Beyond Off-grid: Integrating Mini-grids with India's Evolving Electricity System

Supported by:

Asha Impact

The Rockefeller Foundation

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Prepared by:

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Foreword

Up to 250 million Indians are not connected to the national grid and the majority of rural consumers have grossly unreliable power supply. Electricity is one of the most important drivers of socio-economic development, giving students light to study at home and adults the time to carry out income generating (or leisure) activities after sunset. From lighting, charging mobile phones and powering small fans, rural energy demand increases exponentially up the energy ladder as families with greater incomes purchase televisions, computers, refrigeration and air-conditioning. From an income perspective as well, electricity is critical, allowing small businesses to power machines and shops to stay open after dark. Enabling 100% rural electrification is important, and possible with collaboration.

Through our work at Asha Impact – an impact investment and policy advocacy platform for philanthropists to engage with the government – we have come across a range of innovative business models providing decentralized (usually renewable) energy solutions in electricity-starved areas in states like UP and Bihar. More than solar lanterns and home systems that power a few lights and fans, we have found the most promising way to efficiently provide reliable electricity in remote areas is through local mini-grids: 10 to 50 KW solar or biomass plants with their own distribution network that power both village households, as well as rural businesses and anchor clients like telecom towers. India has several energy service companies running such mini-grid networks, usually funded by philanthropic capital.

The reason most of these enterprises have not been able to raise commercial capital and scale-up their impact meaningfully is partly because of business model challenges, but also due to the risk of grid entry into their markets (upon which the mini-grid is made unviable). Rather than seeing "grid versus mini-grid" as a policy choice, we need to encourage more of both – and to have the grid operate in partnership with a network of distributed mini-grids.

The government knows the importance of mini-grids. The National Tariff Policy allows the legacy grid to purchase power from mini-grid operators. The UP government announced a major policy for the sector in 2016. But the devil is in the details, on how interconnection works in practice. And here there is less visibility. To achieve the goal of universal electricity access, we need to establish a collaborative approach that draws on the strengths of the national grid, distribution companies, investors and mini-grid operators.

What does the roadmap for this 'interconnection' of our energy system look like? How can we leverage both government and private investment? What are the different interconnection models and their commercial, technical and regulatory implications? Where do mini-grids go from here? This timely report – commissioned by the Asha Impact Trust in collaboration with Shakti Foundation and Rockefeller Foundation – provides a multi-layered perspective to address these questions based on extensive research, wide-ranging policymaker interactions, and our investment experience evaluating mini-grid operators.

At its core the report aims to provide a framework and roadmap that enables the national grid and mini-grid operators to work together towards an integrated electricity system. We hope the study ignites constructive dialogue in both government and industry and leads to concrete action to achieve the common vision of universal electrification of India.

Vikram Gandhi & Pramod Bhasin
Asha Impact Trust

Foreword

As India's economic engine continues to accelerate, the need to drive growth and opportunities for its 1.3 billion people as quickly and as equitably as possible has never been greater. In a global economy powered by machines, technology and information, access to electricity will make the difference between a promise fulfilled and potential squandered.

The Indian government has recognized the importance of universal energy access for India's future, setting the laudable goal of electrifying every corner of the country by 2018. The private sector has rallied around this ambition, harnessing their resources alongside the government's efforts to make this a possibility. The Rockefeller Foundation has been a proud partner in catalyzing the growth of India's decentralized renewable energy (DRE) sector, bringing together a coalition of Central and state governments, non-profits, technology companies, investors, social entrepreneurs and business owners to build 1,000 decentralized mini-grids in rural India and uplift the communities they power.

Together, we have sparked productivity and helped strengthen rural economies by connecting them to the transformative power of energy. Early indicators show that village GDPs and socio-economic wellbeing are growing, incomes are rising, and villagers are beginning to set up their own enterprises. Today, we have reached a crossroads – how can we help the government's ambitions meet with the economic dynamism mini-grids have unleashed in different regions of India?

This report lays out the ways in which mini-grids can work with the national grid to accelerate and strengthen universal electrification in India. With the right policy support, dedication and commitment to wellbeing of India's most vulnerable, I am convinced that interconnection will catapult us to the next great leap for India's DRE sector, allowing its multiplier effects to touch the lives of countless millions. The policies, actors and market conditions are in place to make the dream of 24x7 Power For All a reality. It is now time to make it happen. This report will help us get there.

Deepali Khanna
Director, Smart Power for Rural Development
The Rockefeller Foundation

Foreword

This study around the integration prospects of decentralized renewable energy based mini-grid solutions with the utility grid was born out of the observation that electricity infrastructure could be built in a variety of ways – as an extension of existing grid infrastructure, as a collection of decentralised and islanded solutions at the household and community scale, or as a combination of these two forms coming together.

Clarity around interconnection was thus important for enabling these possibilities to emerge in order to address all options available for enhanced electricity access.

The study was conducted in two phases. In the first phase, a technical assessment was undertaken to explore options for interconnecting mini-grids and the central grid, and their suitability for the integration of decentralised and centralised infrastructure. The findings were corroborated by extensive stakeholder inputs. The second phase built on the findings of the first phase, by further engaging with key stakeholders, such as policy makers, regulators, utilities, investors, project developers and sector experts around the initial findings.

Okapi Research and Advisory was commissioned to undertake this study in line with our vision of strengthening the energy security of the country by aiding the design and implementation of policies that encourage renewable energy, energy efficiency and the adoption of sustainable transport solutions. Our team also provided technical guidance from time to time. I hope that this study will create awareness about the role mini-grids can play as an integral long term solution for electricity access by offering inputs on policy and business models for the integration of mini-grids with the utility grid.

I sincerely hope that this study will lead to better communication and collaboration amongst stakeholders and create an improved policy and investment climate for mini-grids in India.

Krishan Dhawan
Chief Executive Officer
Shakti Sustainable Energy Foundation

Foreword

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We live in an era of vast technological possibility, but often struggle with the policy and regulatory frameworks, the business models, and the community collaboration required to leverage these tools to meet pressing needs. Energy access is no exception. We have more possibilities than ever to meet household and business needs for clean, reliable sources of electricity; but a significant proportion of the Indian population – and more than a billion people around the world – remain underserved.

We initiated this project in 2015 as an exploration of the opportunities and obstacles for various technologies and delivery models to effectively collaborate in accelerating electricity access in India. A number of academic analyses had highlighted the potential for expanding access by "growing in" from decentralised generation and smaller grids as well as "growing out" by extending the main grid. We wanted to understand whether and how these possibilities might play out in rural India, and what kinds of interventions might support an open innovation ecosystem for electricity services. These questions are immediately relevant for rural India, but also important for understanding and shaping the global transition from centralised to decentralised infrastructure models.

We were fortunate to find similarly curious partners in Shakti Sustainable Energy Foundation, Rockefeller Foundation, and Asha Impact. With their support and collaboration, we have had the opportunity to interview a wide variety of stakeholders and delve into commercial, regulatory and infrastructure aspects of interconnection. We hope that the resulting analysis and recommendations will contribute to the growing body of knowledge on infrastructure transitions, and, more immediately, help accelerate the integration of mini-grids with the main grid as complementary tools for rapid expansion of electricity access.

Jessica Seddon
Founder, Managing Director
Okapi Research & Advisory

Acknowledgements

The authors would like to express their gratitude to Shakti Sustainable Energy Foundation, Rockefeller Foundation, and the Asha Impact Trust for their financial support, expert inputs, and guidance for this study and report. The lead author of this report was Amber Luong, with research assistance from Geetanjali Shahi, Anjali Neelakantan, and the team at Asha Impact during the course of the project. Dr. Jessica Seddon served as an advisor to the project.

