regarding localized experiences of solar related waste (Cross and Murray 2018). Such experiences compel local communities to raise questions about the equity and fairness of energy systems, which also is seen in conflicts with the global calls for energy justice through clean, modern and sustainable energy for all.

Making OGS interventions sensitive to local experiences is struggle for many policy makers who are striving for universal electrification. The energy services from OGS get embedded in daily lives and livelihoods of the local communities and becomes more than just technical infrastructure that exists within their household or vicinity. Thus, the associated socio-cultural and political processes of the OGS infact have deeper implications for energy justice (Kumar 2018; Ariztia and Raglianti 2020). For example, Kumar (2018) argues that the cultural notions mediate how electricity is perceived by the local communities which eventually influence the outcomes of the OGS projects for local development. As a result, it is also contested that the smarter technologies that facilitate energy access can make local communities more vulnerable to energy burdens (Jacome and Ray 2018; Kumar 2019). There is further a concern that the decentralized energy infrastructures at times are not amendable to the changing practices of local communities' in OGS interventions (Feron, Heinrichs, and Cordero 2016). Adding to such complexities, these practices do not necessarily result in predictable linear patterns of energy usages (Bisaga and Parikh 2018; Harrington, Athavankar, and Hsu 2020), which can hamper the technical performance of the energy systems. While such challenges

emerge, there still a lot to be learned and understood in terms of OGS as just means of electrification.

The current study captures the lived experiences of rural communities with OGS in terms of three important aspects – affordability, reliability, and community engagement. Rooted in the realities of the rural communities experiencing energy poverty, we develop an understanding of the interconnections between these three aspects and its evolution over-time to shed light specifically also on the dynamic process of OGS interventions within the landscape of on-going grid electrification efforts in India. In doing so, the paper also extends the discussion of energy justice associated with OGS in achieving the universal electrification goal under SDG 7.

Our findings in this study sheds light on the lived experiences of communities i.e. what rural communities experiences are as they start electrification with OGS and how does it get transformed over the years. We observed that communities' vision of electrification in India are deeply connected with 'grid' and governments provisioning of electrification through it. However, rejections from grid expansion over the last two decades provided avenues for communities to become welcoming of OGS. While enthusiastic and optimistic at the beginning of the solar micro-grid intervention, the study reveals that the communities have over the years moved towards skepticism and rejection. This came about as a result of the interlocking issues relating to the technical, economic and social aspects of the solar micro-grids. Thus, we argue that the changing notions of OGS electrification in rural communities largely rely on three main facets: affordability,

reliability and community engagement. Unless successful in addressing these issues, the global efforts to energy justice, particularly through OGS will fall short and quite possibly exacerbate vulnerabilities like energy burdens within rural communities. In addition, this paper also is able to shed light on the attitudes of the local communities towards OGS when intersecting with grid provisioning. Often framed as the grid-off-grid conundrum (S. C. Bhattacharyya and Palit 2021; Urpelainen 2014; Aklin, Cheng, and Urpelainen 2018), this subject increasingly gaining attention in past few years to accelerate electrification across the world. When intersecting with grid expansion, the communities showed preference for grid which does not bode well for future of OGS. Some lessons can be drawn from this study in efforts to integrate OGS into overall global electrification efforts.

4.2. Analytical Framework

4.2.1. Energy justice

There has been an increasing call to recognize and address justice aspects of energy transitions (Jenkins, Sovacool, and McCauley 2018; Sareen and Haarstad 2018). Emerging from the environmental justice and climate justice scholarship, energy justice has become an important analytical tool to understand concerns and issues rooted in ideas of social justice of global energy systems (Jenkins 2018; Sovacool and Dworkin 2015). In the scholarship, we mainly observe three different tenets of energy justice – distributive, recognition and procedural (McCauley et al. 2013). First, the distributive justice within the context of energy justice mainly concerns with the distribution of costs and benefits of energy systems and responsibility (Heffron, McCauley, and Sovacool

2015; Walker 2009a). The prevailing energy poverty in itself is constructed as distributive problem (Guruswamy 2010). Second, procedural justice is concerned with the ways in which community engagement occurs, normally understood through the fairness in procedures of institutions and implementation processes, where there is inclusion of all stakeholders in equitable manner (Walker 2009a). Procedural injustices occurs when there is lack of information, or exclusion in decision making. Third, recognition justice emphasizes on those who may be disenfranchised from the energy systems as various groups are unrecognized, under-recognized or mis-recognized (Schlosberg 2003a; McCauley et al. 2013). This at times manifests as devaluation, insults, degradation, and political and cultural domination (McCauley et al. 2013). While distinct in their own sense, all the three tenets are connected with each other (Schlosberg 2004).

The framework of energy justice has been critical in enhancing our understanding of societal interactions with energy system through social justice perspective. However, at the beginning, large section of the studies focused on the developed countries or what normally is referred to as global north (Graff, Carley, and Pirog 2019; Lacey-Barnacle, Robison, and Foulds 2020). In the last couple of years, energy justice has been increasing been applied to understanding the application of low-carbon energy technologies within global south countries, helping to shed light on variety of contexts such as indigenous identities (Velasco-Herrejon and Bauwens 2020), local politics and power relations (Setyowati 2021; Pandey and Sharma 2021), elite capturing (Chatterjee and Pal 2021) and failures of local off-grid markets (Samarakoon 2020) and wastes (Cross and Murray

2018). Another caveat to such studies is the relationship of energy justice to local practices within electrification of global south countries which are undergoing massive transformations. Infact, communities navigate through range of anticipatory socio-material practices in expectation of electrification (Enslev, Mirsal, and Winthereik 2018). What can be understood is that the concept or the term 'energy justice' is not internalized in the daily discourse, but rather manifest in the day-to-day experiences of being embedded in the energy systems. For example, Boamah et al. (2021) find that practice of corruption can become an (informally) accepted way of remedial measure among energy users who perceive the electrification regime to be unjust. This led scholars to observe a dissonance between the local experiences of energy poverty and technologies in global south countries, and the international efforts of pursuing SDG 7 (Munro, van der Horst, and Healy 2017; Baker et al. 2021). In context of decentralized renewables like OGS, such experiences tend to shape the perception of fairness and equity of the energy systems and sometimes understood through aspects such as affordability, reliability, and community engagement shaping the outcomes of the last-mile electrification (Tomei et al. 2020). These aspects can also be linked to distributive justice (Menghwani et al. 2020), recognition justice (Wolsink 2013) and procedural justice (Forman 2017). Such studies have extended the breadth of energy justice understanding in global south as the set of problems at times are quite unique and context specific.

The three tenets of justice often are temporally static i.e. measured or understood at a single point of time (Fuller and McCauley 2016). Similarly, the temporal dimension of energy justice is associated to long-term implications of climate change (Sovacool and

Dworkin 2015), and not necessarily with the experiences of societal interactions with the energy systems. However, with transitions taking place over years, it is possible that what may have been fair and equitable at one point of time will not necessarily be in the future. In such scenarios, the possibility of decentralized renewable energy like OGS as just means of electrification which not only serves as immediate solutions to the problems of energy poverty, but also as the time progresses have to be addressed by policymakers. Through this study, we add to the debates around the role of OGS as means of just electrification in global south.

Within India where this study takes place, energy justice has predominantly been applied towards utility scale renewable energy projects (Stock 2021; Yenneti and Day 2016). However, we need to recognize that the small-scale community-based systems produce different processes and outcomes than large scale utility systems (Wiese 2020). Thus, we focus on India where OGS has played an important role in rural electrification, with many initiatives now prioritizing justice in their operational models (Joshi and Yenneti 2020). Yet, very little studies have gone into looking at this form of electrification embedded in larger electrification paradigms through lens of energy justice (Yadav, Davies, and Sarkodie 2019).

4.2.2. Rural electrification in India – a quick glance

India has grappled with energy poverty for decades with as many as almost 55 percent of rural population lacking access to electricity in 2001. In response such large scale energy poverty, massive electrification efforts have been undertaken by the government in the

last decade and a half, predominantly focusing on extending the grids to rural areas (Palit and Bandyopadhyay 2017). Almost half a billion people in India gained access to electricity since 2000, often cited as a success story of electrification efforts of past two decades (IEA 2017b). More recently, India made significant progress with achieving universal village electrification. Despite such, almost 17 percent of households are still living without access to electricity (Agrawal, Kumar, and Rao 2019). It was found that almost 65 percent of the households are more or most energy poor in India (Gupta, Gupta, and Sarangi 2020). A deeper look reveals a large disparity in terms who normally is energy poor in India. For example, 93 percent of those without electricity in 2011 resided in rural areas, while 40 percent were in poorest income quartile (Banerjee et al. 2015). In addition to spatial aspects to electrification, the social positionality of communities also seems to have determined energy poverty. Acharya and Sadath (2019) highlight the energy poverty decline among marginalized groups like the tribal populations have been marginal as compared to communities like Hindus or Jains. In addition to such factors, the availability of electrification in itself has been dismal in India. In a large-scale survey of five states in India, it was found that households connected to grid received only 13 hours of supply on a typical day with almost four outage days per month (Thomas and Urpelainen 2018). This underscores that the energy poverty and related inequality is quite predominant in India despite its electrification efforts and leaves quite a gap for scholars to understand the reasons for it.

4.3. Methods

This study relies on in-depth case-study method. The fieldwork for the research was carried out between April and June 2019 in three villages in the district of Palghar from state of Maharashtra. The district of Palghar district has a population of over 2.9 million people with four (out of eight) talukas: Jawhar, Mokhada, Vikramgad and Palghar having a tribal population of more than 90 percent (Census of India 2011a). The district has low Human Development Index as a result of its low life expectancy and inadequate education infrastructure. The three villages selected were part of a cluster of seven villages that had solar micro-grids installed for their power supply. Given the nature of this research was to examine the community based solar micro-grids within rural electrification landscape, it was important such systems were in the communities for longer time. Often a quick turnaround assessment does not provide sufficient insights into sustainability of decentralized initiatives at community level (Terrapon-Pfaff et al. 2014; López-González, Ferrer-Martí, and Domenech 2019). A long-term time frame is important for such studies, particularly because communities may not have developed an appropriate understanding about technology, its suitability, their own changing practices etc. which will then have implications on the societal interactions with such a system. Thus, the three villages (hereafter village A, B and C) which had solar micro-grids for the longest time were selected for the fieldwork. On average, each of the village had used solar micro-grids for 40 months during the time fieldwork. Similarly, the changing grid-electrification paradigm in this region also influenced this particular selection of villages. For example, village C had grid poles within the community for almost a year, but still households were not connected to electricity. Other important selection criteria included

the author's access to these communities and ability to communicate in local language (Marathi).

The data collection was primarily relied on the semi-structured interviews and participant observation. In total, 52 interviews were conducted from three villages. The questions revolved around the communities regarding satisfaction of with energy infrastructure. Further probing questions was designed to delve into reasoning by asking 'why do you believe so' or 'what makes you say that?'. In combination, these questions reflect the user experience of solar micro-grids as well as any other forms of electrification which communities may have received. As far as the participant observation goes, it became an important tool for this study as communities and surrounding area were inundated with various kinds of off-grid solar interventions like solar streetlamps, and solar water pumps (for water wells), etc. which gave further insights into communities' interaction with the technology itself. Similarly, observing the rural landscape and other local infrastructural such as grid lines, etc. allowed to further contextualize findings.

4.4. Analysis

This section elaborates the findings from the three villages which are the midst of energy transition. We first highlight the electrification dynamics and communities feeling with 'being left out', followed by their experience of using solar home systems, which were first form OGS (and modern energy) used by the communities. Then, we move on to the experiences of community-led solar micro-grids which became their primary form of electrification.

4.4.1. Being left out – Electrification dynamics

Like thousands of other communities across India, the three study villages remained unelectrified for decades. The communities here associate electricity (or more colloquially batti in these communities) with the grid-based power. For example, despite transitioning into some form of modern energy thorough solar home systems (as seen sec 4.4.2.), there was a feeling of rejection within these communities. The recent developments with respect to electrification in India has infact highlighted some of the disparities and the feeling of being 'left out' of developmental paradigms and priorities of the government. This was further exacerbated when the surroundings of some these villages boasted with electricity infrastructure like high tension power lines (figure 10). Thus, interviewees argued that the government system was being unfair to their communities as many other villages received electricity connection years ago. The topographical barriers which resulted in these villages being unelectrified made little sense to them when they saw such infrastructures providing electricity to other villages, which had similar such features. Some made comparisons of the (un)electrification to their weak economic positionality in the society. This feeling can be captured through responses like "poor people always suffer here." For such rural communities, the electrification as phenomena not only represents mere material presence, but more symbolic to their self-identity and citizenry (Cross 2019). Thus, the sentiment of being left out corresponded to having less opportunities for these communities to engage in modern ways of life.

Figure 10: High-tension Power Lines Visible from the Unelectrified Study Villages

4.4.2. Initial experience of solar home systems

During the fieldwork, it was found that many of the households previously owned solar home systems. In this case, the solar home lighting systems were predominantly the first form of modern and clean lighting source to the households, which until then relied on kerosene as primary source of primary lighting. It was found that over 88 percent of the interviewees previously owned (or currently owning) solar home lighting systems. As per the recollection of few interviewees, many of the initial systems were received more than 7 years ago. These systems delivered energy services of few lightings and a mobile charging. Despite owning such systems, kerosene still played a role in the energy needs, primarily because of the inexperience and unfamiliarity with the technology. However, interviewees agreed that transitioning to home lightening systems helped reduce household's reliance of kerosene for their lighting needs and thus pushing it to secondary source (or more as a back-up option).

Long term reliance and usage provided a unique opportunity to understand how solar home systems gets embedded in households transition to modern energy. Interestingly though, none of the interviewees reported of purchasing such a system on their own, implying it was provided either through a local non-governmental organization or government initiatives. Having used and relied on SHS systems for a long-time, the interviewees highlight certain challenges, which also in many ways is a reflection of attitude towards off-grid solar. On asking why they haven't made a purchase on their own through local markets or suppliers, majority of the interviewees suggested cost as a barrier, followed by its unreliability in longer time frame.

Of all the interviewees who had previously received atleast one such systems, almost 72 percent are not in working condition anymore. Some households (20) even received two systems through various programs and initiatives over different period of times and in half of those cases both have stopped working.

In addition, 18 households (from village C) recently received solar home lighting system (under the rural electrification scheme of Saubhagya), which apart from lighting and mobile charging also has a DC fan. The household's dissatisfaction with home lighting systems as explained by one interviewee, '*we previously received a solar lantern and then a home lighting system, and both have stopped working. Not sure how long this current one will work either.*' The repeated experience of low quality of the systems in rural areas have created a distrust for the technology, and also does not inspire much confidence to infact integrate it in their daily energy practices. During interviewees, we

observed how some households infact did not care for the recently received solar home systems (fig. 4.2a).

Such distrust is further compounded by the fact that none of the interviewees had any information on who to contact for repair and maintenance for the recently received SHS. Thus, if the system stopped functioning, the households had no means to get it repaired or replaced and ended up either being stored in their homes (as seen in fig 10b) or informally disposed in nearby wastelands. These practices often have become norm as there is no appropriate waste disposal or buy-back mechanisms in these rural areas, and with interviews further suggesting that they have little knowledge about the risks either.

(a) All dusted panels not cared for by the household

(b) Non-functioning SHS stored at home

Figure 11: Integration of SHS in the Current Energy Practices

4.4.3. Community-led solar micro-grid experience

After transitioning into modern energy through solar home systems, the three villages each had a solar micro-grid installed between 2015 and 2016. All the households in the three villages were connected to the solar micro-grids and this transition came as a result of a social enterprise in efforts with local nongovernmental organization installing these systems. These solar micro-grids were managed by the locally formed institutions called village energy committee (VEC) with daily operations and maintenance (O&M) being its primary responsibility. The creation of local institutions (VECs) with specific role and responsibilities for such community managed solar micro-grids are quite common in India (Palit, Sarangi, and Krithika 2014; Katre and Tozzi 2019). In all the three study villages, the connected household had to pay a fixed cost of ₹50 each month, along with ₹10 per kWh consumed. This money was collected and kept as a corpus fund with the VEC to cover O&M related short-term expenses such as repairs or replacement of parts or long-term ones like battery replacement.

The solar micro-grids added a new dimension to the communities' energy transition to modern sources, as they were able completely move away from traditional fuel (for lighting) while also expanding their available bucket of energy services to cooling, entertainment, street lighting, etc. Many of the interviewees' reliance on kerosene for lighting ceased to exist as the solar micro-grids was effectively satisfying all the lighting needs, also aided by possessing solar home lighting systems which acted as back-up if needed. As per the interviewees, such a move along the continuum of energy transition received with excitement and enthusiasm during the earlier days of solar micro-grids as it

provided sense of modernity to members of the community. One interviewee recalls, '*We were so happy when we got solar micro-grids. We could also do things which others could*.' This reference 'to do things which others could' is often understood in pure sense of what electrification enables in rural communities in terms of their daily lives and practices (see Malakar, 2018 and Rajagopalan, 2021 for more details).

In this study, a change was observed in the perception of the communities with solar micro-grids as the time progressed. As per the interviewees, over the years the excitement and enthusiasm with solar micro-grids was replaced with skepticism and rejection. In each village, we observed different situation with respect to functionality of the solar micro-grids. The first village discontinued using solar micro-grids (and switched over to grid), while the second was facing constant disruption with very limited hours of supply and the third was still using it as their main source of electrification. As a result, most of interviewees from village A and B held relatively poor opinion about the solar micro-grids at the time of the fieldwork, while village C acknowledged that they would face a problem sooner if not later.

The reasons highlighted by the interviewees about the perception change regarding solar micro-grids after years of being electrified through it are mainly classified into three main categories – technical, economic and social. The technical challenges relate to insufficient or poor reliability of the solar micro-grids that emerged over time. Interviewees felt this was the case because of the aging solar micro-grids, particularly the batteries which were unable to charge fully and subsequently leading to continuous

power-outages. As per the interviewee, such power outages were common in village A and B, while village C relatively had stable supply with few outages in every week or so. As a result of such power outages and shutdowns, many interviewees drew parallels between the functionality solar micro-grids and their experience with solar home systems. One interviewee explains, '*This is also like the other lighting systems. After few years, this also started giving problems like the smaller one.*' Furthermore, the respondents also acknowledged that the supply was more erratic during the monsoon time due to lack of sunshine and batteries were unable to charge to meet the supply requirements within the communities. Additionally, the aging batteries which in any case was not able to provide continuous power supply, along with seasonal variation emerged as the reason for decreased satisfaction over period of time. Furthermore, the changing consumption behavior also seems to affect peoples' perception about the solar micro-grids and its ability to satisfy their energy needs. The interviewees acknowledged the fact the solar micro-grids though initially were sufficient for their needs, however, started falling short as the various households in the communities started purchasing appliances such television, refrigerator, mixer-grinder, etc. which needed higher load capacity. This eventually started leading to either voltage fluctuations or power-outages as the load increased within the communities. In such a case, the households sometimes had to revert back to using kerosene as source of lighting and be deprived of desired energy services when the supply was disrupted.

Other than reliability, the interviewees also express concerns about the affordability through solar micro-grids. However, there is distinction within households who are

somewhat well to do and others not so much. The households which have appliances like television and refrigerator (and thus higher consumption) started to feel that micro-grids are rather expensive as per-unit kWh price was ₹10. It means they are not fully able to realize energy services that they feel is essential for them as costs becomes an important barrier. On the other hand, interviewees who do not possess appliances like television and refrigerator but have aspirations also express similar concerns, indicating affordability as serious hindrance towards improving energy consumption and thereby well-being. They express concerns regarding solar micro-grids being more expensive than the grid-power is cheaper, which supplies relatively electricity at lower price. However, the interviewees which belonged to particularly households with marginal energy consumption were less bothered about such comparisons. For these interviewees, what seemed unfair in terms of the costs was relatively well to do households were paying the same rate as against other.

In accordance with the above findings, we tried to understand households' perception towards the VECs which was responsible for the O&M, and thereby also any issues that arise in the communities with respect to the solar micro-grids. While in the case of village A and B, the VECs stopped meeting as the problems emerged with the solar micro-grids whereas VEC of village C was still continuing with O&M responsibilities as it had regular and reasonably uninterrupted supply. Interviewees helped us understand the technology and societal interactions in long-term and how challenges emerge over a period of time which may eventually lead to the breakdown of such community-led energy initiatives. As time progresses, new set of challenges emerged within the communities which made enforcing the rules and its compliance difficult. Many of the

community members, particularly men of working age find employment outside their villages during non-monsoon months. As one interviewee (who was also part of VEC) notes, '*despite it (solar micro-grids) giving us autonomy of using systems, taking care is more efforts and work for us.*' Another interviewee elucidates, '*everyone won't agree always, which at times makes certain issues even more serious.*' Keeping the cohesion and uniformity over a long period of time became a challenging task here, which was amplified as the expectations of the communities were not adequately fulfilled. Echoing such a concern, one of the interviewees explains, 'if many people stop following rules, it becomes difficult to enforce them altogether. And then no one can properly manage such systems.' One primary reason the interviewees mention that created tensions within the community with respect to solar micro-grids was demand-side management. Demand-side management in this case here reflects the ability of VECs to enforce rules and regulation to manage the consumption of electricity. Load issues were mentioned as one of the factors for the solar micro-grids to not being able to meet their energy needs over time. Such load issues required demand-side management, which despite being within the ambit of VECs couldn't be appropriately addressed. The load issues arising due to overdrawing has also been observed in renewable energy based off-grid initiatives (GNESD 2014; Ngowi, Bångens, and Ahlgren 2019) which reflects the constraints on the local managing institutions like VECs towards making of rules and its enforcement. Here the load issues were directly related to increasing energy consumption within the communities. As per the interviews, it became difficult for the VECs to monitor and restrict consumption with time as many households started purchasing and using televisions, refrigerators and other appliances. As one interviewee (who is also a member

of VEC) highlights, '*how can we tell people not to purchase these appliances? And we cannot exclude someone by saying they cannot use the appliances or else they complain about VECs being partial. It became difficult over a period of time to monitor and regulate*.' Through few in communities have purchased appliances like televisions, refrigerators, etc. there are many within the communities who have aspirations for it but were not able to due to inability of solar micro-grids to provide sufficient power (i.e. load issues). One interviewee explains, '*I want to get television for the house as kids keep asking for it. But what is the point if we can't get power supply to use the television?*' This shed lights on the fact how the solar micro-grid within the communities did not evolve with their needs and preferences over time.

Another important contention that is seen within the communities is regarding the management of the funds and its ability to cater to the future large expenses. It is evident from this study that the regularity of the payment of bills is tied to the reliability and households' satisfaction of energy supply. A bad payments practice was observed in two communities (village A & B), and the reason given was the inability of the solar micro-grids to supply continuous power as one interviewee mentions '*no one is willing to pay their bill because of the constant disruptions.*' However, the situation observed is different in village C, where the payments seem fairly regular as per the records maintained by the VEC. Yet, in all the three villages, it was observed that the amount collected and kept in corpus would not have been sufficient for a major expense like battery replacement without external funding and this fact seems to be recognized by some of within the communities. This has also led to further led to tensions within village

A, where the solar micro-grid was subsequently uninstalled. The interviewees report that they have not received their money back from the VEC. The most prevailing opinion among community members was that the corpus was created for specific purpose of O&M, and that money should be distributed back to the households now that the repairs (or maintenance) of the solar micro-grid is not going take place. A similar view was also expressed by interviewees from village B, who do not see the solar micro-grids to be repaired and operate to full reliability in the near future.

All these issues eventually lead to communities questioning of the long-term sustainability of the solar micro-grids, both from cost and reliability perspective. Long-term sustainability in this case refers to the period for which the communities feel that they will derive energy services without any disruption or issues. For example, the batteries need replacement every few years in such solar micro-grids, specifically 5-6 times over the lifetime of solar panels (Chandran-Wadia et al. 2015). Thus, most of the interviewees in all the three communities express that they do not see solar micro-grid as a permanent solution i.e. as their primary source of electricity through which they may want to derive their energy services. An interviewee explains, ‘even if we are able to fix the problems, I am sure this problem will arise again after few years.’ Such a perception led most of the households from all the three villages to say they would prefer to have grid connections in long term as compared to solar micro-grids.

4.5. Discussions

In this section, we discuss the implication of the findings observed from the fieldwork. Through the case-study, it was seen that rural communities' transition to modern energy through solar micro-grids (and OGS in general) presents various challenges. Three main aspects namely: *affordability*, *reliability* and *community engagement* quite often dictate how solar micro-grid engages or disengages with rural energy transition efforts in India (Figure 11). This has some implications for energy justice through solar micro-grids (and OGS in general) to evolve as just means of electrification.

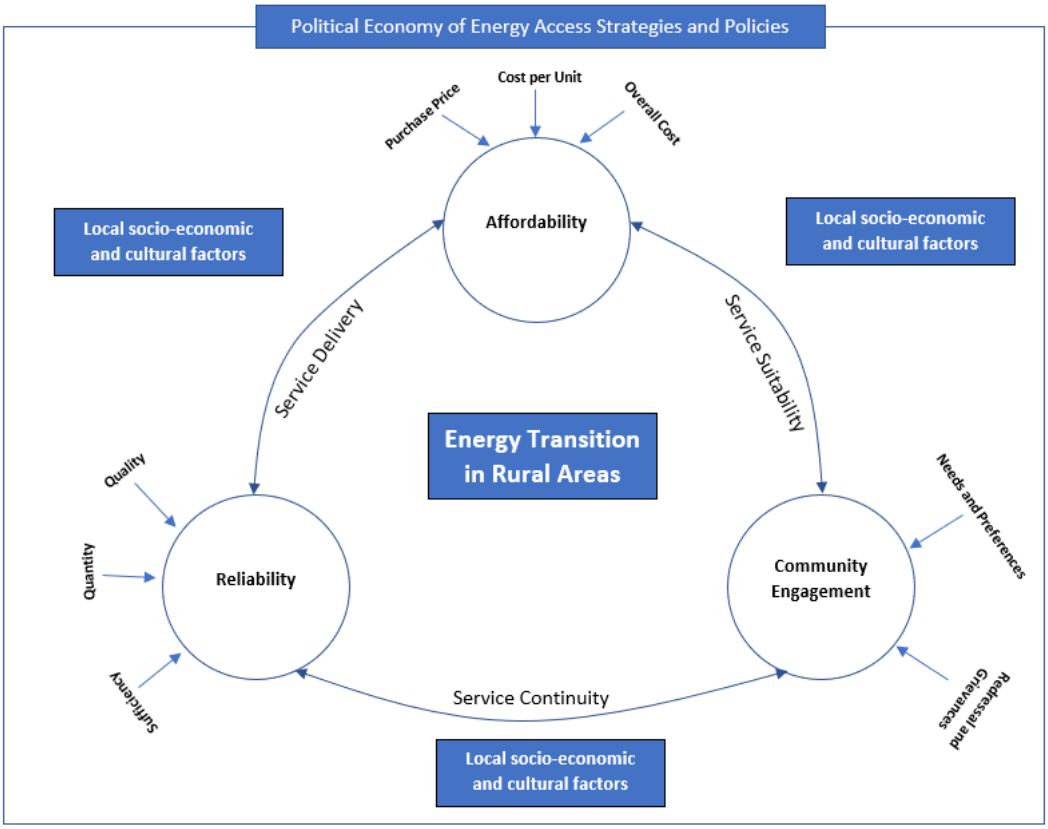


Figure 7: Dimensions of Community Based Off-grid Solar Energy Transitions

4.5.1. Affordability and OGS

This case-study particularly highlighted the concern of the communities regarding the affordability of energy services with solar micro-grids. Often, these rural communities had seasonal incomes and thus affording clean energy became more of a burden. The implicit concerns about the high per unit tariffs displayed how affordable energy through solar micro-grids could also be challenging. In the study of three communities, the initial tariff setting may have seemed acceptable at the beginning, but it became problematic with time, particularly to those who have (or want to have) higher consumption other the basic lighting loads. For households which relied only required lighting, it was easier to assume that the cost paid for consumption is in many ways a substitution for price of kerosene and efforts required to acquiring it. However, for others using energy through solar micro-grids became expensive, thus restricting their current consumption of energy services like entertainment or adding new ones.

As rural communities get embedded in the modern energy transition, affordability related concerns have showcased that rural communities struggle with energy costs on a daily basis. Affordability as a principle is important within distributional paradigm of energy justice (Sareen and Haarstad 2018; Williams and Doyon 2019). This case-study shows that the rural communities can disproportionately suffer from such a burden during their transition to modern sources of energy. Also, one has to effectively talk about solar micro-grids in comparison to grids. In this case, the communities compared the price differences with the grid, making it more glaring for them the inequalities they faced. Thus, appropriate measures are necessary to address the affordability concerns through

solar micro-grids if it were to emerge as just means of electrification. Important steps such as standardizing per unit price to grids and rural realities like disposable income, etc. are necessary in this regard, particularly for economically weaker communities in rural areas. The back-end economics of OGS like solar micro- and mini-grids at rural community level have to make available sufficient funds through targeted subsidies and cash transfers (Bhattacharyya et al. 2019).

4.5.2. Reliability and OGS

The reliability concerns with energy transitions as seen through the lived experiences of these rural communities are quite glaring. Here, the reliability is understood as the combination of quality, service level and sufficiency (timely delivery of desired quantity) (Schillebeeckx et al. 2012). It was observed that the reliability of solar micro-grids declined over period of time within these communities and thus many explicitly expressing that it will not be able satisfy their energy needs on continuous basis for very long. In many other cases, rural communities in India became reluctant to use solar micro-grids calling it ‘fake energy’ (Sharma 2020).

The underlying reason for communities to experience reliability issues points out to the fact that the local needs and preferences are often ignored or misrecognized. However, reliability is not often given importance within the paradigms of energy justice, which reflects on the ways the OGS interventions take place in rural areas. We argue that the inherent mismatch between the needs and preferences indicates the lack of focus on recognition-based justice within energy transition efforts, particularly in OGS. For OGS

to reflect recognition justice, the system characteristics have to reflect the characteristics of communities (Wolsink 2013). In contrast, the solar micro-grid solutions designed for these rural communities being deprived of energy did not match with socio-economic and cultural realities, the emergent result of which was unreliability. The expectation with electrification and associated energy services changes with time as communities get embedded in transition towards modern energy source. This change in expectations also influences the notion of reliability as seen here. By ignoring accounts of recognition based-justice, what emerged in these three communities in form of reliability issues is the questioning of solar micro-grids as a just form of electrification. For communities which started off their transition towards modern sources of energy almost a decade ago, the inability to achieve reliable supply despite such a long time develops a skepticism over the viability of OGS like solar micro-grids. Thus, we argue that the absence of recognition-based justice also unintentionally creates the intra-generational inequity where disparity emerges within different communities (Sovacool and Dworkin 2015). The fact that these communities remained unelectrified for decades, and then suffer from unreliable power supply through OGS makes them question their positionality in the society.

Policy vagueness around reliability is considered as a critical challenge for sustainable electrification (Monyei et al. 2019). When designing pathways, it will be important to ensure monitoring the performance of solar micro-grids over longer term. The needs of rural communities' change (or increase) over-time, which will directly impact the reliability of OGS like solar micro-grids. Thus, reliability i.e. hours of sufficient power

supply has to be integrated as an important criteria within policy dimensions, particularly for OGS. Of course, we do not discount that the energy requirements are quite context specific and technology designs such as system sizing play an important role. However, without accounting into near future and long-term requirements, solar micro-grids will effectively not emerge as a just electrification for rural communities.

4.5.3. Community Engagement and OGS

The results suggest that there was insufficient community engagement in terms of establishing processes and mechanisms to engage in decision-making in these communities. Involvement of local communities and institutions is often considered important for sustainability of interventions (Joshi et al. 2019). Community participation in form of consultation was observed in energy related decision making for solar micro-grids, yet various issues have emerged overtime. This led to us to ask how communities are involved in decision making that affects them on a daily basis. The community engagement in off-grid projects in the global south tends undermine user needs and preferences (Herington et al. 2017). Here, the energy needs of the communities were not appropriately accounted into, which in turn highlighted the inadequacies within the consultation process and inclusion of local views to begin with. In addition, these communities could not get their issues of constant breakdown resolved nor were they effective in having a load management strategy. Thus, the breakdown of rules and trust deterioration over time can be attributed to the deficiencies in processes needed for effective management of solar micro-grids. This eventually led for to communities to

wonder if solar micro-grids are a just means of electrification as it did not provide sufficient stakes for the communities to be invested in long term basis.

This case study successfully highlights that the participation and engagement of local communities in infrastructural decision making is dominated by the approach of gathering information instead of inclusionary planning (Herington et al. 2017). There are important lessons to be learnt in terms of establishing processes that will be effectively in building a more just community led solar micro-grids. If such community led solar micro-grids are to become an effective pathway for electrification and contribute towards universal electrification, rural communities have to be placed at center of the decision-making instead of them being a peripheral actor. We understand that the challenges pertaining to system failures, load management and payments, etc. will emerge overtime, which have to managed and resolved within the communities. Unlike their roles in grid pathways, the role of communities in such community led systems goes beyond the usual consumer status to become producers and managers, which means the processes for engagement with external actors (e.g., technology suppliers and/or project implementors) have to be robust and transparent.