Given the importance of understanding interconnection from a range of perspectives, many organizations gave generously of their time for interviews with the study team. In particular, we would like to thank: Supreme & Co., G.R.I.D. India, OMC, Avani Bio Energy, Biotech India, Boond, DESI Power, Mera Gao Power, SELCO Foundation, Vayam Renewables, Husk Power Systems, Naturetech, Mlinda Foundation, TARA Urja, Gram Oorja, SunMoksha, Gram Power, Sangam Ventures, Insitor Impact Fund, and Acumen Fund. We also express our sincere appreciation for the time taken by officials from various government organisations to meet with the study team, including the Ministry of Power (MoP), NITI Aayog, Ministry of New and Renewable Energy (MNRE), Central Electricity Regulatory Commission (CERC), Central Electricity Authority (CEA), Uttar Pradesh New & Renewable Energy Development Agency (UPNEDA), Uttar Pradesh Electricity Regulatory Commission (UPERC), Odisha Renewable Energy Development Agency (OREDA), Odisha Electricity Regulatory Commission (OERC), and Grid Corporation of Odisha. We also thank OMC, Naturetech, and SunMoksha for facilitating field visits to some of their mini-grid installations in Uttar Pradesh and Odisha.

We are also grateful to a range of sector experts consulted across all stages of this project who helped us better understand various dimensions of interconnection and the potential impacts on mini-grids and the legacy grid system, including: Shalabh Srivastava, K. Rahul Sharma, Parimita Mohanty, Rahul Tongia, Ashis Sahu, Hari Natarajan, Ankita Jena, I. H. Rehman, Arun Maira, Jarnail Singh, Jay Shiv, Siddhartha Saha, Satish Agnihotri, Prof. Suryanarayana Doolla, and Ashwin Gambhir. We especially thank S.P. Gon Chaudhuri, Upendra Bhatt, Rakesh Jha, Swaraj Bose, Debajit Palit, Sunil Dhingra, Col. Vijay Bhaskar, Sudeshna Mukherjee, Rohit Chandra, and Sarraju Narasingha Rao for in-depth discussions and/or feedback provided on the full range of possible interconnection models.

Abbreviations

AC	alternating current
APL	above poverty line
AVVNL	Ajmer Vidyut Vitran Nigam Ltd (Ajmer DISCOM)
BERC	Bihar Electricity Regulatory Commission
BPL	below poverty line
Capex	capital expenditure
CB	circuit breaker
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
DC	direct current
DDG	Decentralised Distributed Generation
DDUGJY	Deendayal Upadhyaya Gram Jyoti Yojana
DISCOM	distribution company
DTR	distribution transformer
ESCO	energy service company
ESMI	Electricity Supply Monitoring Initiative
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
INR	Indian Rupee
IPP	independent power producer
JKSERC	Jammu & Kashmir State Electricity Regulatory Commission
kV	kilovolt
LED	light emitting diode
LT	low tension
MBC	metering, billing, collection
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
NG	national grid
NEP	National Electricity Policy
NTP	National Tariff Policy
UPPCL	Uttar Pradesh Power Corporation Limited
PDN	power distribution network
PPA	power purchase agreement
PV	photovoltaic
RESSPO	Rural Electrification and Secondary System Planning Organisation (Uttar Pradesh)
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
SERC	State Electricity Regulatory Commission
SME	small and medium enterprise
UPERC	Uttar Pradesh Electricity Regulatory Commission
UPNEDA	Uttar Pradesh New and Renewable Energy Development Agency
V	volt
W	watt

Executive Summary

India has ambitious targets for providing electrification to all its villages by May 2018 and 24x7 power to all households by March 2019. Part of this goal will be achieved by expansion of the national grid, as well as the amount of power that flows through it. But it will also require an expansion of off-grid electricity provided by private energy service companies (ESCOs). These companies, often small and medium enterprises operating in rural areas with unreliable or no grid electricity, provide a range of services from generation and distribution to user services and maintenance through mini-grids, often based on renewable energy (solar or biomass).

This report addresses the policy, regulatory, and market infrastructure needed for these two sets of electricity providers – ESCOs and the national grid – to co-exist and collaborate to accelerate energy access. It draws on primary and secondary research including extensive stakeholder interviews across central and state governments, private mini-grid enterprises, and investors and academia to develop a multi-dimensional understanding and possible roadmap for enabling energy access in India.

Evolving Regulatory Environment

There have been several positive developments for mini-grid operators and investors and mini-grids have gained national prominence due to the focus on rural electrification. The regulatory landscape for public and private participation in electricity generation and distribution has evolved dramatically in the last decade and a half. The Electricity Act of 2003 de-licensed rural generation and distribution, which allowed private enterprises to service rural areas, and the Decentralised Distributed Generation (DDG) scheme encouraged mini-grids to provide energy to remote areas. The National Tariff Policy (NTP) of 2016 set out the need for regulators to ensure that the legacy grid would purchase power from ESCOs operating mini-grids in areas to which it was expanding.

Limited Understanding of Interaction between ESCOs and Grid

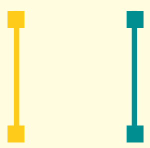
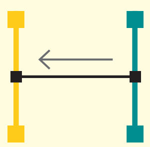
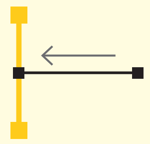
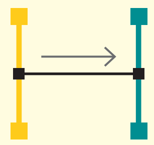
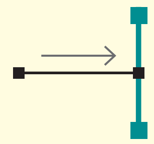
Despite awareness about the potential of mini-grids to serve rural areas where the grid is not economically viable, there is limited understanding of how these two forms of electricity provision can co-exist and complement each other going forward. The kind of interconnection that would allow for buying and selling of power between ESCOs and the grid, for example, is not prevalent in India. It is quite common, however, to have the ESCOs and the grid operating in parallel. While mini-grid operators cite concerns about the ability of grid based electricity to undercut their costs, in practice customers are often willing to pay higher mini-grid tariffs in exchange for more reliable supply.

Moreover, there are regulatory ambiguities yet to be resolved. The Central Electricity Authority (CEA) regulations for interconnection of distributed generation are modeled on international guidelines. These are not always relevant or specific to interconnection of mini-grids. For example, regulations in India do not allow for islanding, a feature that can be valuable for ESCOs. It is also important to consider the location of the point of interconnection, since this has a material impact on the cost and technical challenges of interconnection for the mini-grid and the utility. Overall, whilst the policy relevance of interconnection is increasingly accepted, what it entails in practice is not as well known.

Five Models of Interconnection

Our research identifies five models through which utilities and ESCOs can constructively interact when both are present in the same area. The five models are not mutually exclusive; the nature of interconnection could transition over time from one model to another depending on power supply dynamics, economics, and other factors.

TABLE 1: Summary of Interconnection Models

MODEL	SCHEMATIC	DESCRIPTION
Parallel Operation		Before physical interconnection in areas where grid supply is unreliable where both the mini-grid and the grid operate and customers may have both connections.
Interconnection with Partial Export		Mini-grid only exports the excess power generated from its mini-grid customers to the main grid.
Interconnection with Full Export		ESCO becomes an independent power producer (IPP) and exports its entire power generation to the main grid. The erstwhile mini-grid operator either moves or scraps its primary distribution grid or sells it to the larger utility.
Interconnection with Import		ESCO becomes a bulk customer of the larger utility and imports some part of power supplied, while continuing to supply to its customers through its own primary distribution network.
Interconnection with Import, Mini-grid PDN		The utility essentially assumes control over the ESCO's primary distribution network, either by purchasing or franchising the mini-grid company to generate and/or distribute on behalf of the grid.

Commercial Implications

The business model viability for ESCOs is impacted by interconnection in terms of:

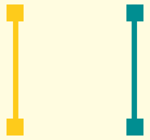
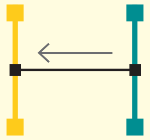
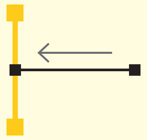
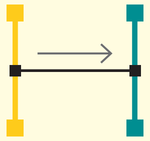
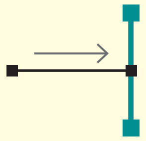
- **Sources of revenue:** Depending on the model, could include feed-in tariffs for exporting power to the grid, proceeds from asset sales to the larger utility or franchisee fees.
- **Customer tariff flexibility:** Whether the mini-grid has tariff flexibility in what it can charge its customers or if it must charge the (much lower) regulated tariff.
- **Operational flexibility**: Under what conditions can the mini-grid company sell power directly to its customers or to the grid (e.g. forced halts in supply during load shedding).
- **Capital expenditure:** The type of interconnection model dictates the degree of infrastructure investment required by the ESCO.

Policy and Regulation Challenges

When evaluating policy options for interconnection it is important to consider the setting under which mini-grids operate, namely:

i. Areas that are unlikely to ever gain grid connectivity;
ii. Areas that are expected to get grid connectivity in the near future; or
iii. Areas with grid connectivity and ESCO-provided power.

An effective policy framework should enable the transition between models if needed in a particular area to optimize outcomes for consumers as well as the distribution utility and/or ESCO. For

MODEL	SCHEMATIC	POLICY OR REGULATORY CLARITY	ESCO CAPEX CHANGE	RETAIL TARIFF FLEXIBILITY	POTENTIAL FOR OTHER REVENUE / COMPENSATION TO ESCO		
					FEED-IN TARIFF	ASSET PURCHASE	FRANCHISEE AGREEMENT
Parallel Operation		✓	Unchanged	✓	N/A	N/A	✓*
Interconnection with Partial Export		✓	Depends ↑/↓	✓	✓	N/A	✓*
Interconnection with Full Export		✓	Depends ↑/↓	N/A	✓	✓	✓*
Interconnection with Import		Uncertain	Likely unchanged	Uncertain	N/A	N/A	Uncertain
Interconnection with Import, Mini-grid PDN		Uncertain	↑	Uncertain	Uncertain	Uncertain	Uncertain

** Per the UPERC mini-grid regulation, the ESCO may seek to become a Franchisee of the DISCOM as long as the mini-grid was established before the grid is extended to a given area. This option is not specified in cases where the mini-grid is established in areas that are already electrified.*

TABLE 2:
Commercial Implications

example, in an area with unreliable supply from the main grid, the interconnection with import model (where the mini-grid purchases power from the main grid) may be most appropriate for all participants. Then, in the long-term, as the main grid becomes stable, the ESCO can switch to export some or all its power to the larger utility and also sell its primary distribution network assets.

Thus, the regulatory framework needs to both allow the flexibility for such evolving scenarios and, at the same time, resolve commercially relevant procedural uncertainty around selection of intercon-

nection points, equipment and infrastructure guidelines, distribution franchisee frameworks, and compensation mechanisms for ESCOs.

The Way Forward

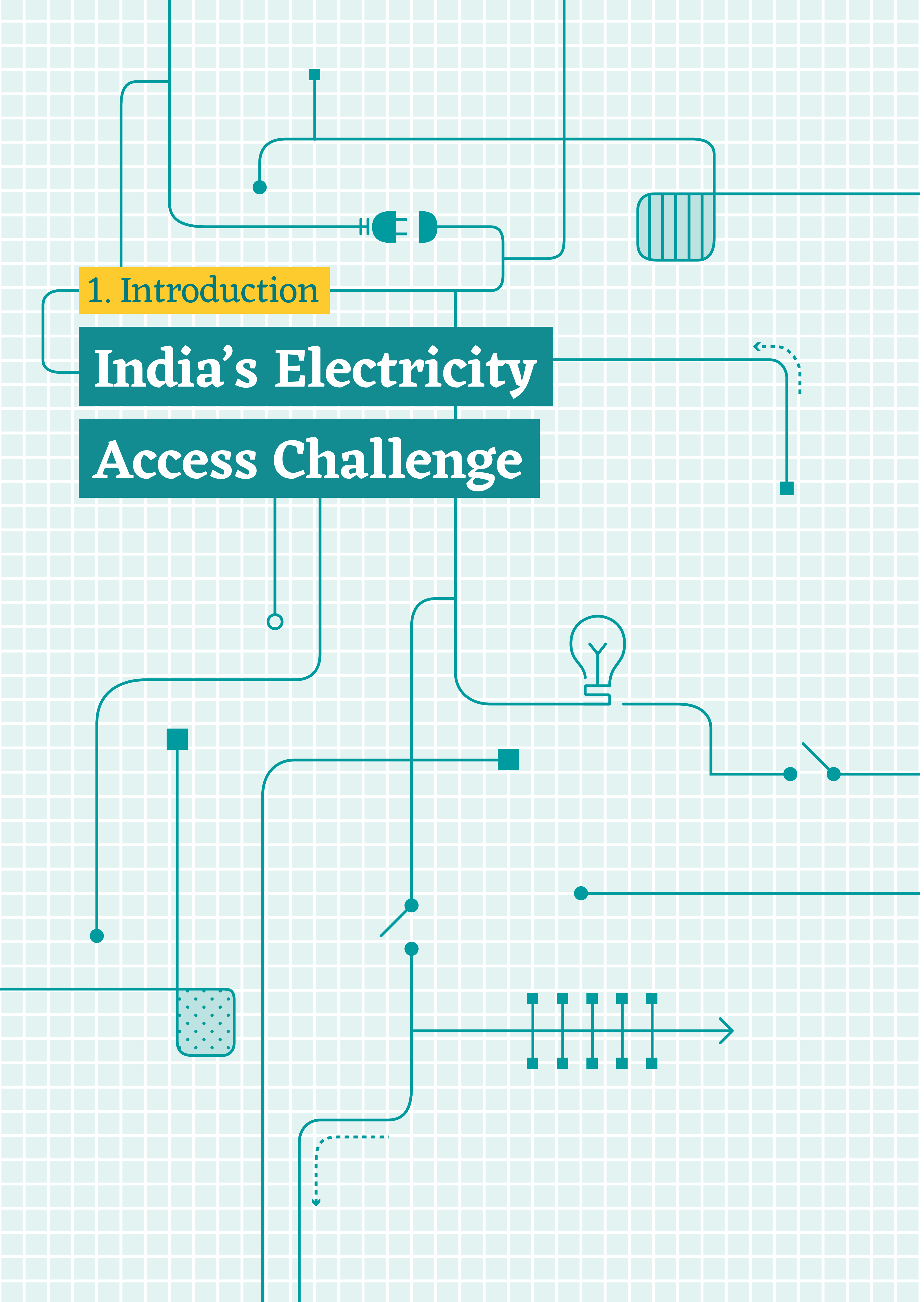
Evaluating the five models of interconnection from a commercial, infrastructure and regulatory standpoint, we outline recommendations across four broad areas to support the move toward an integrated multi-scale electricity system:

1. **Partnerships between equipment providers and ESCOs:** Partnerships between mini-grid operators and large technology providers to reduce costs of the interconnection model would be valuable and also signal confidence to policy-makers and regulators on the quality of the mini-grid infrastructure.
2. **Business model innovation among ESCOs and shifting of the conversation towards closer engagement with government:** ESCOs need to continue to innovate their business models and engage policy-makers and regulators to get greater alignment on the economics of reliable, decentralized energy.
3. **Sector-wide experimentation and learning around interconnection pilots:** The various interconnection models described here are being piloted in various parts of India. Greater support should be given to these efforts which can inform implementation guidelines and build confidence among DISCOMs and regulators on the feasibility of operationalizing mini-grid interconnections.
4. **Establish national guidelines for intentional islanding of interconnected mini-grids:** Much of grid unreliability in rural India is from unpredictable load shedding. Interconnected mini-grids provide greater stability in rural areas with intentional islanding. The current CEA guidelines and draft mini-grid policy does not specifically address this, while international standards for intentional islanding do exist and simply need to be customized for Indian conditions.

Together, these four recommendations will substantially accelerate the integration of mini-grids and the legacy grid in a way that is beneficial to both the public sector and private players in the electricity sector, and most of all, to the millions of customers whose aspirations to reliable energy remain to be fulfilled.

1. Introduction

India's Electricity Access Challenge



India has significant gaps in access to modern, clean energy, particularly in rural areas and for low-income households and small businesses. Basic needs for lighting and some electronics can be met by dissemination of new consumer products (e.g. solar lanterns) and small solar home systems, but meeting India's energy needs for development will require substantially increasing access to electricity. Enabling small businesses, powering rural industry, and accommodating an expanding array of consumer appliances will require moving beyond lifeline provisioning. This, in turn, is likely to require moving beyond household-scale solutions to access based on some form of community-scale or larger grid.[1]

Toward these goals, aggressive timelines have recently been announced by the central government for extension of the national grid: electrification of all villages by May 2018 and 24x7 power for all households by March 2019.[2] These ambitious targets will address several of the key infrastructure gaps that prevent rural households from accessing grid electricity. However, last mile challenges are likely to remain in providing consistent power supply to these areas.