4.5.4. Intersectionality between affordability, reliability, and community engagement

While individually a challenge, all the three dimensions are important in relation to each other in achieving SDG 7 through OGS (figure xx). First, affordability and reliability ties into service delivery i.e. delivering important energy services through OGS to rural communities. As millions in India and across the world struggle with energy poverty, it

will be critical to take a holistic approach towards ensuring that affordable energy is reliable and reliable energy is affordable. For international community, it must take cognizance of the fact that the service delivery through OGS like solar micro-grids to rural communities becomes ineffective if the energy interventions and policies do not address these two in relation to each other, which further traps communities into energy poverty. This itself becomes a condition for energy (in)justice despite having access to modern energy.

Second, the linkage between affordability and community engagement is important to understand service suitability i.e. the suitability of OGS and associated energy services as per the needs and preferences of the rural communities. Energy practices of communities evolve according to their social and cultural practices, in accordance with their economic conditions. At times, OGS may suit current needs, but not the changes in preferences, thus raising questions of service suitability in the long run. In failing to do so creates situation of energy (in)justice which diminishes the efforts of SDG 7.

Third, the reliability and community engagement ties into service continuity i.e. to ensure that required services are delivered to communities on continuous basis as they move forward on energy service continuum. The case study offered insighted into how disengaged the solar micro-grids became with the needs and preference of the communities, and thus leading to service discontinuity. Research shows the electrification is not a static goal, but a goal post which will require substantial efforts towards maintaining people within the ambit of energy access (Harris, Collinson, and Wittenberg

2017). Without centering discussion around service continuity, OGS like solar micro-grids will face challenges as a long-term just option for electrification.

4.5.5 Reflections on Energy Justice

This study also an important addition to the discourse of the temporal element of energy justice, which often does not attract as much attention as studies focus tend to be temporally specific of energy systems and not in its entirety (Fuller and McCauley 2016). This issue gets further magnified for decentralized renewable energy approaches as examples of OGS as primary pathway of electrification for a sustained period like a decade or more is uncommon, which makes understanding such temporal dimensions quite difficult. However, we can establish that the changing dynamics of rural energy transitions and household behaviors mean that the perception of communities of what is just and fair change with time. This lesson will serve as an important for policymakers aiming for universal electrification through OGS not to discount the temporal change of practices and perception regarding energy systems. While energy justice of what (distributional), who (recognition) and how (procedural) is a dominant paradigm shedding lighting on fairness and equity relating to energy systems, there is also a need to talk about ‘when’ in the same frame. It will be important to account for temporal dimension within energy justice to figure out if current energy systems will remain fair and just over time.

4.6. Conclusion

This article has presented the dilemmas that OGS like solar micro-grids face to become as a just form of electrification. This article does not in anyways tries to suggest that the OGS do not bring in benefits or discount the potential it has to contribute to renewable energy deployment but instead contest that they at times inadequately address some energy (in)justice related concerns. The long-standing goal of universal electrification has proven to quite challenging and international agencies see a big role of OGS including solar micro- and mini-grids in achieving it (IEA 2017b). However, policymakers have to be cognizant that their efforts do not create and exacerbate energy related vulnerabilities of the rural communities. With grids being ubiquitous to electrification in India, particularly from perspective of the rural communities, integration of OGS within policy landscape has become challenging. The efforts towards electrification have triggered aspiration of modernity among rural communities, which becomes closely linked to ideas of unfairness and injustice if they remain devoid of it. By identifying the issues relating to changing perception of energy justice towards energy systems, there is a need to specifically address the affordability, reliability, and community engagement aspects of OGS interventions to strengthen its approach towards universal electrification.

Finally, we would want to call for a cautious approach towards eradicating energy poverty at the moment. The universal electrification is not a static goal, that once achieved will be not irreversible. The COVID 2019 has displayed that rural communities are quite vulnerable to such shocks and can be driven into poverty again, which will impact their ability to have meaningful access to energy services. The learnings and

experiences here will help create opportunities for OGS to become universally part of just electrification efforts that every nation today across the world is trying to achieve.

CHAPTER 5

CONCLUSION

This dissertation has explored the role of off-grid solar (OGS) in rural electrification landscape in India. In addition to large-scale grid expansion, decentralized renewable energy like OGS has played an important role in rural electrification, particularly in the remote economically disadvantaged communities. While currently there are millions in India and across the global south who depend on OGS as means of electrification, the attainment of SDG 7 by 2030 also strongly depends on successful transition. Despite its obvious advantages of expanding energy access and tackling climate change, it is still unclear how far the OGS is oriented towards creating fair and equitable means of electrification. This at times manifests as a gap between expected and actual outcomes from the local projects. Motivated by this dilemma, the dissertation questions the assumption of suitability of OGS in rural electrification landscape. Embedded within the analytical paradigm of multi-level perspective (MLP), capabilities approach (CA) and energy justice, the dissertation has following objective: (a) tracing the evolution of OGS in Indian rural electrification landscape and identify narratives that influenced its development; (b) identifying what and how capabilities are impacted as result of OGS using community based solar micro-grids; and (c) examining community based solar micro-grids as just means of electrification.

5.1. Key Learnings

Through empirical work, the results from chapter two, three and four present important learnings towards OGS as means of electrification in rural landscape. These learnings shed light on what has been achieved so far either effectively or ineffectively in context of Indian rural electrification through OGS. While the decentralized renewable energy systems are built for communities with either no access or minimal access to modern energy, this dissertation indicates there will be effective challenges associated with creating business and operational models for long term sustainability. It provides some possible pathways for the future for OGS in India and elsewhere in global south countries which are undergoing or expected to undergo rapid expansion of electrification in the near future.

5.1.1. Research objective one: Tracing the evolution of OGS in context of the rural electrification

The understanding of energy transitions in context of institutional settings is valuable for informing policymakers about the process through which societal transitions unfolds and how different policies influence them. The confluence of various narratives and actors within climate-energy-development discourse brings about specific set of innovations across spatial and temporal scales. Most importantly, it is valuable to note that the transition towards OGS is a multi-scalar process with innovation breakthroughs from state and non-state actors. These set of innovations are nurtured and scaled through various means such as technological deployment, financial support and policy environment. Firstly, we learn that the OGS transitions is a result of the interactions

within the systems and the influence of external factors over a long-time frame. Atleast in the beginning, the OGS transitions in India emerged as a ‘state-influenced niche empowerment’. This also points to the fact that non-state actors (or niches) are not only ones responsible of driving the transition towards of decentralized renewable energies as normally envisioned in the MLP theory, but states (or governments) can play the initiator role in development of alternative energy sources. The Indian government influenced niche development through funding for research and technological deployments, which was primarily driven through the concerns of energy insecurity. Overtime, the changing electrification dynamics played a key role in ways the national government perceived OGS within its policies. Despite the slow progress, the learnings and relative success of various niche experiments in various pockets of the country led to legitimization of DREs, including OGS at national level.

In addition, the electrification in large parts is seen as a responsibility of the governments, however, non-state actors have an important role in enabling energy access in India. The role of non-state actors evolved according to the prevailing narratives dominated, which in turn were largely influenced by internal and external social, political and environmental considerations. For example, the participation of social enterprises in the past two decades are very much motivated by the energy for development, while the transnational actors clearly facilitated the environmental goals for development of renewables within global south countries like India. The actors in successful transition processes often tend to leverage on the resources and capabilities of each other. As observed in India, the transnational actors leveraged the indigenous institutions and

capabilities during early 1990s as means for effective implementation for their renewable energy deployment objectives. This is an important lesson for creating a partnership-based model, where national and regional government can create effective spaces for engagement (either through policies or institutions) for non-state actors like international funders and local energy enterprises to facilitate smooth diffusion and transition of OGS. The goal of universal electrification will require adequate support from through multi-stakeholder partnerships with adequate space for mutual sharing of knowledge and resources.

5.1.2. Research objective two: Understand the process of energy related capabilities enhancement from solar micro-grids

The OGS like solar micro-grids have important implications for capabilities enhancement in the rural communities. The communities largely associated their well-being to what they are able to accomplish as a result of access to modern energy. As seen in chapter three, various capabilities including health, education, communication and entertainment, household activities were enhanced by the solar micro-grids. Many of the capabilities were something these individuals had never experienced. For example, the communities experienced new form of entertainment through television. The improvements in availability of mobile phones and ability to use them, had implications for availing health services or maintaining social connections. With solar micro-grids becoming engrained in day-to-day lives of the people, change in routines were visible. The communities were able to socialize more, particularly during the evening hours. It was clear that households

associated electricity with ‘modernity’ and the acquisition of appliances with ‘status symbol’.

Despite the perception of improved well-being, this dissertation also sheds light on the contextual factors that influence energy related capabilities. But such capabilities are also gender sensitive i.e., men and women seem to value different capabilities. These capabilities are defined as per the gender roles and decision-making ability within the households. For example, the capabilities enhancements related to women comes from their ease in doing household chores which is dominantly seen as their primary role within the household. Similarly, it was observed that the leisure and entertainment are more valued by men, which they derive from modern appliances like television. And the decision-making ability for such purchases dominantly reside with men. Such distinction within energy related capabilities at the individual level is clearly visible, which highlights that dissimilarity comes from embedded norms and cultures that have established specific gender roles and power asymmetries. In addition, energy related capabilities enhancements are also never constant and can move away from the desired effect from OGS like solar micro-grids. This was visible in this case-study through the example of health improvements not being realized during summers as the availability of water became scarce. The dependency of energy related capabilities on the local environment of the communities showcases how OGS like solar micro-grids have to not just be suited to local norms but also to geo-physical characteristics.

5.1.3. Research objective three: Understand the links between OGS and energy justice in the context of rural electrification

When considered in isolation, the energy services from modern energy sources are no doubt better than having no access, however, the real-world situation is observed to be quite complex as various technologies, pathways intersect with peoples' experiences and expectations. The rural electrification landscape in India is rapidly evolving with mix of both grid and OGS pathways. However, it clear that rural communities have a clear preference towards grid as it is tied to the notion of what the perceive as 'development'. This makes communities view OGS like solar home systems and solar micro-grids as a transient pathway towards clean and modern energy access. While the rural communities studies in this dissertation seem to benefit from the OGS as it helped them move along the clean and modern energy access continuum, the pathway is not as straightforward. These challenges dominantly emerge from their lived experiences which often dictate the perception towards OGS as just means of electrification. Three main factors, namely, affordability, reliability, and community engagement, play an important role in determining if OGS are viewed as just means of electrification by the rural communities.

First, there are direct implications of distributional justice when energy services from OGS are evaluated for its affordability. In a nutshell, the study highlights that the energy services through solar micro-grids can become unaffordable as rural communities move towards higher energy consumption. Similar unaffordability related issues are also seen in other solar micro-grid interventions in India (Sharma 2020). The households within communities which often just depend upon lighting services find OGS technologies more

suited to their needs, however, households with or aspiring of higher consumption than basic lighting perceive it to be unaffordable to derive energy services from solar micro-grids. In addition, when the comparisons between the prices between solar micro-grids with grids are made, communities perceive that the solar micro-grids are unjust is terms of pricing. This intra- and inter-community differences, particularly in terms of cost of energy technology and services, served as a deterrent for effective embedment of OGS within rural communities in this case.

Second, the reliability factor associated with OGS energy systems has implications in ways communities derive energy services, which also ultimately reflects on how justice as recognition is manifests within OGS. It was found that the OGS such as solar micro-grids do not fit into perceived reliability criteria the three communities establish for the energy systems. Failing on sufficiency and continuity in a long-time frame, it was understood through three communities that the diminished reliability makes it difficult for rural communities to integrate OGS into their daily lives. Reliability of OGS often manifest differently than grids, where the grid's reliability (with hours of power availability) increase, the same is not necessarily true for OGS like solar micro-grids or even solar home systems seen in the rural communities. In this case, this had implications for not just households which had higher consumption, but also with the ones which had only lighting as their primary energy service need. Not being to recognize the aspirations of communities is associated often mean such OGS approach to electrification is not recognized as fair and just by the communities in the long run as seen here.

Third, the OGS did not appropriately address the issues of community engagement as seen in this case-study. Unlike grids, the OGS is situated within the communities making them producers as well as the consumers. If energy systems are embedded in the households and communities, it means effectively means that additional responsibility as recognized by the rural communities. It is important to note that the pre- and post-installation community engagement process will be different for OGS interventions, and inadequacies in such processes established for engagement led to technological and managerial problems. This in turn has implications for procedural justice for OGS, which seems a deterrent in terms of establishing such approaches to electrification as just and fair from the perspective of communities.

5.2. Policy implications and recommendations

From the learnings through studying the Indian context, some policy implications can be prescribed towards creating a better ecosystem for decentralized renewable energy systems like OGS for effective actions in eradicating energy poverty in the global south countries. A large portion of population that is being served through OGS like solar micro-grids will need adequate technological and financial support towards over the next coming years.

5.2.1. Build a capability centric approach to OGS designs

It is of paramount importance that the OGS initiatives are designed with capabilities as a central focal point. A traditional approach to designing is often too focused on improving energy access, not what it is supposed to enable. The current methods leave very little

space to understand why people value what they value, an aspect which is important for designing and improving energy access initiatives. While engineers might think about the technology, the communities think in terms of daily practicalities. This approach will also compliment the traditional ways to address methodologies of needs assessments which to provide emphasis on local context cultural norms, power symmetries and geo-physical characteristics. For example, a clear ramification was the installation of water pumps and tanks, but that did not address the needs of communities in the most crucial summer-time when water was scarce. Understanding energy capabilities as the core function of OGS will enable to target energy service satisfaction. The capabilities approach is a true bottom-up investigation method, allowing the communities to be placed at center of energy interventions instead of peripheral actors.

5.2.2. Recognize affordability, reliability and community engagement as key principles of OGS energy interventions

While it is clear from the OGS interventions is that while it contributes towards eradicating energy poverty and facilitating capabilities enhancements, this case-study tells us that there is a lot more to be done in terms of addressing justice concerns that emerge from the current ways of thinking. The infrastructure at local levels should have a strong sense of energy justice principles infused at the core of project or program implementation. These principles will be necessary to ever changing dynamics of rural electrification landscape in global south countries as public infrastructure and service delivery to basic necessities improves. The goal to have universal electrification which facilitates achievement of other human needs and climate mitigation cannot move

without forward without have a strong sense of justice principles incorporated in energy infrastructure.

First, the affordability of OGS as a criterion has to be incorporated within policy discourses of OGS. Within energy justice, affordability is often given importance, however, it has failed to become a tool in facilitating just means of electrification in OGS due to current approaches. With direct comparison to grids, OGS often observed to be expensive and thus finding less support from communities. Primarily, the energy access practitioners have to think about such cost directly in-terms of how communities define affordability. For example, if the cost of electricity from grids is around ₹ 5 per kWh and same is around ₹10 per kWh for the solar micro-grids, it is quite evident what the rural communities will prefer over the long term from pure cost perspective. There is a need for standardization of affordability as a principle within electricity access, along with making concessions for poorer communities to enable energy access through OGS in not just facilitating access, but also consumption.

Second, the reliability of power supply through OGS requires more rigorous conceptualization, particularly in terms of hours of supply, adequacy and sufficiency. Surprisingly, the reliability for the lowest levels of consumption (where most of these OGS communities start) has been left completely undefined in the multi-tier energy access framework by the World Bank's Energy Sector Management Assistance Program (ESMAP) (M. Bhatia and Angelou 2015). There is a need to think to about reliability related problems within the OGS discourse, with stringent measures to create a

framework that will allow to measuring hours of supply, adequacy and sufficiency of energy service levels over longer periods of time.

Third, community engagement practices and procedures have to be given special attention in OGS related intervention and policies. Given how OGS materials and technology are embedded in the communities, the interaction between hard infrastructure (panels, controllers and batteries) and soft infrastructure (rules, regulations, O&M procedures) have to clearly established. Furthermore, these interactions must be monitored over a long term to understand how it evolves. The local capacity building has to be an on-going process instead of one-time activity as it will help establish baselines and integrate growing energy needs of the communities.

Importantly, there is a need to lay out what is that the OGS intends to achieve from a policy perspective. Is it a stop gap measure until grid arrives, or is it the intended long-term means of electrification? The uncertainty from the governments approach is not conducive for a non-state participation within the sector. For example, the governments aggressive move towards grid-expansion created a sense of uncertainty within private energy enterprises that built their business models catering to rural population with minimal or no access to electricity. Also, such approach led to the mini-grid policy never actually being adopted as government decided that grid is the way to go for rural electrification. Thus, there is clear need to establish long-term timelines for OGS projects in lines with governments vision, along with measures for energy service institutions

(either the community-based organization or private enterprise) to facilitate smooth functioning of both, hard and soft infrastructures.

5.2.3. Integration of OGS within national and state policy framework

The energy access strategies have to integrate a long-term vision of towards electrification in rural areas. National policymakers often face a large-scale hurdle in terms of achieving universal electrification as seen from the case in India. While India has achieved universal electrification, continuous and reliable power supply still remains an elusive goal for the government. The application of decentralized renewable energy like OGS can possibly provide achieve such a goal but would require strategic approach from all stakeholders. While government is a dominant player in creating pathways for energy access for the country, the non-sate actors will have to be incentivized towards extending OGS as effective means of electrification in rural areas. In addition, the governments cannot look at OGS with just lighting approach but has to go beyond it. The need to integrate OGS with other sectors including health and livelihoods have emerged as critical intervention points in the last half a decade. The opportunities created for such integration will provide avenues to not just solve energy problems in India, but also to cater to sectors that depend upon on energy as critical input to provide essential basic services to rural communities.

The evolution of multiple stakeholders enabled a niche role for each of the actors. As against the earlier days of OGS in India, governments have to act as rather a facilitator than implementors of local projects through creating an implementation framework for

OGS actors. In addition, as OGS becomes more viable for other areas like livelihoods or health, the government has to work on creating a fully integrated policy ecosystem to facilitate smoother cross-functional co-ordination with other ministries (apart from MNRE). Similarly, the multilateral and bilateral institutions efforts will have to emerge as a large-scale mobilizer of finance and policy support for the use of decentralized renewables. These institutions at times can work with directly with governments in building capacities or with private energy enterprises in facilitating diffusion and scaling. Having said, there is need for to make sure such efforts are in lines with electrification plans of the government to further reduce the uncertainty and create a conducive ecosystem for development and integration OGS.

5.3. Limitations of this dissertation

As with any other research, this dissertation also suffers from few limitations, primarily related to methodology. Given how the dissertation was divided in part I (chapter 2), and part II (chapter 3 and 4), relying on multiple sources of data analyzed, it is ideal to discuss the limitations accordingly.

In part I, data availability served as a critical constraint. For example, the research could not find installations (either in number or capacity) for periods during 1980s, 1990s and early 2000s in an organized year-on-year manner. Also, there can be biases as the participants were asked to recall some of the narratives driving off-grid transitions during the early periods. The applicability of the findings from understanding of off-grid solar beyond Indian context is also another limitation as the study highlights many institutional

developments, which has dominantly been a characteristic of India. For example, India showcased niche innovations driven by state-led initiatives, which might not necessarily have same implications in other countries with similar problems of energy poverty. Thus, having multiple case-studies of off-grid transitions in different countries might improve external validity.

In part II, the generalizability of the findings from a particular case-study is critical limitation in the study. This emerged from the case-selection criteria for the exploring the objectives of part II of this dissertation. Firstly, the representativeness of the selected villages to the all the other villages in India electrified through solar micro-grids is not possible with this study. Furthermore, the three communities under study are a socially homogenous with most of them belonging to a particular tribal community, making comparisons or distinction between social groups a difficult proposition. Thus, the findings here lack the ability of extrapolation to communities in other villages in India. Similarly, the study also acknowledges different kind of DRE based models might lead to different type of results. For example, the model studied in this dissertation is based on a community operated solar micro-grids, which is a specific kind of DRE based energy intervention model. However, there are other models where energy enterprises own the systems and are responsible for the operation and maintenance. Hence, one might argue that the service delivery model designed by the organization in itself can be flawed in this case, thus presenting somewhat negative perception about the solar micro-grids. So, the results emerging from this particular case-study might not necessarily be applicable to other models of energy interventions. In practical sense, the knowledge produced here

can be difficult to replicate in other settings if similar such a case-study is not accurately described or picked for a study.

Other than above mentioned methodological limitations, this dissertation was also impacted by CoVID 19, which in ways disrupted the data collection process and created logistical challenges. For example, access to energy experts became limited as the interviews were conducted through either Zoom or Skype as against the initial plan to visit India to meet with experts in-person. Being embedded in organizations focusing on DREs and conducting such research while being in India could have added deeper insights to this work. Similarly, the plan to have additional case-study which could in way supplement the case-study of part II could not be undertaken either, thus making part II a single case-study adding to the methodological challenges outlined above.

5.4. Theoretical contribution of this study

This study has made some important contributions in terms of bringing the disciplines of socio-technical transition and energy justice together for understanding OGS in rural electrification. The dissertation, while examining the OGS transitions and its implication for just electrification in India has enriched some theoretical aspects of justice in energy transition in context of global south countries. First, the historical understanding of OGS transitions has often been weak link in literature, and insights from studying how rural electrification is achieved can strengthen the approaches towards studying other related energy transitions as well. The addition of narrative analysis to MLP in chapter two sheds light on the motivations various actors and institutions across spatial and temporal scales

towards development of OGS in India. For example, the studies involving MLP do not give much importance to transnational actors and narratives that influences transitions. In context of strong multi-lateral partnerships which today facilitates renewable energy projects across the global south countries, it will be important to understand such linkages as it has significant implications on how various aspects such as technology transfer or funding works in such contexts. Thus, extending the discussions of MLP through insights on how innovations can be pushed through governments, narrative analysis has added new perspectives to transition discourse.

Second, the need to integrate justice within socio-technical transition is a critical one as the societies move from a fossil fuel to low-carbon economy. Any such transitions must not to reproduce issues or marginalities that were created in the earlier efforts. For example, the ability of new technologies like decentralized renewable energy to not be able to sufficiently focus on intra-household capabilities or community dynamics in rural areas can infact dehumanize the energy transition efforts. The calls for including justice in transition is growing within policy making circles, and ability to understand how such transformations can be bought about through detailed case-study work can theoretically enhance our understanding of linkages between justice and socio-technical transitions. This dissertation effectively used capabilities approach to infact highlight the intra- and inter-households' dynamics of OGS in rural communities, and thus calling to add more capabilities centric approach to solar micro-grid development for rural electrification.

And lastly, this dissertation also effectively tries to bring in discussions around temporal nature of energy justice, particularly in relationship to OGS to the forefront. The temporal nature of energy justice is not just important from the perspective of the large infrastructural assemblages, but can also emerge from people's practices of small, decentralized energy systems. There are eventual shifts in terms of how people perceive technologies from the lens of their lived experiences makes energy justice a dynamic concept instead of a static one. What may have been fair yesterday may not necessarily be fair today or tomorrow. In case of OGS, we noticed such shifts in relatively few years period of projects, which also highlights that even smaller time frames are enough to highlight the temporal nature of energy justice. Questioning the OGS through temporality of socio-technical systems really highlighted the energy justice issues within decentralized approaches to electrification, thus making some important theoretical contributions in that regard.

5.5. Future Work

This dissertation calls for few areas of future research work to expand on the theoretical and empirical evidence emerging from the finding. From part I, two important areas of research are suggested. First, expanding the knowledge around the role of OGS as India moves forward with rural energization. While India has achieved total electrification at the household level, OGS are increasingly being used to support public services (water and primary healthcare, etc.) and livelihoods (small and medium enterprises and agriculture) in rural areas. While the current findings have touched upon the recent developments in chapter 2, how actors are conceptualizing the next phase of OGS needs

further investigation, particularly on the aspects of business and operational models, and financing of the sector. Similarly, there are needs to identify opportunities and challenges that next phase of OGS might bring including identifying synergies and trade-offs. For example, techno-economic analysis indicates that OGS technologies like solar irrigation might not necessarily be much of benefit (Bassi 2018). Adding detailed perspective to emerging debates of OGS will be necessary for furthering the knowledge in this sector for effective policy-making. And second, studies on OGS should expand beyond India to identify the factors enabling or inhibiting transitions. Similar case examples from other global south countries can be studied to understand – (a) role of various actors and narratives in facilitating off-grid development and diffusion; and (b) emerging cross-spatial linkages including niche-regime-landscape interactions across domains such as research, finance and deployment for OGS. This will not just improve our understanding of the efforts of various countries in global south towards universal electrification, but also can provide theoretical insights to the MLP literature on pro-poor frugal innovations, which often flies under the radar within larger socio-technical energy systems scholarship.

Similar to part I, the insights from part II also call for two future areas of research. First, it is essential to build on the finding observed in chapter 3 and 4 by including case studies from other initiatives in India at a similar scale with varied demographics. As mentioned before, the findings emerge from one case study of community operated SMG in three villages in Maharashtra. This approach can be taken to study such other models (such as service from private enterprises) in India and or similar initiatives other global south

countries. It will add depth to the discourse energy poverty in global south countries by conceptualizing the capabilities and justice beyond this one case-study to broaden the contribution of OGS. Second, further investigation is needed to understand the debates around capabilities and justice beyond local energy initiatives, and its inclusion with larger OGS transition paradigms are levels of government policies and international frameworks like Agenda 2030 or Paris Agreement. This will be critical in producing evidence-based research for policy-based decision making.

REFERENCES

Acharya, Rajesh H., and Anver C. Sadath. 2019. "Energy Poverty and Economic Development: Household-Level Evidence from India." *Energy and Buildings* 183: 785–91. https://doi.org/10.1016/j.enbuild.2018.11.047.

Agrawal, A, A Kumar, and T.J Rao. 2019. "100% Rural Electrification in India: Myth or Reality?" In *Energy, Environment and Globalization: Recent Trends, Opportunities and Challenges in India*, edited by Anshuman Gupta and Narendra Dalei. Springer, Singapore.

Ahluwalia, Montek Singh. 1986. "Balance-of-Payments Adjustment 1970-71 to 1983-84." *World Development* 14 (8): 937–62.

Aklin, M., Patrick Bayer, S. P. Harish, and Johannes Urpelainen. 2017. "Does Basic Energy Access Generate Socioeconomic Benefits? A Field Experiment with off-Grid Solar Power in India." *Science Advances* 3 (5): 1–9. https://doi.org/10.1126/sciadv.1602153.

Aklin, M., Chao Yo Cheng, and Johannes Urpelainen. 2018. "Social Acceptance of New Energy Technology in Developing Countries: A Framing Experiment in Rural India." *Energy Policy* 113 (May 2017): 466–77. https://doi.org/10.1016/j.enpol.2017.10.059.

Alkire, Sabina. 2005. "Why the Capability Approach?" *Journal of Human Development* 6 (1): 115–35. https://doi.org/10.1080/146498805200034275.

Alstone, Peter, Dimitry Gershenson, and Daniel M Kammen. 2015. "Decentralized Energy Systems for Clean Electricity Access." *Nature Climate Change* 5 (4): 305–14. https://doi.org/10.1038/nclimate2512.

Ariztia, Tomas, and Felipe Raglianti. 2020. "The Material Politics of Solar Energy: Exploring Diverse Energy Ecologies and Publics in the Design, Installation, and Use of off-Grid Photovoltaics in Chile." *Energy Research and Social Science* 69 (June): 101540. https://doi.org/10.1016/j.erss.2020.101540.

Arnaiz, M., T. A. Cochrane, R. Hastie, and C. Bellen. 2018. "Micro-Hydropower Impact on Communities' Livelihood Analysed with the Capability Approach." *Energy for Sustainable Development* 45: 206–10. https://doi.org/10.1016/j.esd.2018.07.003.

Azam, Mehtabul, and Geeta Gandhi Kingdon. 2013. "Are Girls the Fairer Sex in India? Revisiting Intra-Household Allocation of Education Expenditure." *World Development* 42 (1): 143–64. https://doi.org/10.1016/j.worlddev.2012.09.003.

Aziz, Shakila, and Shahriar Ahmed Chowdhury. 2021. "Determinants of Off-Grid

Electrification Choice and Expenditure: Evidence from Bangladesh." *Energy* 219: 119578. https://doi.org/10.1016/j.energy.2020.119578.

Baker, Erin, Destenie Nock, Todd Levin, Samuel A. Atarah, Anthony Afful-Dadzie, David Dodoo-Arhin, Léonce Ndikumana, Ekundayo Shittu, Edwin Muchapondwa, and Charles Van Hein Sackey. 2021. "Who Is Marginalized in Energy Justice? Amplifying Community Leader Perspectives of Energy Transitions in Ghana." *Energy Research and Social Science* 73 (May 2020). https://doi.org/10.1016/j.erss.2021.101933.

Banerjee, Sudeshna Ghosh, Douglas Barnes, Bipul Singh, Mayer Kristy, and Hussain Samad. 2015. "Power for All: Electricity Access Challenge in India." Washington, DC: World Bank.

Basu, K. 1987. "Achievements, Capabilities and the Concept of Well-Being." *Social Choice and Welfare* 4 (1): 69–76. https://doi.org/10.1007/bf00433957.

Baurzhan, Saule, and Glenn P. Jenkins. 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: 1405–18. https://doi.org/10.1016/j.rser.2016.03.016.

Bertheau, Paul, Josephine Dionisio, Clara Jütte, and Clarisse Aquino. 2020. "Challenges for Implementing Renewable Energy in a Cooperative-Driven off-Grid System in the Philippines." *Environmental Innovation and Societal Transitions* 35 (September 2018): 333–45. https://doi.org/10.1016/j.eist.2019.03.002.

Bhamidipati, P.L., 2019. Actors, Agency and Politics in Sustainability Transitions: Evolution of the solar PV market in East Africa. PhD Thesis. Technical University of Denmark.

Bhatia, M, and N Angelou. 2015. "Beyond Connections: Energy Access Redefined." Conceptualization Report 008/15, Energy Sector Management Assistance Program (ESMAP) of the World Bank Group, Washington D.C.

Bhatia, Ramesh. 1987. "Institutional Aspects of Promoting Renewable Energy Technologies in India." WEP2-22/WP177. Technology and Employment Programme Working Paper. Geneva, Switzerland.

Bhattacharya, T K. 1982. "Solar Photovoltaics: An Indian." *Solar Cells* 6: 251–62.

Bhattacharyya, S. C., and D. Palit. 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 (February): 110792. https://doi.org/10.1016/j.rser.2021.110792.

Bhattacharyya, Subhes C. 2006. “Energy Access Problem of the Poor in India: Is Rural Electrification a Remedy?” *Energy Policy* 34 (18): 3387–97. https://doi.org/10.1016/j.enpol.2005.08.026.

Bhattacharyya, Subhes C. 2014. “Viability of Off-Grid Electricity Supply Using Rice Husk: A Case Study from South Asia.” *Biomass and Bioenergy* 68 (0): 44–54. https://doi.org/10.1016/j.biombioe.2014.06.002.

Bhattacharyya, Subhes C., and Chinmoy Jana. 2009. “Renewable Energy in India: Historical Developments and Prospects.” *Energy* 34: 1169–83. https://doi.org/10.1016/j.energy.2008.10.017.

Bhattacharyya, Subhes C., Debajit Palit, Gopal K. Sarangi, Vivek Srivastava, and Prerna Sharma. 2019. “Solar PV Mini-Grids versus Large-Scale Embedded PV Generation: A Case Study of Uttar Pradesh (India).” *Energy Policy* 128 (October 2017): 36–44. https://doi.org/10.1016/j.enpol.2018.12.040.

Bhushan, Chandra, and Joel Kumar. 2012. “Going Remote: Re-Inventing the off-Grid Solar Revolution for Clean Energy for All.” Centre for Science and Environment. New Delhi, India.

Bickerstaff, Karen, Gordon Walker, and Harriet Bulkeley. 2013. *Energy Justice in a Changing Climate: Social Equity and Low-Carbon Energy*. Zed Books.

Bisaga, I., 2018. 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. University College London.

Bisaga, Iwona, and Priti Parikh. 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 (September 2017): 293–303. https://doi.org/10.1016/j.erss.2018.05.019.

Blair, Erik. 2015. “A Reflexive Exploration of Two Qualitative Data Coding Techniques.” *Journal of Methods and Measurement in the Social Sciences* 6 (1): 14. https://doi.org/10.2458/v6i1.18772.

BNEF. 2016. “Financing India’s Clean Energy Transition.” Bloomberg New Energy Finance.

Boamah, Festus, David Aled Williams, and Joana Afful. 2021. “Justifiable Energy Injustices? Exploring Institutionalised Corruption and Electricity Sector ‘Problem-Solving’ in Ghana and Kenya.” *Energy Research and Social Science* 73 (May

2020): 101914. https://doi.org/10.1016/j.erss.2021.101914.

Bouzarovski, Stefan. 2017. *Energy Poverty: (Dis)Assembling Europe's Infrastructural Divide*. *Energy Poverty: (Dis)Assembling Europe's Infrastructural Divide*. https://doi.org/10.1007/978-3-319-69299-9.