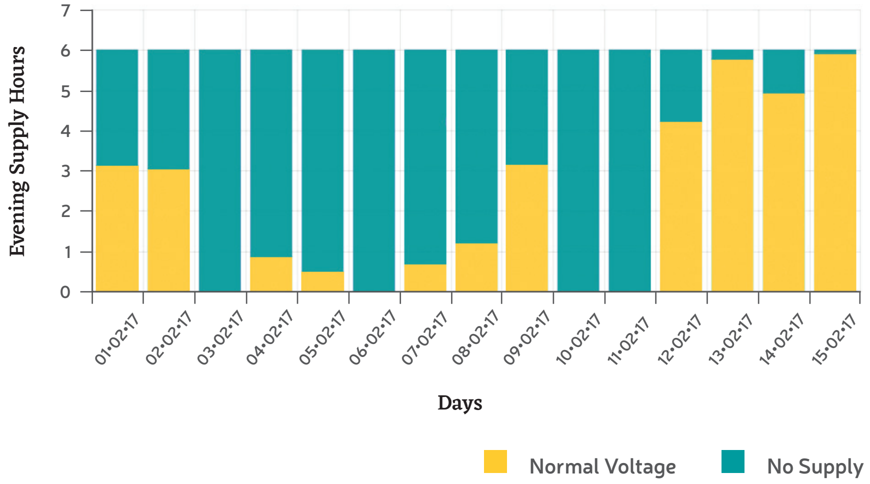
According to the January 2017 report of the Electricity Supply Monitoring Initiative (ESMI), only 16% of the monitoring locations in rural areas had the full six hours of power supply during peak evening hours.[3] Figures 1 and 2 below show power supply data for two selected monitoring locations in Uttar Pradesh. In both locations, over a period of two weeks in February 2017, there was significant variation in average power availability during peak hours, including several days with no supply at all. In Muradpur (Figure 2), even when power was available, the voltage levels remained well below the designated normal range.

The prevalence of these partially-electrified areas, in addition to the remote, unelectrified areas traditionally seen as the purview of mini-grids, points to an important role for decentralised solutions such as mini-grids, which can be deployed relatively quickly, provide local, renewable generation sources, and can be scaled to meet the needs of both household and productive loads.

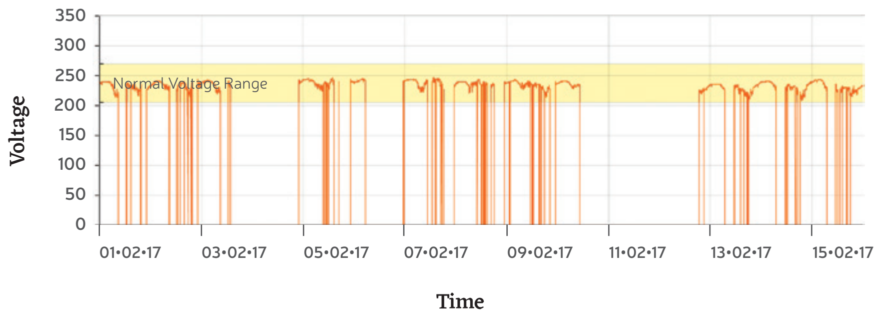
...important role for decentralised solutions such as mini-grids, which can be deployed relatively quickly, provide local, renewable generation sources, and can be scaled to meet the needs of both household and productive loads.

FIGURE 1:
Tewadih, Sitapur District,
Uttar Pradesh
(Source: www.watchyourpower.org)

Average Availability during 6 hours of evening (5pm—11pm)



Voltage Profile

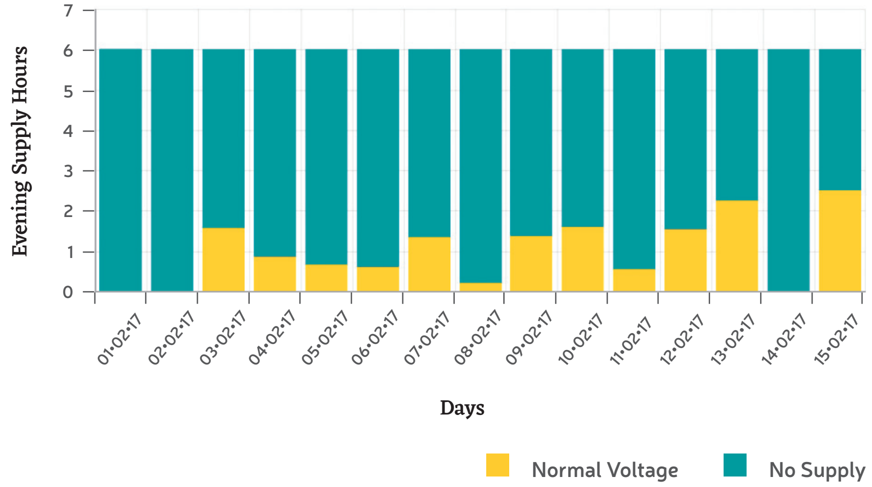


Further, it is important to establish a definition for electricity access that goes beyond the provision of infrastructure (poles, wires, customer connections) and power supply to also include ongoing services such as maintenance, metering, billing, and collections. The government's ambitious targets for rural grid infrastructure and generation capacity are commendable, but to reap the full benefits of these measures will also require locally-based support services that can improve reliability of supply and reduce losses from theft and unmetered connections. The National Electricity Policy (NEP), 2005 makes this exact point: "5.1.6 Necessary institutional framework would need to be put in place not only to ensure creation of rural electrification infrastructure but also to operate and maintain supply system for securing reliable power supply to consumers."[4]

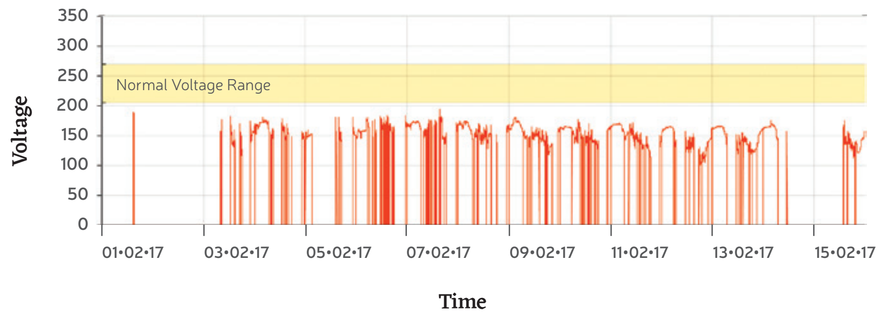
These services are challenging and costly to provide in many rural areas, yet essential for the level of reliability that can improve the quality of life and support economic development. It is this last-mile service challenge that is increasingly being met by small and

FIGURE 2:
Muradpur, Sitapur District,
Uttar Pradesh
(Source: www.watchyourpower.org)

Average Availability during 6 hours of evening (5pm—11pm)



Voltage Profile



It is this last-mile service challenge that is increasingly being met by small and medium enterprises (SMEs) known as energy service companies (ESCOs), who often provide the full range of services from generation to distribution to user services and maintenance.

medium enterprises (SMEs) known as energy service companies (ESCOs), who often provide the full range of services from generation to distribution to user services and maintenance.

These higher costs translate into a need to charge higher customer tariffs, relative to the highly-subsidised grid tariffs, which has led some to question the ability of the ESCO mini-grid model to compete in areas where the national grid has also been extended.[5] However, taking a narrow view of mini-grids and the grid as mutually exclusive options based on retail tariffs alone ignores the potential benefits from combining both scales of infrastructure. Therefore, it is important to move away from the narrative of competition between the grid and mini-grids and to find ways that the two can collectively provide better service to underserved areas in the most cost-effective manner. **Interconnection of mini-grids and the legacy grid is an important pathway to achieving this goal that can keep the door open for mini-grids to reach their full potential in accelerating electricity access in India.**

The primary objective of this project was therefore to develop and communicate a multi-dimensional understanding of the pathways to interconnection, building on the initial steps taken by policy makers and regulators at the central and state level.

This vision for the future of India's electricity system requires inputs and participation from both the public and the private sector actors who will shape this future landscape – ranging from central and state government policy makers and regulators to distribution companies (DISCOMs) to investors and companies of all scales. The primary objective of this project was therefore to develop and communicate a multi-dimensional understanding of the pathways to interconnection, building on the initial steps taken by policy makers and regulators at the central and state level. With this understanding, the study team developed recommendations for different ecosystem actors to work together more collaboratively toward this integrated future system.

The project activities consisted of a combination of primary research and secondary research, including extensive stakeholder interviews across the mini-grid and grid ecosystem. The consultations included meetings with government stakeholders at the central and state levels (Uttar Pradesh and Odisha), 17 mini-grid enterprises, 4 investors, numerous sector experts from academia and research organisations, and others with mini-grid project development experience. The secondary research was focused on developing a better technical understanding of options that exist for interconnection based on domestic and international experience, which was also vetted through further discussions with sector experts. The study team also conducted field visits to mini-grid sites in Uttar Pradesh and Odisha.

This report presents the main findings of this research and aims to deepen the conversation around interconnection to bring together a wide range of sector stakeholders that will play pivotal roles in moving toward this vision.

1.1

Evolving in Parallel: Public and Private Sector Approaches to Electricity Access in India

To understand the current dynamics between public sector and private sector providers of electricity services in India, it is useful to review several important institutional developments that have shaped this sector over time. A major milestone was the passage of the Electricity Act, 2003, which delicensed rural generation and distribution, opening the door to greater private sector participation in electricity provision for rural areas.

Under subsequent schemes such as the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) launched in 2005, the government sought to extend grid infrastructure to all areas except for those remote areas where grid extension was deemed economically infeasible. These areas were designated as off-grid, and solutions such as standalone mini-grids were encouraged via the Decentralised Distributed Generation (DDG) Scheme under RGGVY. In addition to mini-grid projects supported by government funds, a number of private sector ESCOs entered the market with a focus on establishing mini-grids in these off-grid areas and distributing electricity under the delicensed regime. However, the lack of transparency around grid planning was often seen as a risk to these business models given the prospect of competition from the heavily subsidised power supplied by the grid.

In time, the government's distinction between grid versus off-grid began to blur, as the DDG scheme was revised in 2013 to also include electrified areas with less than six hours of power supply per day. These under-electrified areas also presented a business opportunity for some ESCOs that felt they could compete with the grid on reliability of supply, despite needing to charge higher, unsubsidised tariffs in order to cover their costs. Over time, the mini-grid infrastructure being built by ESCOs has also evolved, in some cases following the same technical and safety guidelines as the Deen Dayal Upadhyay Gram Jyoti Yojana (DDUGJY) projects for extending the legacy grid.[6]

1.2

An Increasingly Favourable Policy Environment

More recent state level mini-grid policies and regulations openly acknowledge the supply gaps that persist even in administratively-designated electrified areas

The subsidiary role of mini-grids in national and state policy conversations has shifted considerably in the past year, with a number of important developments at the national and state level that have brought mini-grids to a more prominent role in the national conversation around rural electrification. Only recently has there been explicit policy recognition of the existence of this middle ground of under-electrified areas, as well as explicit assertion of the right of mini-grids to continue operating in these areas. More recent state level mini-grid policies and regulations openly acknowledge the supply gaps that persist even in administratively-designated electrified areas.[7]

Early this year, the first major development to impact the broader mini-grid sector was the amendment to the National Tariff Policy (NTP), which included a passage citing the risk of the grid reaching an area where a mini-grid operates prior to the end of its payback period and "a need to put in place an appropriate

JANUARY 2016
NTP Amendment

FEBRUARY 2016
UPNEDA Mini-grid Policy

APRIL 2016
UPERC Mini-grid Regulation

JUNE 2016
Draft National Mini-grid Policy

JUNE 2016
Draft JKSERC Mini-grid Regulation

JULY 2016
Draft BERC Mini-grid Regulation

FIGURE 3:
Timeline of recent mini-grid specific policy changes

regulatory framework to mandate compulsory purchase of power into the grid from such micro grids".[8]

Later in 2016, the advent of state level policies and regulations for mini-grids from the Uttar Pradesh New & Renewable Energy Development Agency (UPNEDA) and the Uttar Pradesh Electricity Regulatory Commission (UPERC) set the foundation for state level efforts to encourage and support mini-grid development. Subsequently, draft mini-grid regulations following the UPERC example were posted for comment on the websites of the Jammu & Kashmir State Electricity Regulatory Commission (JKSERC)[9] and Bihar Electricity Regulatory Commission (BERC)[10]. At the same time, the Ministry of New and Renewable Energy (MNRE) published a draft national mini-grid policy for public comments on its site, providing a framework for all states to follow.

1.3

Moving from Competition to Cooperation

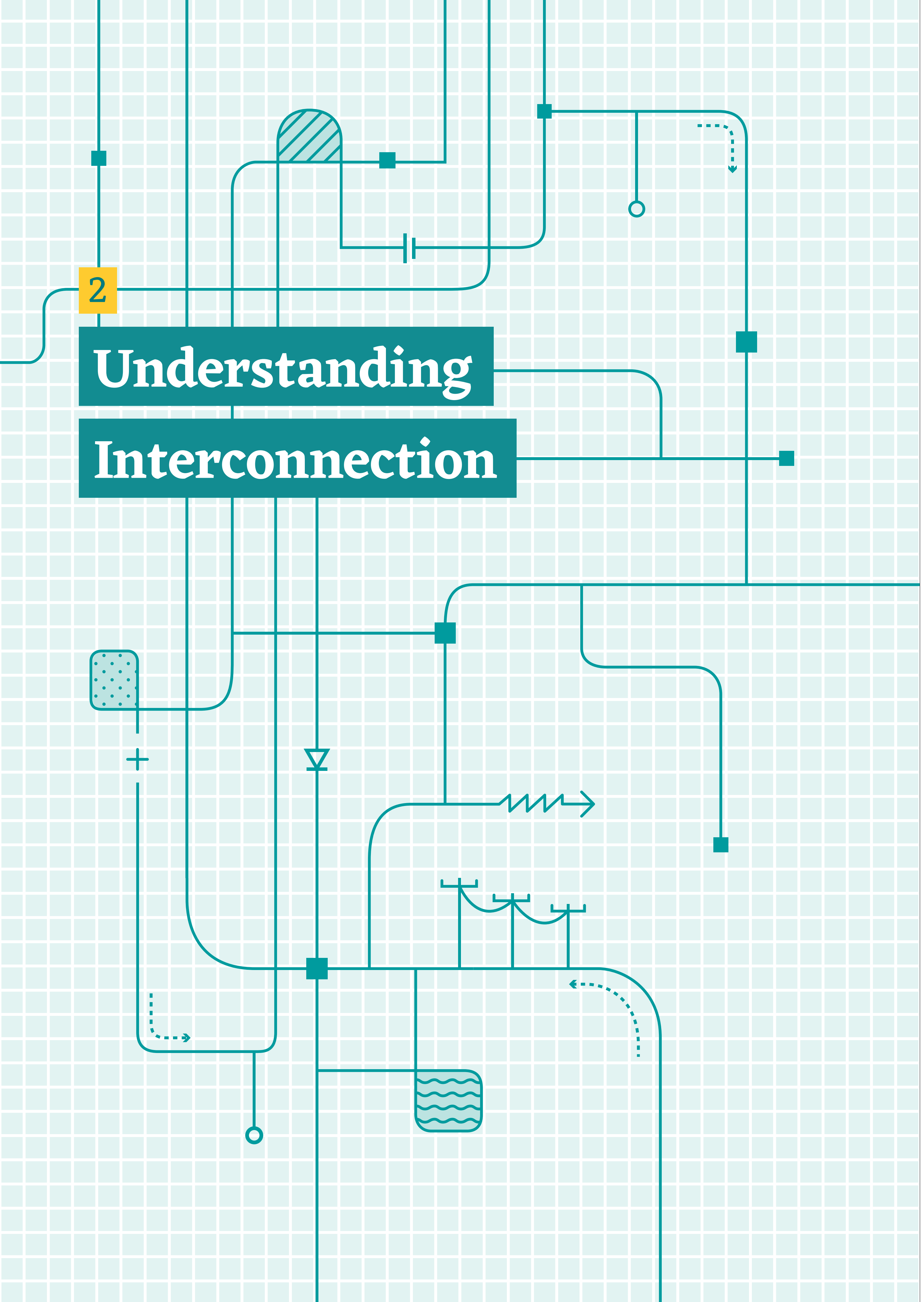
Even as the reach of the grid, and by extension the domain of DISCOMs, expands to more rural villages in India, there is minimal confidence among private and public sector stakeholders alike that DISCOMs can rise to meet the challenge of providing reliable service to rural customers. It is this sustained service provision which defines true energy access more than the mere existence of poles, wires, and even a household grid connection.