Brooks, Chris, and Tania Urmee. 2014. "Importance of Individual Capacity Building for Successful Solar Program Implementation: A Case Study in the Philippines." *Renewable Energy* 71: 176–84. https://doi.org/10.1016/j.renene.2014.05.016.

Byrne, Rob, Kennedy Mbeva, and David Ockwell. 2018. "A Political Economy of Niche-Building: Neoliberal-Developmental Encounters in Photovoltaic Electrification in Kenya." *Energy Research and Social Science* 44 (March): 6–16. https://doi.org/10.1016/j.erss.2018.03.028.

Byskov, Morten Fibieger. 2018. *The Capability Approach in Practice: A New Ethics for Setting Development Agendas*. New York: Routledge.

Census of India. 2001. "Census of India, 2001." New Delhi, India.

Census of India. 2011a. "Population Enumeration Data." 2011. http://www.censusindia.gov.in/2011census/population_enumeration.html.

Census of India. 2011b. "Sources of Lighting 2001-2011." New Delhi, India. http://censusindia.gov.in/2011census/hlo/Data_sheet/MP/Source_Lighting.pdf.

Chandran-Wadia, L, S.M. Deorah, S Nair, and A Lath. 2015. "Prospects for Electricity Access in Rural India Using Solar Photovoltaic Based Mini-Grid Systems." In *Decentralized Solutions for Developing Economies*, edited by Subhes C. Bhattacharyya, 53–64. Springer, Cham.

Chatterjee, Somdeep, and Debdatta Pal. 2021. "Is There Political Elite Capture in Access to Energy Sources? Evidence from Indian Households." *World Development* 140: 105288. https://doi.org/10.1016/j.worlddev.2020.105288.

Chaurey, Akanksha, and Tara C. Kandpal. 2009. "Carbon Abatement Potential of Solar Home Systems in India and Their Cost Reduction Due to Carbon Finance." *Energy Policy* 37 (1): 115–25. https://doi.org/10.1016/j.enpol.2008.07.038.

Chaurey, Akanksha, and Tara C. Kandpal. 2010. "Assessment and Evaluation of PV Based Decentralized Rural Electrification: An Overview." *Renewable and Sustainable Energy Reviews* 14 (8): 2266–78. https://doi.org/10.1016/j.rser.2010.04.005.

Choragudi, Sravanthi. 2013. "Off-Grid Solar Lighting Systems: A Way Align India's

Sustainable and Inclusive Development Goals." *Renewable and Sustainable Energy Reviews* 28: 890–99. https://doi.org/10.1016/j.rser.2013.08.028.

Chorghade, GP, M Barker, S Kanade, and CHD Fall. 2006. "Why Are Rural Indian Women so Thin? Findings from a Village in Maharashtra." *Public Health Nutrition* 9 (1): 9–18. https://doi.org/10.1079/phn2005762.

Cole, Peter. 2018. "Assessing the Impact of a Renewable Energy Programme in Bamyan, Afghanistan: The Value of a Capability Approach." *Energy for Sustainable Development* 45: 198–205. https://doi.org/10.1016/j.esd.2018.06.014.

Comello, Stephen D., Stefan J. Reichelstein, Anshuman Sahoo, and Tobias S. Schmidt. 2017. "Enabling Mini-Grid Development in Rural India." *World Development* 93: 94–107. https://doi.org/10.1016/j.worlddev.2016.12.029.

Creswell, J.W., 2014. Research Design. Qualitative, Quantitative, and Mixed Methods Approaches, 4th Editio. ed. SAGE Publications, Thousand Oaks, London, New Delhi.

Cross, Jamie. 2019. "No Current: Electricity and Disconnection in Rural India." In *Electrifying Anthropology: Exploring Electrical Practices and Infrastructures*, edited by Simone Abram, Brit Ross Winthereik, and Thomas Yarrow, 65–81. Routledge.

Cross, Jamie, and Declan Murray. 2018. "The Afterlives of Solar Power: Waste and Repair off the Grid in Kenya." *Energy Research and Social Science* 44 (August 2017): 100–109. https://doi.org/10.1016/j.erss.2018.04.034.

Crowe, S., Creswell, K., Robertson, A., Huby, G., Avery, A., Sheikh, A., 2011. The case study approach. BMC Med. Res. Methodol. 11.

Damgaard, Caroline, Darren McCauley, and Jed Long. 2017. "Assessing the Energy Justice Implications of Bioenergy Development in Nepal." *Energy, Sustainability and Society* 7 (1). https://doi.org/10.1186/s13705-017-0111-6.

Day, Rosie, Gordon Walker, and Neil Simcock. 2016. "Conceptualising Energy Use and Energy Poverty Using a Capabilities Framework." *Energy Policy* 93: 255–64. https://doi.org/10.1016/j.enpol.2016.03.019.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification on Employment : New Evidence from South Africa." *American Economic Association* 101 (7): 3078–3108.

Doukas, A, and A Ballesteros. 2015. "Clean Energy Access In Developing Countries: Perspectives On Policy and Regulation." 2. *Keys to Achieving Universal Energy Access Series*. Keys to Achieving Universal Energy Access Series. Washington, DC.

Dubash, N, and R Bradley. 2005. “Pathways to Rural Electrification in India: Are National Goals Also and International Opportunity.” In *Growing in the Greenhouse: Protecting the Climate by Putting Development First*, edited by R Bradley and K Baumert. Washington D.C.: World Resources Institute.

Enslev, Lea, Lykke Mirsal, and Brit Ross Winthereik. 2018. “Anticipatory Infrastructural Practices: The Coming of Electricity in Rural Kenya.” *Energy Research and Social Science* 44 (October 2017): 130–37. https://doi.org/10.1016/j.erss.2018.05.001.

ESMAP. 2019. “Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. Executive Summary.” Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/31926.

Fathoni, Hilman S., Abidah B. Setyowati, and James Prest. 2021. “Is Community Renewable Energy Always Just? Examining Energy Injustices and Inequalities in Rural Indonesia.” *Energy Research and Social Science* 71 (May 2020): 101825. https://doi.org/10.1016/j.erss.2020.101825.

Fell, Michael James. 2017. “Energy Services: A Conceptual Review.” *Energy Research and Social Science* 27: 129–40. https://doi.org/10.1016/j.erss.2017.02.010.

Fernández-Baldor Martínez, Á., A Boni Aristizábal, P Lillo Rodrigo, and A. Hueso. 2014. “Are Technological Projects Reducing Social Inequalities and Improving People’s Wellbeing? A Capability Approach Analysis of Renewable Energy Based Electrification Projects in Cajamarca, Peru.” *Journal of Human Development and Capabilities* 15 (1): 13–27. https://doi.org/10.1080/19452829.2013.837035.The.

Feron, Sarah, Harald Heinrichs, and Raul R. Cordero. 2016. “Sustainability of Rural Electrification Programs Based on Off-Grid Photovoltaic (PV) Systems in Chile.” *Energy, Sustainability and Society* 6 (1). https://doi.org/10.1186/s13705-016-0098-4.

Forman, Alister. 2017. “Energy Justice at the End of the Wire: Enacting Community Energy and Equity in Wales.” *Energy Policy* 107 (December 2016): 649–57. https://doi.org/10.1016/j.enpol.2017.05.006.

Fraser, Nancy. 1995. “From Redistribution to Recognition? Dilemmas of Justice in a ‘post-Socialist’ Age.” *New Left Review*.

Fraser, Nancy. 1998. “Social Justice in the Age of Identity Politics: Redistribution, Recognition, Participation.” FS I 98-108. WZB Discussion Paper. Berlin.

Fudge, Shane, Michael Peters, and Bridget Woodman. 2016. “Local Authorities as Niche Actors: The Case of Energy Governance in the UK.” *Environmental Innovation and Societal Transitions* 18: 1–17. https://doi.org/10.1016/j.eist.2015.06.004.

Fuller, Sara, and Darren McCauley. 2016. “Framing Energy Justice: Perspectives from Activism and Advocacy.” *Energy Research & Social Science* 11: 1–8. https://doi.org/10.1016/j.erss.2015.08.004.

Geels, F. W. 2005. “Processes and Patterns in Transitions and System Innovations: Refining the Co-Evolutionary Multi-Level Perspective.” *Technological Forecasting and Social Change* 72 (6 SPEC. ISS.): 681–96. https://doi.org/10.1016/j.techfore.2004.08.014.

Geels, Frank W. 2002. “Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study.” *Research Policy* 31 (8–9): 1257–74. https://doi.org/10.1016/S0048-7333(02)00062-8.

Geels, Frank W. 2004. “From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory.” *Research Policy* 33 (6–7): 897–920. https://doi.org/10.1016/j.respol.2004.01.015.

Geels, Frank W. 2010. “Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective.” *Research Policy* 39 (4): 495–510. https://doi.org/10.1016/j.respol.2010.01.022.

Geels, Frank W. 2012. “A Socio-Technical Analysis of Low-Carbon Transitions: Introducing the Multi-Level Perspective into Transport Studies.” *Journal of Transport Geography* 24: 471–82. https://doi.org/10.1016/j.jtrangeo.2012.01.021.

Geels, Frank W. 2014. “Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective.” *Theory, Culture & Society* 31 (5): 21–40. https://doi.org/10.1177/0263276414531627.

Geels, Frank W. 2019. “Socio-Technical Transitions to Sustainability: A Review of Criticisms and Elaborations of the Multi-Level Perspective.” *Current Opinion in Environmental Sustainability* 39: 187–201. https://doi.org/10.1016/j.cosust.2019.06.009.

Geels, Frank W., Florian Kern, Gerhard Fuchs, Nele Hinderer, Gregor Kungl, Josephine Mylan, Mario Neukirch, and Sandra Wassermann. 2016. “The Enactment of Socio-Technical Transition Pathways: A Reformulated Typology and a Comparative Multi-Level Analysis of the German and UK Low-Carbon Electricity Transitions (1990-2014).” *Research Policy* 45 (4): 896–913. https://doi.org/10.1016/j.respol.2016.01.015.

Geels, Frank W., and Johan Schot. 2007a. “Typology of Sociotechnical Transition Pathways.” *Research Policy* 36 (3): 399–417.

https://doi.org/10.1016/j.respol.2007.01.003.

Geels, Frank W., and Johan Schot. 2007b. “Typology of Sociotechnical Transition Pathways.” *Research Policy* 36 (3): 399–417. https://doi.org/10.1016/j.respol.2007.01.003.

Geels, Frank W., Benjamin Sovacool, Tim Schwanen, and Steve Sorrell. 2017. “The Socio-Technical Dynamics of Low-Carbon Transitions.” *Joule* 1 (3): 463–79. https://doi.org/10.1016/j.joule.2017.09.018.

Genus, Audley, and Anne Marie Coles. 2008. “Rethinking the Multi-Level Perspective of Technological Transitions.” *Research Policy* 37 (9): 1436–45. https://doi.org/10.1016/j.respol.2008.05.006.

GNESD. 2014. “Renewable Energy-Based Rural Electrification: The Mini-Grid Experience from India.” New Delhi.

Graff, Michelle, Sanya Carley, and Maureen Pirog. 2019. “A Review of the Environmental Policy Literature from 2014 to 2017 with a Closer Look at the Energy Justice Field.” *Policy Studies Journal* 47 (S1): S17–44. https://doi.org/10.1111/psj.12316.

Groh, Sebastian. 2014. “The Role of Energy in Development Processes-The Energy Poverty Penalty: Case Study of Arequipa (Peru).” *Energy for Sustainable Development* 18 (1): 83–99. https://doi.org/10.1016/j.esd.2013.12.002.

Gupta, Srishti, Eshita Gupta, and Gopal K. Sarangi. 2020. “Household Energy Poverty Index for India: An Analysis of Inter-State Differences.” *Energy Policy* 144 (June 2019): 111592. https://doi.org/10.1016/j.enpol.2020.111592.

Guruswamy, Lakshman. 2010. “Energy Justice and Sustainable Development.” *Colorado Journal of International Environmental Law and Policy*.

Haas, Tobias. 2019. “Comparing Energy Transitions in Germany and Spain Using a Political Economy Perspective.” *Environmental Innovation and Societal Transitions* 31 (October 2017): 200–210. https://doi.org/10.1016/j.eist.2018.11.004.

Hansen, Ulrich Elmer, and Ivan Nygaard. 2013. “Transnational Linkages and Sustainable Transitions in Emerging Countries: Exploring the Role of Donor Interventions in Niche Development.” *Environmental Innovation and Societal Transitions* 8: 1–19. https://doi.org/10.1016/j.eist.2013.07.001.

Harrington, Elise, Ameya Athavankar, and David Hsu. 2020. “Variation in Rural Household Energy Transitions for Basic Lighting in India.” *Renewable and Sustainable Energy Reviews* 119 (January 2019): 109568.

https://doi.org/10.1016/j.rser.2019.109568.

Harris, Tom, Mark Collinson, and Martin Wittenberg. 2017. “Aiming for a Moving Target: The Dynamics of Household Electricity Connections in a Developing Context.” *World Development* 97: 14–26. https://doi.org/10.1016/j.worlddev.2017.03.016.

Harriss-White, Barbara, Sunali Rohra, and Nigel Singh. 2009. “Political Architecture of India’s Technology System for Solar Energy.” *Economic and Political Weekly* 44 (47): 49–60.

Haum, Rudiger. 2014. “Mitigating Climate Change: An Additional Role for Technology and Policy in India as Well as International Arenas.” In *Evironmental and Climate Change in South and South East Asia*, 231–53. BRILL.

Heffron, Raphael J., Darren McCauley, and Benjamin Sovacool. 2015. “Resolving Society’s Energy Trilemma through the Energy Justice Metric.” *Energy Policy* 87: 168–76. https://doi.org/10.1016/j.enpol.2015.08.033.

Herington, M. J., E. van de Fliert, S. Smart, C. Greig, and P. A. Lant. 2017. “Rural Energy Planning Remains Out-of-Step with Contemporary Paradigms of Energy Access and Development.” *Renewable and Sustainable Energy Reviews* 67 (October 2016): 1412–19. https://doi.org/10.1016/j.rser.2016.09.103.

Hermwille, Lukas. 2016. “The Role of Narratives in Socio-Technical Transitions - Fukushima and the Energy Regimes of Japan, Germany, and the United Kingdom.” *Energy Research and Social Science* 11: 237–46. https://doi.org/10.1016/j.erss.2015.11.001.

Hillerbrand, Rafaela. 2018. “Why Affordable Clean Energy Is Not Enough. A Capability Perspective on the Sustainable Development Goals.” *Sustainability* 10 (7). https://doi.org/10.3390/su10072485.

Hiremath, R.B., Bimlesh Kumar, P. Balachandra, N.H. Ravindranath, and B.N. Raghunandan. 2009. “Decentralised Renewable Energy: Scope, Relevance and Applications in the Indian Context.” *Energy for Sustainable Development* 13 (1): 4–10. https://doi.org/10.1016/j.esd.2008.12.001.

Hurlbert, Margot, Mac Osazuwa-Peters, Kathleen McNutt, and Jeremy Rayner. 2020. “Transitioning from Coal: Toward a Renewables-Based Socio-Technical Regime in Saskatchewan.” *Environmental Innovation and Societal Transitions* 36 (November 2019): 321–30. https://doi.org/10.1016/j.eist.2019.11.005.

IEA. 2002. “World Energy Outlook.” Paris, France. https://doi.org/ceo871024 [pii].

IEA. 2017a. “Southeast Asia Energy Outlook 2017 - World Energy Outlook Special Report.” International Energy Agency. Paris, France.

IEA. 2017b. “World Energy Outlook 2017.” International Energy Agency, Paris, France. http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/.

IEA. 2020. “India 2020: Energy Policy Review.” International Energy Agency. Paris, France.

Ikejemba, Eugene C.X., Peter B. Mpuan, Peter C. Schuur, and Jos Van Hillegersberg. 2017. “The Empirical Reality & Sustainable Management Failures of Renewable Energy Projects in Sub-Saharan Africa (Part 1 of 2).” *Renewable Energy* 102: 234–40. https://doi.org/10.1016/j.renene.2016.10.037.

IRENA. 2018. “Polcies and Regulations for Renewable Energy Mini-Grids.” International Renewable Energy Agency. Abu Dhabi.

Jacome, Veronica, and Isha Ray. 2018. “The Prepaid Electric Meter: Rights, Relationships and Reification in Unguja, Tanzania.” *World Development* 105: 262–72. https://doi.org/10.1016/j.worlddev.2018.01.007.

Jenkins, Kirsten. 2018. “Setting Energy Justice Apart from the Crowd: Lessons from Environmental and Climate Justice.” *Energy Research and Social Science* 39 (September 2017): 117–21. https://doi.org/10.1016/j.erss.2017.11.015.