The smaller entrepreneurial initiatives of ESCOs in mini-grid development have been faster to take advantage of developments in mobile-money based payments, advanced controllers and meters, and other means of making the relationship between consumer and provider of electricity services more interactive. This experience could prove to be valuable as a "plug in" for the larger utility-scale grid and would greatly benefit the legacy electricity system if integrated in a way that is commercially viable for ESCOs and in a structure that is agreeable to DISCOMs and electricity regulators alike. Furthermore, the emphasis on energy efficiency that is intrinsic to all ESCOs' product offerings is a feature that would also have significant benefits for customers and the management of the main grid as well.

The combined strengths of the decentralised and centralised sources of electricity supply and servicing can be harnessed through interconnection.

On the other hand, as customer electricity consumption rises along with their developing aspirations, it will also be beneficial to link into the legacy grid to meet rising demand at a lower overall cost to end customers. The combined strengths of the decentralised and centralised sources of electricity supply and servicing can be harnessed through interconnection.

FOOTNOTES
[1] Alstone, P., Gershenshon, D., and D. Kammen, (2015) "Decentralized energy systems for clean energy access," *Nature Climate Change – Perspective.* March 25, 2015.
[2] http://economictimes.indiatimes.com/industry/energy/power/budget-2017-all-villages-to-be-electrified-by-2018-says-arun-jaitley/articleshow/56917518.cms
[3] Source: www.watchyourpower.org
[4] http://powermin.nic.in/en/content/national-electricity-policy
[5] The Climate Group (2015). *The Business Case for Off-Grid Energy in India*. Available from: http://www.theclimategroup.org/_assets/files/The-business-case-for-offgrid-energy-in-India.pdf
[6] The DDUGJY scheme replaced RGGVY in 2015
[7] http://www.ddugjy.gov.in/mis/portal/DDG/Amendment-to-DDG-Guidelines-dated-01.04.2013.pdf
[8] http://powermin.nic.in/sites/default/files/webform/notices/Tariff_Policy-Resolution_Dated_28012016.pdf
[9] http://www.jkserc.nic.in/Draft%20JKSERC_Mini%20Grid%20Renewable%20Energy%20Generation%20and%20Supply_%20Regulations.pdf
[10] http://berc.co.in/media/Notice%20%20Adv/draft_min%20grid%20regulations.pdf



2 Understanding Interconnection

A key finding from the stakeholder discussions was that there was a limited understanding of and experience with grid interconnection of mini-grids in India, since few operational interconnections have been completed. However, the recent developments in the policy and regulatory environment for mini-grids necessitates a deeper conversation around interconnection and its implications from a wider range of sector participants who can collectively work toward a vision for the future electricity system in India.

A key finding from the stakeholder discussions was that there was a limited understanding of and experience with grid interconnection of mini-grids in India, since few operational interconnections have been completed.

What follows is a brief survey of the main issues related to interconnection in order to inform this wider audience, with a focus on two core areas:

- The fundamental concepts that influence the range of impacts from a shift toward more integrated decentralised infrastructure (including those from a commercial, infrastructure, policy, and regulatory perspective)
- The range of models for how this integration may occur and the implications for the evolving roles of DISCOMs and ESCOs

The detailed technical requirements for interconnection are beyond the scope of this report, although Chapter 4 will cover several high-level infrastructure and equipment considerations for the different interconnection models presented. Resources for further reading are referenced in the relevant sections.

This discussion also builds on the developments in recent years related to grid connectivity of rooftop solar installations, which have helped to establish baseline requirements for safely connecting a decentralised solar photovoltaic (PV) generation source to the grid. However, beyond those requirements, several additional aspects must be addressed for interconnection of mini-grids:

- requirements for connecting other types of distributed renewable generation to the legacy grid, which may require different control features from those used in solar PV systems
- the treatment of the mini-grid power distribution network (PDN) which is used to supply electricity to customer loads

2.1

Interconnection in the Indian Context

Fundamental to the understanding of interconnection is a familiarity with the different arrangements by which this interconnection can take place and under which scenarios a given form may be preferred. A familiarity with these models is important for a range of stakeholders, not just technical design personnel, because they can have significant system design, customer, and commercial implications.

The models described in this chapter represent different arrangements through which the national grid and a mini-grid may interact once both are present in the same area. These scenarios were derived from a combination of sources, including technical literature on interconnection, existing policies and regulations in India, and discussions with mini-grid operators and a number of sector experts.[11]

A distinguishing feature of the electricity access landscape in India is the fact that it is not uncommon to have the mini-grid and the main grid operating in parallel in areas where grid supply is poor, and that for some ESCOs, parallel operation is considered the preferred arrangement in the near term. This arrangement is in contrast with the experience of sector experts in parts of East Africa such as Kenya and Tanzania, which were seen to have clearer demarcations between grid connected and off-grid areas.[12]

The models described in this chapter represent different arrangements through which the national grid and a mini-grid may interact once both are present in the same area.

Furthermore, many descriptions of interconnection include the narrative of "grid arrival", implying that the mini-grid is always established in areas prior to grid connectivity, which is sometimes, but not always the case in India. Several areas of tension between conventional views of interconnection and the findings of extensive consultations are summarised in the following table.

Conventional View[13]	Practical Reality
Integration with the main grid is needed as an ***exit*** route for an ESCO	There are a number of cases when the ESCO may continue operations in the near-medium term after integration, especially in areas where power supply remains sporadic and/or poor quality after grid extension
The only policy certainty sought by ESCOs is for a route to physically interconnect with the main grid and export power	ESCOs sought clarity on this option plus several others including: ▪ the right to continue operations in areas that have grid connectivity even without a physical connection to the grid ▪ the ability to pursue other types of integration with the grid, including as a bulk customer, purchasing power from the grid instead of exporting
ESCOs prefer to establish mini-grids in un-electrified areas to avoid competing with the grid	Though a number of ESCOs agreed with this view, some were able to establish a customer base in areas with existing grid connectivity, especially areas where markets already exist for grid backup solutions such as diesel generators, battery packs, etc. A single customer may have both a mini-grid and grid connection.

A number of these perspectives have since been addressed in Uttar Pradesh's mini-grid policy and regulation (a more detailed discussion of the current policy and regulatory landscape for mini-grids is covered in Chapter 5).

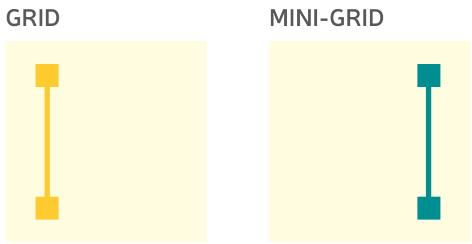
2.2

Interconnection Models

Given the unique features of the electricity access landscape in India, allowing for a range of models for interconnection can permit the form of integration that is most beneficial for all stakeholders in a given area.

These models are summarised in the table that follows. For each model, a simplified schematic presents the basic arrangement.

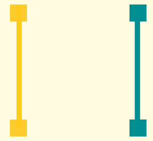
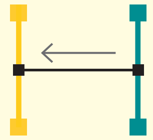
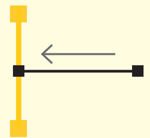
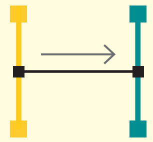
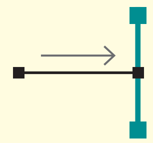
- The main grid network is represented by a yellow line.
- The mini-grid (including generation assets and PDN) is represented by a green line.
- A black line between the two denotes a physical link between the two networks, and the arrow denotes the direction of power flow – whether it is imported from or exported the main grid from the mini-grid.



The nature of interconnection could transition over time from one model to another depending on power supply dynamics, economics, etc.

Though each model is described separately, over time they need not be mutually exclusive for a given area. The nature of interconnection could transition over time from one model to another depending on power supply dynamics, economics, etc. For example, an ESCO that interconnects to the main grid to export only the excess generation may later choose to export all power generated, effectively becoming an Independent Power Producer (IPP) with no local distribution responsibilities. This scenario may occur if the grid supply in the region improves over time to the extent that most customers prefer to only have a grid connection.