Jenkins, Kirsten, Darren McCauley, and Alister Forman. 2017. “Energy Justice: A Policy Approach.” *Energy Policy* 105 (February): 631–34. https://doi.org/10.1016/j.enpol.2017.01.052.

Jenkins, Kirsten, Darren McCauley, Raphael Heffron, Hannes Stephan, and Robert Rehner. 2016. “Energy Justice: A Conceptual Review.” *Energy Research and Social Science* 11: 174–82. https://doi.org/10.1016/j.erss.2015.10.004.

Jenkins, Kirsten, Benjamin K. Sovacool, and Darren McCauley. 2018. “Humanizing Sociotechnical Transitions through Energy Justice: An Ethical Framework for Global Transformative Change.” *Energy Policy* 117 (March): 66–74. https://doi.org/10.1016/j.enpol.2018.02.036.

Jepson, Wendy, Jessica Budds, Laura Eichelberger, Leila Harris, Emma Norman, Kathleen O’Reilly, Amber Pearson, et al. 2017. “Advancing Human Capabilities for Water Security: A Relational Approach.” *Water Security* 1: 46–52. https://doi.org/10.1016/j.wasec.2017.07.001.

Joshi, Gaurav, and Komali Yenneti. 2020. “Community Solar Energy Initiatives in India:

A Pathway for Addressing Energy Poverty and Sustainability?" *Energy and Buildings* 210: 109736. https://doi.org/10.1016/j.enbuild.2019.109736.

Joshi, Lalita, Deepak Choudhary, Praveen Kumar, Jayendran Venkateswaran, and Chetan S. Solanki. 2019. "Does Involvement of Local Community Ensure Sustained Energy Access? A Critical Review of a Solar PV Technology Intervention in Rural India." *World Development* 122: 272–81. https://doi.org/10.1016/j.worlddev.2019.05.028.

Katre, Aparna, and Arianna Tozzi. 2019. "Using Hugs, Carrots and Sticks: How Agents Exercise Power in the Transition to Community-Owned Energy Systems in Remote India." *Energy Research and Social Science* 54 (July 2018): 129–39. https://doi.org/10.1016/j.erss.2019.04.008.

Katre, Aparna, Arianna Tozzi, and Subhes Bhattacharyya. 2019. "Sustainability of Community-Owned Mini-Grids: Evidence from India." *Energy, Sustainability and Society* 9 (1). https://doi.org/10.1186/s13705-018-0185-9.

Khandker, Shahidur R., Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes. 2014. "Who Benefits Most from Rural Electrification? Evidence in India." *The Energy Journal* 35 (2).

Kraft, J., and A. Kraft. 1978. "On the Relationship between Energy and GNP." *Journal of Energy Development* 3 (3): 401–3.

Krithika, P R, and Debajit Palit. 2011. "Review of Alternative Participatory Business Models for Off-Grid Electricity Services." The Energy and Resources Institute. New Delhi, India.

Kruger, Ruth, and Darren McCauley. 2020. "Energy Justice, Hydropower and Grid Systems in the Global South." In *Energy Justice Across Borders*, edited by Gunter Bombaerts, Kirsten Jenkins, Yekeen A. Sanusi, and Wang Guoyu, 91–110. https://doi.org/10.1007/978-3-030-24021-9.

Kumar, A., 2015. Energy Access in an Era of Low Carbon Transitions: Politicising Energy for Development Projects in India. Durham University.

Kumar, Ankit. 2018. "Justice and Politics in Energy Access for Education, Livelihoods and Health: How Socio-Cultural Processes Mediate the Winners and Losers." *Energy Research & Social Science* 40: 3–13. https://doi.org/10.1016/j.erss.2017.11.029.

Kumar, Ankit. 2019. "Beyond Technical Smartness: Rethinking the Development and Implementation of Sociotechnical Smart Grids in India." *Energy Research and Social Science* 49 (September 2018): 158–68. https://doi.org/10.1016/j.erss.2018.10.026.

Lacey-Barnacle, M., R. Robison, and C. Foulds. 2020. “Energy Justice in the Developing World: A Review of Theoretical Frameworks, Key Research Themes and Policy Implications.” *Energy for Sustainable Development* 55: 122–38. https://doi.org/10.1016/j.esd.2020.01.010.

Lam, Nicholas L, Yanju Chen, Cheryl Weyant, Chandra Venkataraman, Pankaj Sadavarte, Michael a. Johnson, Kirk R Smith, et al. 2012. “Household Light Makes Global Heat: High Black Carbon Emissions from Kerosene Wick Lamps.” *Environmental Science and Technology* 46 (24): 13531–38. https://doi.org/10.1021/es302697h.

Lam, Nicholas L, Kirk R Smith, Alison Gauthier, and Michael N. Bates. 2012a. “Kerosene: A Review of Household Uses and Their Hazards in Low- and Middle-Income Countries.” *Journal of Toxicology and Environmental Health. Part B, Critical Reviews* 15 (6): 396–432. https://doi.org/10.1080/10937404.2012.710134.

Lam, Nicholas L, Kirk R Smith, Alison Gauthier, and Michael N Bates. 2012b. “Kerosene : A Review Of Household Uses And Their Hazards In Low- And Middle-Income Countries.” *Journal of Toxicology and Environmental Health B Critical Review* 15: 396–432. https://doi.org/10.1080/10937404.2012.710134.KEROSENE.

Lenz, Luciane, Anicet Munyehirwe, Jörg Peters, and Maximiliane Sievert. 2017. “Does Large-Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda’s Electricity Access Roll-Out Program.” *World Development* 89: 88–110. https://doi.org/10.1016/j.worlddev.2016.08.003.

Levidow, Les, and Theo Papaioannou. 2016. “Policy-Driven, Narrative-Based Evidence Gathering: UK Priorities for Decarbonisation through Biomass.” *Science and Public Policy* 43 (1): 46–61. https://doi.org/10.1093/scipol/scv016.

Levin, Todd, and Valerie M. Thomas. 2016. “Can Developing Countries Leapfrog the Centralized Electrification Paradigm?” *Energy for Sustainable Development* 31: 97–107. https://doi.org/10.1016/j.esd.2015.12.005.

Lin, Tin-chi, and Alícia Adserà. 2013. “Son Preference and Children ’ s Housework :” *Population Research and Policy Review* 32: 553–84. https://doi.org/10.1007/s11113-013-9269-6.

López-González, A., L. Ferrer-Martí, and B. Domenech. 2019. “Long-Term Sustainability Assessment of Micro-Hydro Projects: Case Studies from Venezuela.” *Energy Policy* 131 (October 2018): 120–30. https://doi.org/10.1016/j.enpol.2019.04.030.

Ma, Siyuan, and Johannes Urpelainen. 2018. “Distributed Power Generation in National

Rural Electrification Plans: An International and Comparative Evaluation." *Energy Research and Social Science* 44 (April): 1–5. https://doi.org/10.1016/j.erss.2018.04.002.

Malakar, Yuwan. 2018. "Evaluating the Role of Rural Electrification in Expanding People's Capabilities in India." *Energy Policy* 114 (December 2017): 492–98. https://doi.org/10.1016/j.enpol.2017.12.047.

Malakar, Yuwan, and Rosie Day. 2020. "Differences in Firewood Users' and LPG Users' Perceived Relationships between Cooking Fuels and Women's Multidimensional Well-Being in Rural India." *Nature Energy* 5 (12): 1022–31. https://doi.org/10.1038/s41560-020-00722-4.

Mangotra, A.K. 2016. "Renewable Energy Scenario in India: Quest for an Appropriate Policy." *Renewable Energy Law and Policy Review* 7 (1): 30–43.

Markard, Jochen, Rob Raven, and Bernhard Truffer. 2012. "Sustainability Transitions: An Emerging Field of Research and Its Prospects." *Research Policy* 41 (6): 955–67. https://doi.org/10.1016/j.respol.2012.02.013.

Martinot, E, a. Cabraal, and S. Mathur. 2001. "World Bank/GEF Solar Home System Projects: Experiences and Lessons Learned 1993-2000." *Renewable & Sustainable Energy Reviews* 5 (1): 39–57. https://doi.org/10.1016/S1364-0321(00)00007-1.

McCauley, Darren, Antje Brown, Robert Rehner, Raphael Heffron, and Shashi van de Graaff. 2018. "Energy Justice and Policy Change: An Historical Political Analysis of the German Nuclear Phase-Out." *Applied Energy* 228 (June): 317–23. https://doi.org/10.1016/j.apenergy.2018.06.093.

McCauley, Darren, Raphael J. Heffron, Hannes Stephan, and Kirsten Jenkins. 2013. "Advancing Energy Justice: The Triumvirate of Tenets." *International Energy Law Review* 32 (3): 107–10.

Menghwani, Vikas, Hisham Zerriffi, Alexandros Korkovelos, Babak Khavari, Andreas Sahlberg, Mark Howells, and Dimitris Mentis. 2020. "Planning with Justice: Using Spatial Modelling to Incorporate Justice in Electricity Pricing – The Case of Tanzania." *Applied Energy* 264 (August 2019): 114749. https://doi.org/10.1016/j.apenergy.2020.114749.

Middlemiss, Lucie, Pepa Ambrosio-Albalá, Nick Emmel, Ross Gillard, Jan Gilbertson, Tom Hargreaves, Caroline Mullen, Tony Ryan, Carolyn Snell, and Angela Tod. 2019. "Energy Poverty and Social Relations: A Capabilities Approach." *Energy Research and Social Science* 55 (September 2018): 227–35. https://doi.org/10.1016/j.erss.2019.05.002.

Miller, Damian. 2009. *Selling Solar: The Diffusion of Renewable Energy in Emerging Markets*. London, UK: Earthscan.

Miller, Damian, and Chris Hope. 2000. "Learning to Lend for Off-Grid Solar Power: Policy Lessons from World Bank Loans to India, Indonesia, and Sri Lanka." *Energy Policy* 28 (2): 87–105. https://doi.org/10.1016/S0301-4215(99)00071-3.

Millinger, M., T. Mårlind, and E. O. Ahlgren. 2012. "Evaluation of Indian Rural Solar Electrification: A Case Study in Chhattisgarh." *Energy for Sustainable Development* 16 (4): 486–92. https://doi.org/10.1016/j.esd.2012.08.005.

MNRE. 2009. "Annual Report 2008-2009." Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2010a. "Annual Report 2009-2010." Ministry of New and Renewable Energy. New Delhi.

MNRE. 2010b. "Solar Lantern Program." Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2011. "Annual Report 2010-2011." Ministry of New and Renewable Energy. New Delhi, India. http://mnre.gov.in/file-manager/annual-report/2010-2011/EN/Chapter 6/chapter 6.htm.

MNRE. 2012a. "Annual Report 2011-2012." Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2012b. "Jawaharlal Nehru National Solar Mission, Phase II – Policy Document." Vol. 201. Ministry of New and Renewable Energy, New Delhi. https://doi.org/10.1007/978-81-322-2337-5_3.

MNRE. 2013. "Annual Report 2012-2013." Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2014. "Annual Report 2013-2014." Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2015. "Annual Report 2014-2015." Ministry of New and Renewable Energy. New Delhi.

MNRE. 2016. "Annual Report 2015-2016." Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2017. "Annual Report 2016-2017." Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2018. “Annual Report 2017-2018.” Ministry of New and Renewable Energy. New Delhi, India.

MNRE. 2019. “Annual Report 2018-2019.” Ministry of New and Renewable Energy. New Delhi, India.

Moallemi, Enayat A., Fjalar de Haan, Jan Kwakkel, and Lu Aye. 2017. “Narrative-Informed Exploratory Analysis of Energy Transition Pathways: A Case Study of India’s Electricity Sector.” *Energy Policy* 110 (August): 271–87. https://doi.org/10.1016/j.enpol.2017.08.019.

Moezzi, Mithra, Kathryn B. Janda, and Sea Rotmann. 2017. “Using Stories, Narratives, and Storytelling in Energy and Climate Change Research.” *Energy Research and Social Science* 31 (May): 1–10. https://doi.org/10.1016/j.erss.2017.06.034.

Mohan, Aniruddh, and Kilian Topp. 2018. “India’s Energy Future: Contested Narratives of Change.” *Energy Research and Social Science* 44 (January): 75–82. https://doi.org/10.1016/j.erss.2018.04.040.

Moharil, Ravindra M., and Prakash S. Kulkarni. 2009. “A Case Study of Solar Photovoltaic Power System at Sagardeep Island, India.” *Renewable and Sustainable Energy Reviews* 13 (3): 673–81. https://doi.org/10.1016/j.rser.2007.11.016.

Moniruzzaman, Md, and Rosie Day. 2020. “Gendered Energy Poverty and Energy Justice in Rural Bangladesh.” *Energy Policy* 144 (April): 111554. https://doi.org/10.1016/j.enpol.2020.111554.

Monyei, Chukwuka G., Lukumon O. Oyedele, Olugbenga O. Akinade, Anuoluwapo O. Ajayi, and Xiaojun J. Luo. 2019. “Benchmarks for Energy Access: Policy Vagueness and Incoherence as Barriers to Sustainable Electrification of the Global South.” *Energy Research and Social Science* 54 (December 2018): 113–16. https://doi.org/10.1016/j.erss.2019.04.005.

Morse, J.M. 1995. “The Significance of Saturation.” *Qualitative Health Research* 5 (2): 147–49.

Moulik, T.K. 1988. “Energy and Development Options: The Case of India.” *The Journal of Energy and Development* 13 (2): 239–73.

Müggenburg, Hannah, Annika Tillmans, Petra Schweizer-Ries, Tim Raabe, and Peter Adelmann. 2012. “Social Acceptance of PicoPV Systems as a Means of Rural Electrification — A Socio-Technical Case Study in Ethiopia.” *Energy for Sustainable Development* 16 (1): 90–97. https://doi.org/10.1016/j.esd.2011.10.001.

Muhoza, Cassilde, and Oliver W. Johnson. 2018. “Exploring Household Energy Transitions in Rural Zambia from the User Perspective.” *Energy Policy* 121 (January): 25–34. https://doi.org/10.1016/j.enpol.2018.06.005.

Mulvaney, Dustin. 2014. “Are Green Jobs Just Jobs? Cadmium Narratives in the Life Cycle of Photovoltaics.” *Geoforum* 54: 178–86. https://doi.org/10.1016/j.geoforum.2014.01.014.

Mundaca, Luis, Henner Busch, and Sophie Schwer. 2018. “‘Successful’ Low-Carbon Energy Transitions at the Community Level? An Energy Justice Perspective.” *Applied Energy* 218 (March): 292–303. https://doi.org/10.1016/j.apenergy.2018.02.146.

Munro, Paul, Greg van der Horst, and Stephen Healy. 2017. “Energy Justice for All? Rethinking Sustainable Development Goal 7 through Struggles over Traditional Energy Practices in Sierra Leone.” *Energy Policy* 105 (November 2016): 635–41. https://doi.org/10.1016/j.enpol.2017.01.038.

Murthy, M.R.L.N. 2001. “PV Promotion in Developing Countries by World Bank and Other International Organisations.” *Solar Energy Materials and Solar Cells* 67 (1–4): 629–37. https://doi.org/10.1016/S0927-0248(00)00335-4.

Muyanja, D., J. G. Allen, J. Vallarino, L. Valeri, B. Kakuhikire, D. R. Bangsberg, D. C. Christiani, A. C. Tsai, and P. S. Lai. 2017. “Kerosene Lighting Contributes to Household Air Pollution in Rural Uganda.” *Indoor Air* 27 (5): 1022–29. https://doi.org/10.1111/ina.12377.

Ngowi, Joseph M., Lennart Bångens, and Erik O. Ahlgren. 2019. “Benefits and Challenges to Productive Use of Off-Grid Rural Electrification: The Case of Mini-Hydropower in Bulongwa-Tanzania.” *Energy for Sustainable Development* 53: 97–103. https://doi.org/10.1016/j.esd.2019.10.001.

Numminen, Sini, and Peter D. Lund. 2019. “Evaluation of the Reliability of Solar Micro-Grids in Emerging Markets – Issues and Solutions.” *Energy for Sustainable Development* 48: 34–42. https://doi.org/10.1016/j.esd.2018.10.006.

Nussbaum, Martha C. 2011. *Creating Capabilities: The Human Development Approach*. Cambridge, Massachusetts: Harvard University Press. https://doi.org/10.1080/13691457.2012.705970.

Nussbaum, Martha C., and Amartya Sen. 1993. *The Quality of Life*. Oxford University Press.

Ouedraogo, Nadia S. 2013. “Energy Consumption and Human Development: Evidence from a Panel Cointegration and Error Correction Model.” *Energy* 63: 28–41.

https://doi.org/10.1016/j.energy.2013.09.067.