In the chapters that follow, these models are evaluated across three critical dimensions of interest to a range of stakeholders: commercial impacts, technology and infrastructure requirements, and policy and regulation. While these considerations are explored separately, they are closely interlinked, as illustrated in the figure below. Chapters 3, 4, and 5 review these relationships in more detail.

	SCHEMATIC	DESCRIPTION + ROLES OF ESCO AND DISCOM
Parallel Operation		Prior to physical interconnection, in areas where the grid supply is unreliable and/or unpredictable, there may be areas where both the grid and mini-grid are operating. Some customers may have both connections. Roles: • ESCO continues generation and distribution independently • DISCOM continues distribution independently
Interconnection with Partial Export		The ESCO interconnects its mini-grid to the main grid and exports only the excess power generated, beyond that which is consumed by its customers, to the main grid. Roles: • ESCO continues generation and distribution independently, also supplies excess generation to DISCOM grid • DISCOM continues distribution independently
Interconnection with Full Export		The ESCO transitions into the role of an IPP. The ESCO PDN is either scrapped, moved to another location, or could be purchased by the DISCOM and potentially integrated into its existing network in some manner. Roles: • ESCO continues generation only, unless it becomes a Franchisee of the DISCOM (a contractual arrangement whereby the ESCO undertakes distribution responsibilities on behalf of the DISCOM) • DISCOM continues distribution, unless ESCO takes over these responsibilities as Distribution Franchisee
Interconnection with Import		The ESCO becomes a bulk customer of the DISCOM and imports power to charge its battery bank, while continuing to supply to its customers through its own PDN. Roles: • ESCO continues generation and distribution independently, becomes customer of DISCOM • DISCOM continues distribution independently
Interconnection with Import, Mini-grid PDN		When the grid reaches an area where a mini-grid is already established, rather than establish its own PDN, one of two scenarios for utilising the mini-grid's PDN may occur. Options: 1. The DISCOM connects and feeds power into the mini-grid PDN. ESCO continues generation to supplement grid supply through its PDN and assumes all distribution responsibilities (but would likely need to become a Licensee/Franchisee) ***OR*** 2. The DISCOM purchases the PDN assets of the ESCO and uses them as the foundation for its network. The ESCO transitions into the role of an IPP with its generation asset, exporting to the grid, and the DISCOM assumes distribution responsibilities. Otherwise, the ESCO may also continue distribution responsibilities as a Franchisee of the DISCOM.

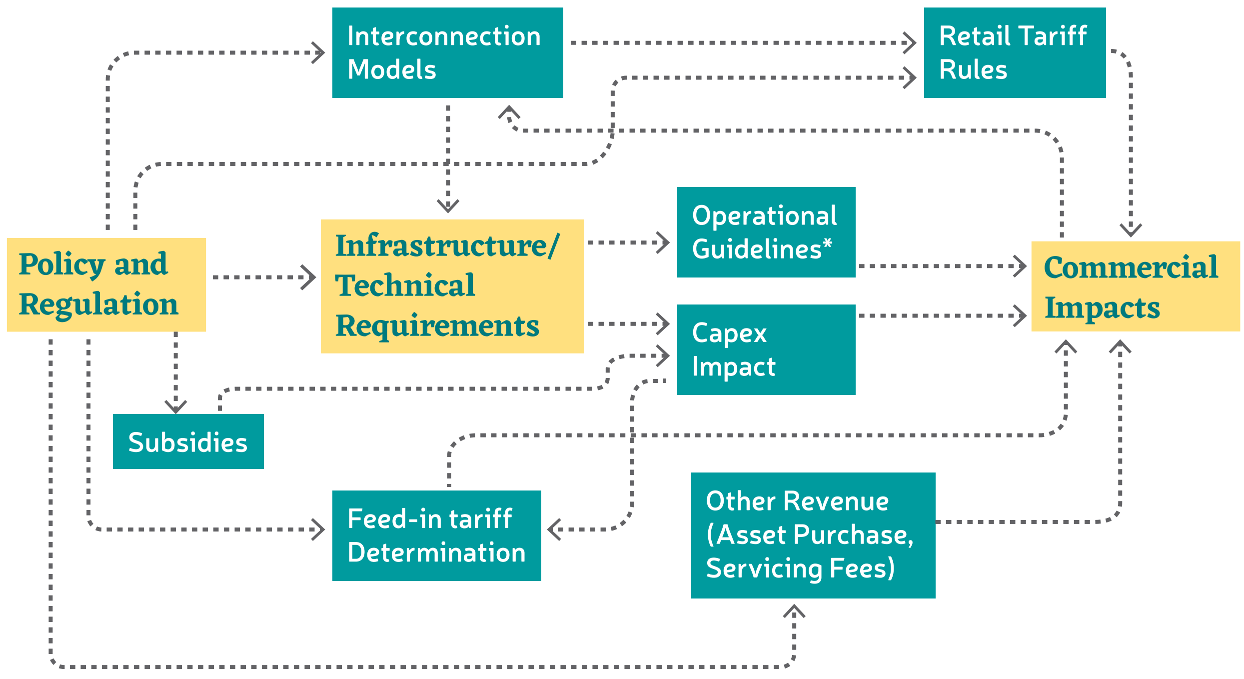


FIGURE 4:
Primary Impacts of Various Interconnection Models

In this figure, the term *operational guidelines* refers primarily to the ability for an interconnected mini-grid to continue to supply power during periods when the main grid has ceased supply due to load shedding (in contrast with periods when supply must be curtailed for safety reasons when repairs are required). The current regulations that would apply to interconnection of mini-grids and the main grid do not permit this activity, known as *intentional islanding*, which reduces the potential hours of supply from the mini-grid as well as the potential benefit to customers of having the mini-grid as a backup source of power.[14] The MNRE draft national mini-grid policy suggests proper controls may be put in place "to the satisfaction of DISCOM" to enable this option, but the need for clear guidelines from the CEA was referenced in both the literature on interconnection and interviews with stakeholders.[15]

FOOTNOTES

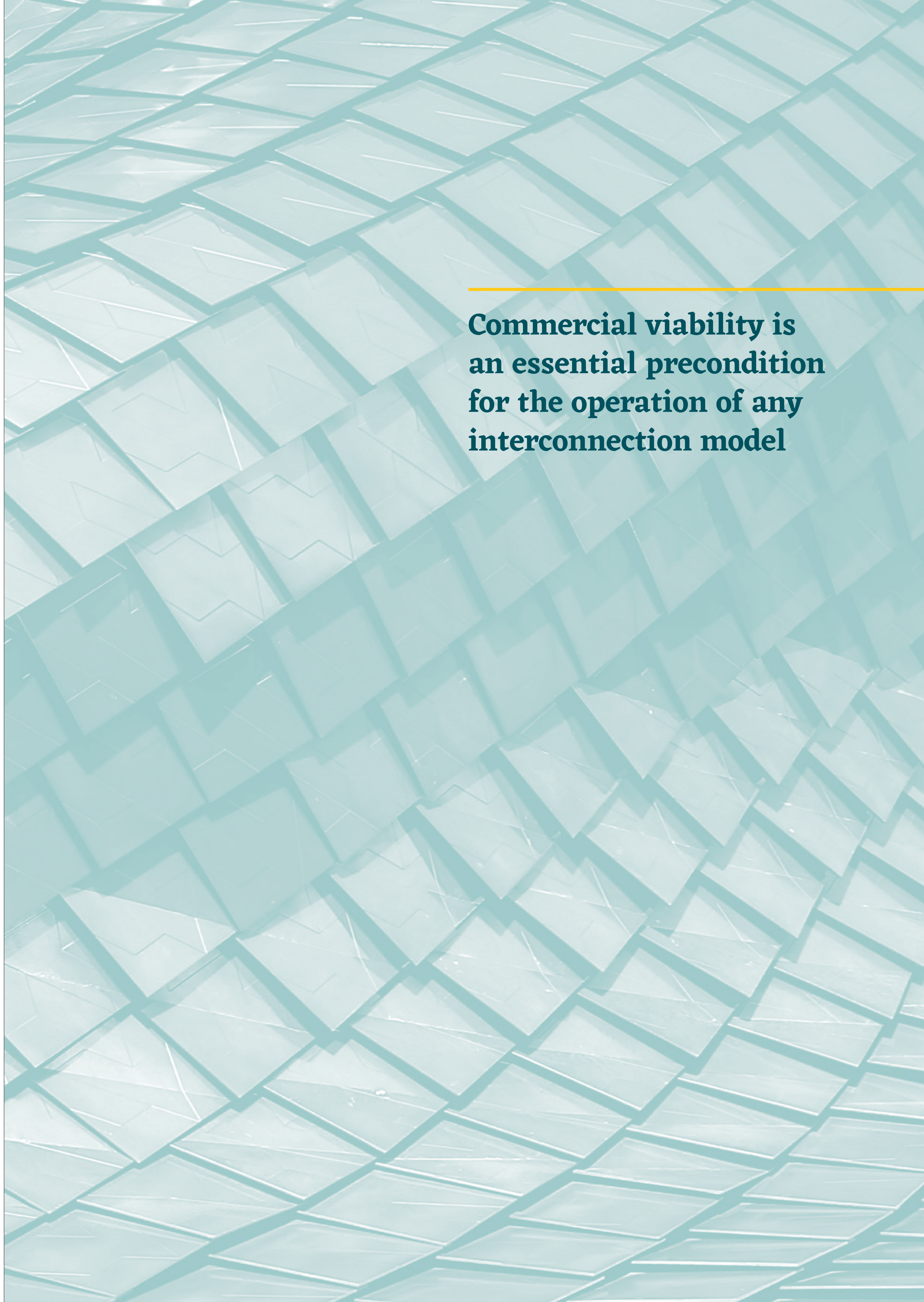
[11] In particular, see: Greacen, Chris et al. (2013). *A Guidebook on Grid Interconnection and Islanded Operation of Mini-grid Power Systems Up to 200kW*. [Available at: https://publications.lbl.gov/islandora/object/ir%3A158819/datastream/PDF/view]