Palit, Debajit. 2013. “Solar Energy Programs for Rural Electrification: Experiences and Lessons from South Asia.” *Energy for Sustainable Development* 17 (3): 270–79. https://doi.org/10.1016/j.esd.2013.01.002.

Palit, Debajit, and Kaushik Ranjan Bandyopadhyay. 2017. “Rural Electricity Access in India in Retrospect: A Critical Rumination.” *Energy Policy* 109 (January): 109–20. https://doi.org/10.1016/j.enpol.2017.06.025.

Palit, Debajit, Gopal K. Sarangi, and P.R. Krithika. 2014. “Energising Rural India Using Distributed Generation: The Case of Solar Mini-Grids in Chhattisgarh State, India.” In *Mini-Grids for Rural Electrification of Developing Countries: Analysis and Case Tudies from South Asia*, edited by S. C. Bhattacharyya and Debajit Palit, 313–42. Springer, Cham.

Pandey, Poonam, and Aviram Sharma. 2021. “Knowledge Politics, Vulnerability and Recognition-Based Justice: Public Participation in Renewable Energy Transitions in India.” *Energy Research and Social Science* 71 (May 2020): 101824. https://doi.org/10.1016/j.erss.2020.101824.

Peter, Raja, B Ramaseshan, and C V Nayar. 2002. “Conceptual Model for Marketing Solar Based Technology to Developing Countries.” *Renewable Energy* 25 (4): 511–24. https://doi.org/http://dx.doi.org/10.1016/S0960-1481(01)00080-5.

Phillips, Jon, and Peter Newell. 2013. “The Governance of Clean Energy in India : The Clean Development Mechanism (CDM) and Domestic Energy Politics.” *Energy Policy* 59: 654–62. https://doi.org/10.1016/j.enpol.2013.04.019.

PIB. 2011. “PM Launches Jawaharlal Nehru National Solar Mission – Solar India.” 2011.

Pilloni, Martina, Tareq Abu Hamed, and Sharon Joyce. 2020. “Assessing the Success and Failure of Biogas Units in Israel: Social Niches, Practices, and Transitions among Bedouin Villages.” *Energy Research and Social Science* 61 (November 2019): 101328. https://doi.org/10.1016/j.erss.2019.101328.

Planning Commission. 1980. “Sixth Five Year Plan 1980-85.” Government of India, New Delhi.

Plutshack, Victoria, Subhanjan Sengupta, Arunaditya Sahay, and Jorge E. Viñuales. 2019. “New and Renewable Energy Social Enterprises Accessing Government Support: Findings from India.” *Energy Policy* 132 (July 2018): 367–78. https://doi.org/10.1016/j.enpol.2019.05.009.

Pokhrel, Amod K., Michael N. Bates, Sharat C. Verma, Hari S. Joshi, Chandrashekhar T.

Sreeramareddy, and Kirk R Smith. 2009. “Tuberculosis and Indoor Biomass and Kerosene Use in Nepal: A Case–Control Study.” *Environmental Health Perspectives* 118 (4): 558–64. https://doi.org/10.1289/ehp.0901032.

Purohit, Pallav. 2009. “CO2 Emissions Mitigation Potential of Solar Home Systems under Clean Development Mechanism in India.” *Energy* 34 (8): 1014–23. https://doi.org/10.1016/j.energy.2008.11.009.

Rajagopalan, Sushil. 2021. “Who Benefits and How? A Capabilities Perspective on Solar Micro-Grids in India.” *Journal of Human Development and Capabilities* 0 (0): 1–20. https://doi.org/10.1080/19452829.2021.1901671.

Ramos-Mejía, Mónica, Maria-laura Franco-garcia, and Juan M Jauregui-becker. 2018. “Sustainability Transitions in the Developing World : Challenges of Socio-Technical Transformations Unfolding in Contexts of Poverty.” *Environmental Science and Policy* 84 (March 2017): 217–23. https://doi.org/10.1016/j.envsci.2017.03.010.

Rao, Nitya. 2012. “Male ‘providers’ and Female ‘Housewives’: A Gendered Co-Performance in Rural North India.” *Development and Change* 43 (5): 1025–48. https://doi.org/10.1111/j.1467-7660.2012.01789.x.

Rao, P. Sharath Chandra, Jeffrey B. Miller, Young Doo Wang, and John B. Byrne. 2009. “Energy-Microfinance Intervention for below Poverty Line Households in India.” *Energy Policy* 37: 1694–1712. https://doi.org/10.1016/j.enpol.2008.12.039.

Rao, Shobha, Medha Gokhale, and Asawari Kanade. 2008. “Energy Costs of Daily Activities for Women in Rural India.” *Public Health Nutrition* 11 (2): 142–50. https://doi.org/10.1017/S1368980007000055.

Raskind, Ilana G., Shailaja S. Patil, Nikhil Tandon, Sharanya Thummalapally, Michael R. Kramer, and Solveig A. Cunningham. 2020. “Household Chores or Play Outdoors? The Intersecting Influence of Gender and School Type on Physical Activity Among Indian Adolescents.” *Health Education and Behavior* 47 (5): 682–91. https://doi.org/10.1177/1090198120931040.

Rathore, Pushpendra Kumar Singh, Durg Singh Chauhan, and Rudra Pratap Singh. 2019. “Decentralized Solar Rooftop Photovoltaic in India: On the Path of Sustainable Energy Security.” *Renewable Energy* 131: 297–307. https://doi.org/10.1016/j.renene.2018.07.049.

Rawls, John. 1971. *A Theory of Justice*. Cambridge, Massachusetts: Harvard University Press.

Rip, A, and R. Kemp. 1998. “Technological Change.” In *Human Choice and Climate*

Change, edited by S Rayner and E. L. Malone, 327–99. Battelle Press.

Roberts, Cameron, and Frank W. Geels. 2018. "Public Storylines in the British Transition from Rail to Road Transport (1896–2000): Discursive Struggles in the Multi-Level Perspective." *Science as Culture* 27 (4): 513–42. https://doi.org/10.1080/09505431.2018.1519532.

Robeyns, Ingrid. 2003. *Sen's Capability Approach and Gender Inequality: Selecting Relevant Capabilities*. *Feminist Economics*. Vol. 9. https://doi.org/10.1080/1354570022000078024.

Robeyns, Ingrid. 2017. *Wellbeing, Freedom and Social Justice*. Cambridge, UK: Open Book Publishers. https://doi.org/http://dx.doi.org/10.11647/OBP.0130.

Roe, Emery. 1994. *Narrative Policy Analysis: Theory and Practice*. Duke University Press.

Rogelj, Joeri, David L Mccollum, and Keywan Riahi. 2013. "The UN's 'Sustainable Energy for All' Initiative Is Compatible with a Warming Limit of 2°C." *Nature Climate Change* 3 (February): 1–7. https://doi.org/10.1038/NCLIMATE1806.

Rosenberg, Meital, Daniel Erian Armanios, Michaël Aklin, and Paulina Jaramillo. 2020. "Evidence of Gender Inequality in Energy Use from a Mixed-Methods Study in India." *Nature Sustainability* 3 (2): 110–18. https://doi.org/10.1038/s41893-019-0447-3.

Rosenbloom, Daniel, and James Meadowcroft. 2014. "The Journey towards Decarbonization: Exploring Socio-Technical Transitions in the Electricity Sector in the Province of Ontario (1885-2013) and Potential Low-Carbon Pathways." *Energy Policy* 65: 670–79. https://doi.org/10.1016/j.enpol.2013.09.039.

Rouse, E.D., Harrison, S.H., 2015. Triangulate and expand: Using multiple sources of data for convergence and expansion to enrich inductive theorizing, in: Elsbach, K., Kramer, R. (Eds.), Handbook of Qualitative Organizational Research. Routledge, New York, pp. 318–329.

Roy, Joyashree, and Sebak Jana. 1998. "Solar Lanterns for Rural Households." *Energy* 23 (1): 67–68. https://doi.org/10.1016/S0360-5442(97)00067-4.

Sadath, Anver C., and Rajesh H. Acharya. 2017. "Assessing the Extent and Intensity of Energy Poverty Using Multidimensional Energy Poverty Index: Empirical Evidence from Households in India." *Energy Policy* 102 (June 2016): 540–48. https://doi.org/10.1016/j.enpol.2016.12.056.

Samarakoon, Shanil. 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.

Sanusi, Y.A., and A. Spahn. 2020. “Exploring Marginalization and Exclusion in Renewable Energy Development in Africa: A Perspective from Western Individualism and African Ubuntu Philosophy.” In *Energy Justice Across Borders*, edited by Gunter Bombaerts, Kirsten E.H. Jenkins, Yekeen Sanusi, and Wang Guoyo. Cham, Switzerland: Springer Nature.

Sareen, Siddharth, and Håvard Haarstad. 2018. “Bridging Socio-Technical and Justice Aspects of Sustainable Energy Transitions.” *Applied Energy* 228 (October 2017): 624–32. https://doi.org/10.1016/j.apenergy.2018.06.104.

Schillebeeckx, Simon J.D., Priti Parikh, Rahul Bansal, and Gerard George. 2012. “An Integrated Framework for Rural Electrification: Adopting a User-Centric Approach to Business Model Development.” *Energy Policy* 48: 687–97. https://doi.org/10.1016/j.enpol.2012.05.078.

Schlosberg, David. 2003a. “The Justice of Environmental Justice: Reconciling Equity, Recognition, and Participation in a Political Movement.” In *Moral and Political Reasoning in Environmental Practice*, edited by Andrew Light and Avner De-Shalit, 125–56. London: MIT Press.

Schlosberg, David. 2003b. “The Justice of Environmental Justice: Reconciling Equity, Recognition, and Participation in a Political Movement.” In *Moral and Political Reasoning in Environmental Practice*, edited by Andrew Light and Anver De-Shalit, 125–56. London: MIT Press.

Schlosberg, David. 2004. “Reconceiving Environmental Justice: Global Movements and Political Theories.” *Environmental Politics* 13: 517–40.

Schlosberg, David. 2012. “Climate Justice and Capabilities: A Framework for Adaptation Policy.” *Ethics and International Affairs* 26 (4): 445–61. https://doi.org/10.1017/S0892679412000615.

Schlosberg, David, and David Carruthers. 2010. “Indigenous Struggles, Environmental Justice, and Community Capabilities.” *Global Environmental Politics* 10 (4): 12–35. https://doi.org/10.1162/GLEP_a_00029.

Sen, Amartya. 1979. “Equality of What?” In *The Tanner Lectures on Human Values*, edited by S McMurrin, 196–220. Salt Lake City: University of Utah Press. https://doi.org/10.4135/9781446215272.n5.

Sen, Amartya. 1990. “Justice: Means versus Freedoms.” *Philosophy & Public Affairs* 19

(2): 111–21.

Sen, Amartya. 1999. *Development As Freedom*. Oxford: Oxford University Press.

Sen, Amartya. 2009. “Capability: Reach and Limit.” In *Debating Global Society: Reach and Limits of the Capability Approach*, edited by Enrica Chiappero-Martinetti, 15–28. Milan: Fondazione Giangiacomo Feltrinelli.

Sen, Amartya K. 1997. “Income Inequality to Economic Inequality.” *Southern Economic Journal* 64 (2): 383–401.

Setyowati, Abidah B. 2021. “Mitigating Inequality with Emissions? Exploring Energy Justice and Financing Transitions to Low Carbon Energy in Indonesia.” *Energy Research and Social Science* 71: 101817. https://doi.org/10.1016/j.erss.2020.101817.

Sharma, Aviram. 2020. “‘We Do Not Want Fake Energy’: The Social Shaping of a Solar Micro-Grid in Rural India.” *Science, Technology and Society* 25 (2): 308–24. https://doi.org/10.1177/0971721820903006.

Sharma, Rohit, Deepak Choudhary, Praveen Kumar, Jayendran Venkateswaran, and Chetan Singh Solanki. 2019. “Do Solar Study Lamps Help Children Study at Night? Evidence from Rural India.” *Energy for Sustainable Development* 50: 109–16. https://doi.org/10.1016/j.esd.2019.03.005.

Shidore, Sarang, and Joshua W. Busby. 2019. “What Explains India’s Embrace of Solar? State-Led Energy Transition in a Developmental Polity.” *Energy Policy* 129 (March): 1179–89. https://doi.org/10.1016/j.enpol.2019.02.032.

Siddiqui, Shawahiq, and Sanjay Upadhyay. 2011. “Need for Integrated Policy and Institutional Framework for the Implementation of Jawaharlal Nehru National Solar Mission in Rural Areas.” New Delhi.

Singh, Abhigyan, Alex T. Strating, N. A. Romero Herrera, Hylke W. van Dijk, and David V. Keyson. 2017. “Towards an Ethnography of Electrification in Rural India: Social Relations and Values in Household Energy Exchanges.” *Energy Research and Social Science* 30 (June): 103–15. https://doi.org/10.1016/j.erss.2017.06.031.

Singh, Kartikeya. 2016. “Business Innovation and Diffusion of Off-Grid Solar Technologies in India.” *Energy for Sustainable Development* 30: 1–13. https://doi.org/10.1016/j.esd.2015.10.011.

Singh, Kartikeya. 2017. “Financing for Whom by Whom? Complexities of Advancing Energy Access in India.” CGD Policy Paper. Washington, DC. https://www.cgdev.org/sites/default/files/financing-whom-whom-complexities-

advancing-energy-access-india.pdf.

Smith, Adrian, and Rob Raven. 2012a. “What Is Protective Space ? Reconsidering Niches in Transitions to Sustainability.” *Research Policy* 41 (6): 1025–36. https://doi.org/10.1016/j.respol.2011.12.012.

Smith, Adrian, and Rob Raven. 2012b. “What Is Protective Space? Reconsidering Niches in Transitions to Sustainability.” *Research Policy* 41 (6): 1025–36. https://doi.org/10.1016/j.respol.2011.12.012.

Smith, Adrian, Andy Stirling, and Frans Berkhout. 2005. “The Governance of Sustainable Socio-Technical Transitions.” *Research Policy* 34 (10): 1491–1510. https://doi.org/10.1016/j.respol.2005.07.005.

Smith, Adrian, Jan Peter Voß, and John Grin. 2010. “Innovation Studies and Sustainability Transitions: The Allure of the Multi-Level Perspective and Its Challenges.” *Research Policy* 39 (4): 435–48. https://doi.org/10.1016/j.respol.2010.01.023.

Sovacool, Benjamin. 2013. “A Qualitative Factor Analysis of Renewable Energy and Sustainable Energy for All (SE4ALL) in the Asia-Pacific.” *Energy Policy* 59: 393–403. https://doi.org/10.1016/j.enpol.2013.03.051.

Sovacool, Benjamin, and Michael H. Dworkin. 2015. “Energy Justice: Conceptual Insights and Practical Applications.” *Applied Energy* 142: 435–44. https://doi.org/10.1016/j.apenergy.2015.01.002.

Sovacool, Benjamin K., and Michael H. Dworkin. 2015. “Energy Justice: Conceptual Insights and Practical Applications.” *Applied Energy* 142: 435–44. https://doi.org/10.1016/j.apenergy.2015.01.002.

Sovacool, Benjamin K., Raphael J. Heffron, Darren McCauley, and Andreas Goldthau. 2016. “Energy Decisions Reframed as Justice and Ethical Concerns.” *Nature Energy* 1 (May). https://doi.org/10.1038/nenergy.2016.24.

Sovacool, Benjamin, Roman Sidortsov, and B.R Jones. 2013. *Energy Security, Equality and Justice*. Routledge.

Stanton, Elizabeth A. 2007. “The Human Development Index: A History.” 127. Amherst.

Stock, Ryan. 2021. “Bright as Night: Illuminating the Antinomies of ‘Gender Positive’ Solar Development.” *World Development* 138: 105196. https://doi.org/10.1016/j.worlddev.2020.105196.

Suri, K C. 2004. “Democracy, Economic Reforms and Election Results in India.” *Economic and Political Weekly* 39 (51): 5404–11.

http://www.jstor.org/stable/4415923.

TERI. 2015. “Analysis of the Electrification Programme in India Using the ‘ Energy plus ’ Framework and the Key Lessons.” New Delhi: The Energy Resources Institute.

Terrapon-Pfaff, Julia, Carmen Dienst, Julian König, and Willington Ortiz. 2014. “A Cross-Sectional Review: Impacts and Sustainability of Small-Scale Renewable Energy Projects in Developing Countries.” *Renewable and Sustainable Energy Reviews* 40: 1–10. https://doi.org/10.1016/j.rser.2014.07.161.

TGC. 2014. “The Business Case for Off-Grid Energy in India.” The Climate Group, New Delhi.

Tharoor, Shashi. 2007. *The Elephant, the Tiger, and the Cell Phone: Reflections on India, the Emerging 21st-Century Power*. Penguin Books India.

Thomas, Daniel Robert, and Johannes Urpelainen. 2018. “Early Electrification and the Quality of Service: Evidence from Rural India.” *Energy for Sustainable Development* 44: 11–20. https://doi.org/10.1016/j.esd.2018.02.004.

Tomei, Julia, Jennifer Cronin, Héctor David Agudelo Arias, Samir Córdoba Machado, Maycol Francisco Mena Palacios, Yenny Marcela Toro Ortiz, Yemilson Espidio Borja Cuesta, Reiner Palomino Lemus, William Murillo López, and Gabrial Anandarajah. 2020. “Forgotten Spaces: How Reliability, Affordability and Engagement Shape the Outcomes of Last-Mile Electrification in Chocó, Colombia.” *Energy Research and Social Science* 59 (March 2019). https://doi.org/10.1016/j.erss.2019.101302.

Turnheim, Bruno, and Frank W. Geels. 2013. “The Destabilisation of Existing Regimes: Confronting a Multi-Dimensional Framework with a Case Study of the British Coal Industry (1913-1967).” *Research Policy* 42 (10): 1749–67. https://doi.org/10.1016/j.respol.2013.04.009.

Ulsrud, Kirsten, Tanja Winther, Debajit Palit, Harald Rohracher, and Jonas Sandgren. 2011. “The Solar Transitions Research on Solar Mini-Grids in India: Learning from Local Cases of Innovative Socio-Technical Systems.” *Energy for Sustainable Development* 15 (3): 293–303. https://doi.org/10.1016/j.esd.2011.06.004.

UNECE. 2004. “The Aarhus Convention: An Implementation Guide.” United Nations, New York: Geneva. http://www.unece.org/fileadmin/DAM/env/pp/Publications/Aarhus_Implementation_Guide_interactive_eng.pdf.

Urpelainen, Johannes. 2014. “Grid and Off-Grid Electrification: An Integrated Model with Applications to India.” *Energy for Sustainable Development* 19: 66–71. https://doi.org/10.1016/j.esd.2013.12.008.

Velasco-Herrejon, Paola, and Thomas Bauwens. 2020. “Energy Justice from the Bottom up: A Capability Approach to Community Acceptance of Wind Energy in Mexico.” *Energy Research and Social Science* 70 (July): 101711. https://doi.org/10.1016/j.erss.2020.101711.

Venema, Henry David, and Ibrahim Hafeezur Rehman. 2007. “Decentralized Renewable Energy and the Climate Change Mitigation-Adaptation Nexus.” *Mitigation and Adaptation Strategies for Global Change* 12 (5): 875–900. https://doi.org/10.1007/s11027-007-9104-7.

Venkatpuram, Sridhar. 2011. *Health Justice: An Argument from the Capabilities Approach*. Wiley.

Verbong, Geert, and Frank Geels. 2007. “The Ongoing Energy Transition: Lessons from a Socio-Technical, Multi-Level Analysis of the Dutch Electricity System (1960-2004).” *Energy Policy* 35 (2): 1025–37. https://doi.org/10.1016/j.enpol.2006.02.010.

Walker, Gordon. 2009a. “Beyond Distribution and Proximity: Exploring the Multiple Spatialities of Environmental Justice.” *Antipode* 41 (4): 614–36. https://doi.org/10.1111/j.1467-8330.2009.00691.x.

Walker, Gordon. 2009b. “Beyond Distribution and Proximity: Exploring the Multiple Spatialities of Environmental Justice.” *Antipode* 41 (4): 614–36.

Walker, Gordon, and Rosie Day. 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.

WGEP. 1979. “Report of the Working Group on Energy Policy.” Planning Commission, Government of India. New Delhi.

Whitmarsh, Lorraine. 2012. “How Useful Is the Multi-Level Perspective for Transport and Sustainability Research?” *Journal of Transport Geography* 24: 483–87. https://doi.org/10.1016/j.jtrangeo.2012.01.022.

Wieczorek, Anna J. 2018. “Sustainability Transitions in Developing Countries: Major Insights and Their Implications for Research and Policy.” *Environmental Science and Policy* 84 (July): 204–16. https://doi.org/10.1016/j.envsci.2017.08.008.

Wieczorek, Anna J., Rob Raven, and Frans Berkhout. 2015. “Transnational Linkages in Sustainability Experiments: A Typology and the Case of Solar Photovoltaic Energy in India.” *Environmental Innovation and Societal Transitions* 17: 149–65. https://doi.org/10.1016/j.eist.2015.01.001.

Wiese, Katharina. 2020. “Energy 4 All? Investigating Gendered Energy Justice Implications of Community-Based Micro-Hydropower Cooperatives in Ethiopia.”

Innovation: The European Journal of Social Science Research 33 (2): 194–217. https://doi.org/10.1080/13511610.2020.1745059.

Williams, Stephen, and Andréanne Doyon. 2019. "Justice in Energy Transitions." *Environmental Innovation and Societal Transitions* 31 (December): 144–53. https://doi.org/10.1016/j.eist.2018.12.001.

Winther, Tanja. 2015. "Impact Evaluation of Rural Electrification Programmes: What Parts of the Story May Be Missed?" *Journal of Development Effectiveness* 7 (2): 160–74. https://doi.org/10.1080/19439342.2015.1008274.

Wolsink, Maarten. 2013. "Fair Distribution of Power Generating Capacity: Justice, Microgrids and Utilizing the Common Pool of Renewable Energy." In *Energy in a Changing Climate: Social Equity and Low-Carbon Energy,* edited by Karen Bickerstaff, Gordon Walker, and Harriet Bulkeley, 116–38. London and New York: Zed Books.

World Bank. 2016. "Reliable and Affordable Electricity Services for the Poor : Lessons from the Wor Ld." Washington, DC: World Bank.

Yadav, Prabhakar, Peter J. Davies, and Sabah Abdullah. 2018. "Reforming Capital Subsidy Scheme to Finance Energy Transition for the below Poverty Line Communities in Rural India." *Energy for Sustainable Development* 45: 11–27. https://doi.org/10.1016/j.esd.2018.04.001.

Yadav, Prabhakar, Peter J. Davies, and Samuel Asumadu-Sarkodie. 2021. "Fuel Choice and Tradition: Why Fuel Stacking and the Energy Ladder Are out of Step?" *Solar Energy* 214 (November 2020): 491–501. https://doi.org/10.1016/j.solener.2020.11.077.

Yadav, Prabhakar, Peter J. Davies, and Samuel Asumadu Sarkodie. 2019. "The Prospects of Decentralised Solar Energy Home Systems in Rural Communities: User Experience, Determinants, and Impact of Free Solar Power on the Energy Poverty Cycle." *Energy Strategy Reviews* 26: 100424. https://doi.org/10.1016/j.esr.2019.100424.

Yadav, Prabhakar, Yuwan Malakar, and Peter J. Davies. 2019. "Multi-Scalar Energy Transitions in Rural Households: Distributed Photovoltaics as a Circuit Breaker to the Energy Poverty Cycle in India." *Energy Research and Social Science* 48 (January 2018): 1–12. https://doi.org/10.1016/j.erss.2018.09.013.

Yaqoot, Mohammed, Parag Diwan, and Tara C. Kandpal. 2016. "Review of Barriers to the Dissemination of Decentralized Renewable Energy Systems." *Renewable and Sustainable Energy Reviews* 58: 477–90. https://doi.org/10.1016/j.rser.2015.12.224.

Yenneti, Komali, and Rosie Day. 2016. "Distributional Justice in Solar Energy Implementation in India: The Case of Charanka Solar Park." *Journal of Rural*

Studies 46: 35–46. https://doi.org/10.1016/j.jrurstud.2016.05.009.

Yin, R.K., 1994. Case Study Research: Design and Methods (Applied Social Research Methods). SAGE Publications, London.

Yin, Robert K. 2014. *Case Study Research: Design and Methods*. Fifth. SAGE Publications.

York, Richard. 2015. "Energy Ethics." *Nature Climate Change* 5 (5): 409–409. https://doi.org/10.1038/nclimate2609.

Young, Iris Marion. 1990. *Justice and the Politics of Difference*. Princeton Press, Princeton NJ.

Zolfagharian, Mohammadreza, Bob Walrave, Rob Raven, and A. Georges L. Romme. 2019. "Studying Transitions: Past, Present, and Future." *Research Policy* 48 (9). https://doi.org/10.1016/j.respol.2019.04.012.

APPENDIX I

EXPERT INTERVIEWEE DETAILS AND QUESTIONS

Code	Organization	Type
Interview 1	ASHDEN India Collective	Indian Policy Think Tank
Interview 2	TERI University	Indian Academic (Also the Former Jt. Secretary of MNRE)
Interview 3	GOGLA (India Representative)	Global Industry Association
Interview 4	GIZ	Global Aid Organization
Interview 5	REC	Government Agency
Interview 6	IIEST	Indian Academic (Also the former chief of WBREDA & former CEO of ASHDEN India)
Interview 7	ARE	Global Industry Association
Interview 8	WRI India	Global Policy Think Tank
Interview 9	Power for All	Global Industry Association
Interview 10	SE4ALL	Global Policy Think Tank
Interview 11	TCG	Global Policy Think Tank
Interview 12	TERI	Indian Policy Think Tank
Interview 13	CLEAN	Indian Industry Association
Interview 14	AEDA	State Government Agency
Interview 15	CEEW	Indian Policy Think Tank
Interview 16	USAID	Global Aid Organization
Interview 17	MNRE	Government Agency
Interview 18	Oorja Solutions	Energy Enterprise
Interview 19	Gram Oorja	Energy Enterprise
Interview 20	Orb Energy	Energy Enterprise
Interview 21	Mlinda	Energy Enterprise
Interview 22	SIMPA Networks	Energy Enterprise

Expert Interview Question Guide

1. To start, I'm interested in an overall sense of how, based on your experience, you've seen interest in DREs [solar off-grid (in India) evolve over time.
    a. When did you first get involved in the sector? What was happening at that time?
    b. Can you describe how its importance changed (increased/decreased/remained same) over time?
    c. Was solar off-grid ever seen as a dominant strategy for rural electrification? Or was it always seen as a "niche"?
    d. Within the solar off-grid sector, do you see the difference between individual lighting systems and community-based systems (mini/micro-grids)?
2. What other groups, agencies, or people from solar off-grid space do you engage/collaborate with? And in what ways (research, implementation, funding, etc.) do you engage with them? (List 3-4 main actors/organizations and major projects and outcomes to give us a familiarity)?
3. What factors has driven the growth of solar off-grid in rural India?
4. What are the barriers (social, political, financial, technological, institutional) inhibiting the expansion of solar off-grid in rural India?
5. As we usher into era of complete electrification, what do you think of the overall role of solar off-grid in India? Does it still have a role to play in rural ecosystem? And if so, what is it?
6. What is needed to promote diffusion of solar off-grid (e.g. in terms of policy, finance, etc.) in India?

APPENDIX II

SEMI-STRUCTURED INTERVIEW GUIDE

Village Household Interview – Mini Grid (and if Solar Lighting)

District: _____ **Village/Hamlet Name:** _____

Gram Panchayat: _____ **Date:** _____

HH GPS Co-ordinate: _____ *Lat* and _____ *Long*

SECTION 1: HOUSEHOLD AND RESPONDENT CHARACTERISTICS		
1.1 Sex of Respondent: M__ F__	**1.2** Sex of Household Head: M__ F__	**1.3** Age:
1.4 Total HH members:		
1.5 Social Group: 1. SC 2. ST 3. OBC 4. NT 5. General (GN)		
1.6 Does your Family hold a ration card? 1. Yes 2. No		
1.7 If Yes, Type of Ration Card? 1. BPL 2. APL 3. Antyodaya 4. Others (Specify) _____		
1.8 Ownership of House: 1. Owned 2. Rented 3. Others (Specify)_____ Number of rooms in the HH _____		
1.9 Type of house: 1. Pucca (RCC) 2. Semi Pucca (Tile/Sheet Roof) 3. Kutcha (Thatched) 4. Others (Specify)_____		
1.10 Sources of Income (Rank first 3)		
☐ Agriculture Cultivation _____ ☐ Leased Agriculture Cultivation _____ ☐ Agricultural Laborer _____	☐ Daily Laborer _____ ☐ Salaried Job _____ ☐ Own Business _____	
1.11 Land Holding		
☐ Landless ☐ Marginal (< 1 ha or < 2.5 acres) ☐ Small (1-2 ha or 2.5 – 5 acres)	☐ Semi-medium (2-4 ha or 5-10 acres) ☐ Medium (4-10 ha or 10-25 acres) ☐ Large (> 10 ha or > 25)	

SECTION 3: ENERGY SERVICE CHARACTERISTICS – SOLAR HOME SYSTEM (SHS)			
	Service	**Number**	**Hours (Daily)**
3.1. What energy services are available to you from SHS?	☐ Lighting		
	☐ Fan		
	☐ Mobile Charging		
	☐ Television		
	☐ _____ (Others)		
3.2. How do you feel about the statement 'I am satisfied with the available energy services (from SHS) in terms of fulfilling the household needs'? ☐ Strongly Agree ☐ Somewhat Agree ☐ Neutral ☐ Somewhat Disagree ☐ Strongly Disagree			
3.2.1. If disagree (in 3.2), why is so? (tick all that matters)	☐ Unreliable (for example voltage fluctuations/malfunction) ☐ Poor maintenance and services ☐ Others _____ (specify)		
3.2.2 If agree (in 3.2), what aspects are critical?			

SECTION 4: SERVICE RELIABILITY AND PREFERENCE (SHS v.s. MINI-GRIDS)		
4.1 Do you know who to contact in case of problem with your household connection?	SHS	☐ Yes ☐ No
	Mini-grids	☐ Yes ☐ No
4.2 What do you prefer for household electrification? (Rank in order of preference ranking 1, 2 and 3)	☐ Grid based electricity _____ ☐ Mini-grid _____ ☐ SHS _____	
4.3 How has the household power consumption differed from mini-grids after the arrival of solar home lighting?	☐ Decreased ☐ Increased ☐ Remained same	
4.4. How often do you have power disruption from?		
SHS/Grid ☐ Atleast once a week ☐ More than once a week ☐ Atleast once a month ☐ More than once a month ☐ Never face disruption	*Mini-Grids* ☐ Atleast once a week ☐ More than once a week ☐ Atleast once a month ☐ More than once a month ☐ Never face disruption	
4.5. Which of the following should be in charge of the supply of electricity in your village? 1.Government 2. Private 3. NGO 4. Community itself 5. Others _____		

SECTION 5: CAPABILITIES, ELECTRIFICATION AND SOLAR ENERGY
5.1. What do think has changed in your day to day life since you gained access to electricity? **Probing Questions:** 5.1.1. How has electrification affected your livelihood options? 5.1.2. How has electrification affected the health of family members household? 5.1.3. How has electrification affected your perceptions about safety of family members in household? 5.1.4. How has electrification affected your ability to reach relevant places (far) from the household (markets, places of worship, water points, etc.)? 5.1.5. How has electrification affected your ability to be autonomous in household (and self-care) activities? 5.1.6. How has electrification affected the ability to socialize with peers in the community? 5.1.7. How have your aspirations changed since access to electricity?
5.2. What do you think electrification as resource/service should be enable, but has not been able to for your household? **Probing Questions:** 5.2.1. What do you think electrification really should be able to do other than current energy services you obtain? 5.2.2. What will happen of the community based solar energy if there is stable electricity supply from the grid? Can solar energy still support development after the grid electrification?

SECTION 6: PARTICIPATION AND FAIRNESS IN PROCESS (MINI-GRID PROJECT)
6.1. Who are/were the actors involved in the decisions regarding the project in the community?
6.2. Who makes the final decision regarding management of mini-grids and what steps are taken to reach that decision?
6.3. What do/did you like about the community-based arrangement of the solar energy?
6.4. What do/did you dislike about the community-based arrangement of the solar energy?

6.5. How do you approach in case of problems regarding the technology, such as failure, under-performance, etc.? What kind of support services do you receive?
6.6. How do you feel about the statement 'The decisions taken by managing committee is/was fair'? ☐ Strongly Agree ☐ Somewhat Agree ☐ Neutral ☐ Somewhat Disagree ☐ Strongly Disagree
6.7. How do you feel about the statement 'The managing committee is/was inclusive in accomodating the views of people from different households, or gender'? ☐ Strongly Agree ☐ Somewhat Agree ☐ Neutral ☐ Somewhat Disagree ☐ Strongly Disagree
6.8. Why do you think the arrangement has not been as successful here in your community? What are the factors that led to such results? Is it just because of the grid (government supply) or are there any other factors? (*To be asked only in Bhatipada, Manmohadipada and Navpada*)