[12] Recently some ESCOs in Africa have started advocating for integrated mini-grids: http://www.powergen-renewable-energy.com/micro-grids-for-the-future-of-power/

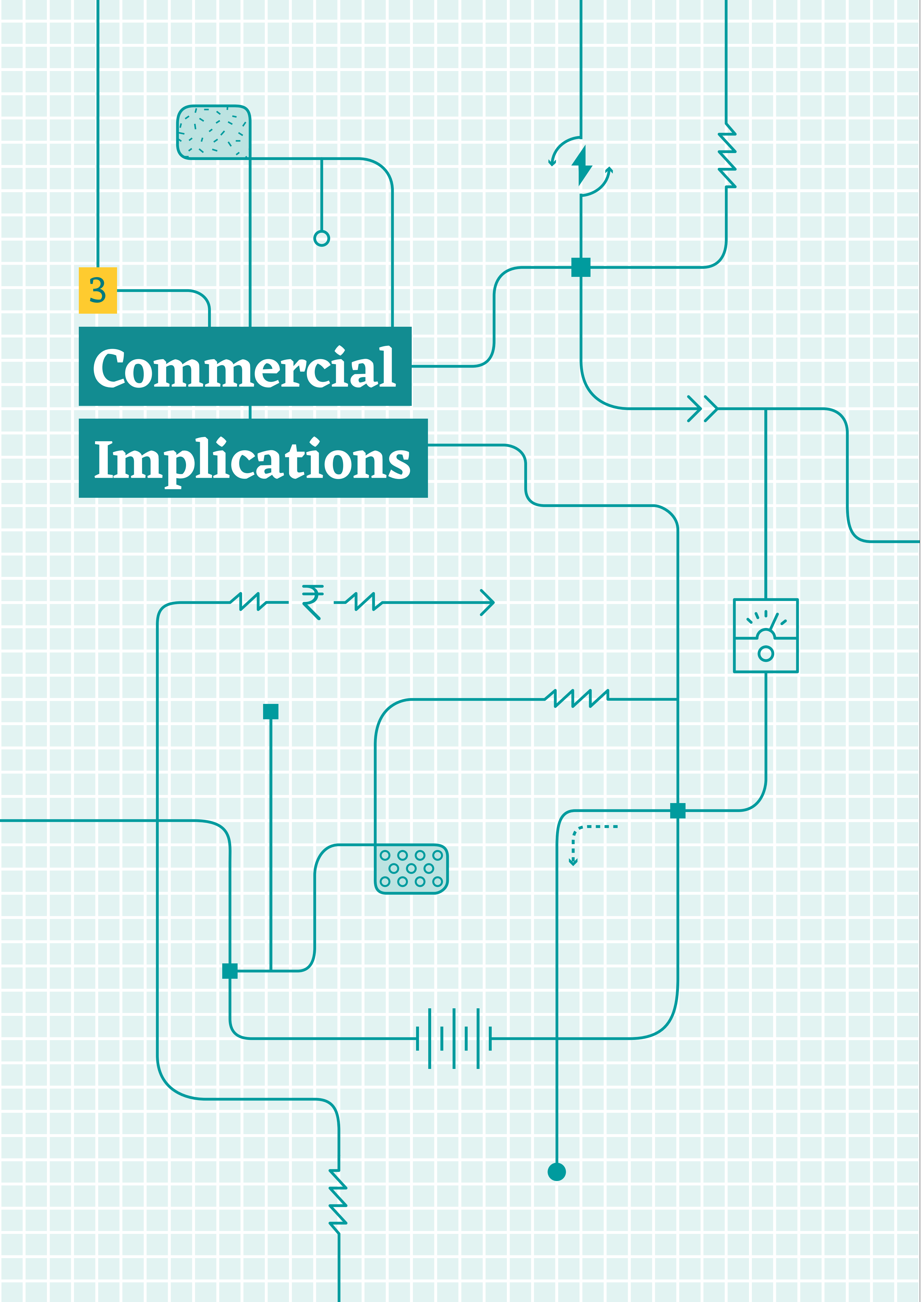
[13] Sources: stakeholder interviews; The Climate Group (2015). *The Business Case for Off-Grid Energy in India*. Available from: http://www.theclimategroup.org/_assets/files/The-business-case-for-offgrid-energy-in-India.pdf

[14] CEA (Technical Standards for connectivity of the Distributed Generation Resources) Regulations, 2013 (http://www.cea.nic.in/reports/regulation/distributed_gen.pdf)

[15] Magal, A. et al (2014). *Grid Integration of Distributed Solar Photovoltaics (PV) in India*. Prayas (Energy Group)



Commercial viability is an essential precondition for the operation of any interconnection model



3 Commercial Implications

Understanding the commercial impacts of interconnecting a mini-grid to the main grid is essential for financing providers and ESCOs, but it is also critical that those shaping the policies and regulations for mini-grid interconnection factor in these considerations as well. In the absence of a clear economic rationale, these policies are unlikely to result in many operational interconnections. Easing the pathway toward integration with the main grid may also be a promising route to scale for the mini-grid sector that can also improve the last mile service quality of the main grid.

3.1 Business Model Impacts of Interconnection

To frame the commercial impacts related to interconnection, it is important to place them in the context of the broader determinants of the commercial viability of a mini-grid. These determinants can be evaluated under different scenarios for the status of grid connectivity in the same location. As outlined in Figure 5, there are three broad scenarios that may exist.

1. The mini-grid is operating in an area that is unlikely to gain grid connectivity. These are increasingly limited in number due to the central government's expanded plans for grid extension, but they may include smaller habitations within electrified villages (hamlets) and remote areas such as protected forest lands.
2. The mini-grid is operating in an area that either has or is expected to get a grid connection.
3. The mini-grid is operating in an area with grid connectivity and is integrated with the grid via one of the interconnection models.

As emphasised in conversations with investors, the fundamentals of each ESCO's business model remain a central consideration. If grid connectivity is also present, then the commercial viability of the mini-grid depends on its ability to effectively compete and retain customers. While the ability to compete with the grid on retail (or customer) tariffs is often cited as a concern for mini-grids, in practice some ESCOs have found that customers are willing to pay the higher mini-grid tariff in exchange for greater reliability of supply.

Understanding the commercial impacts of interconnecting a minigrid to the main grid is essential...

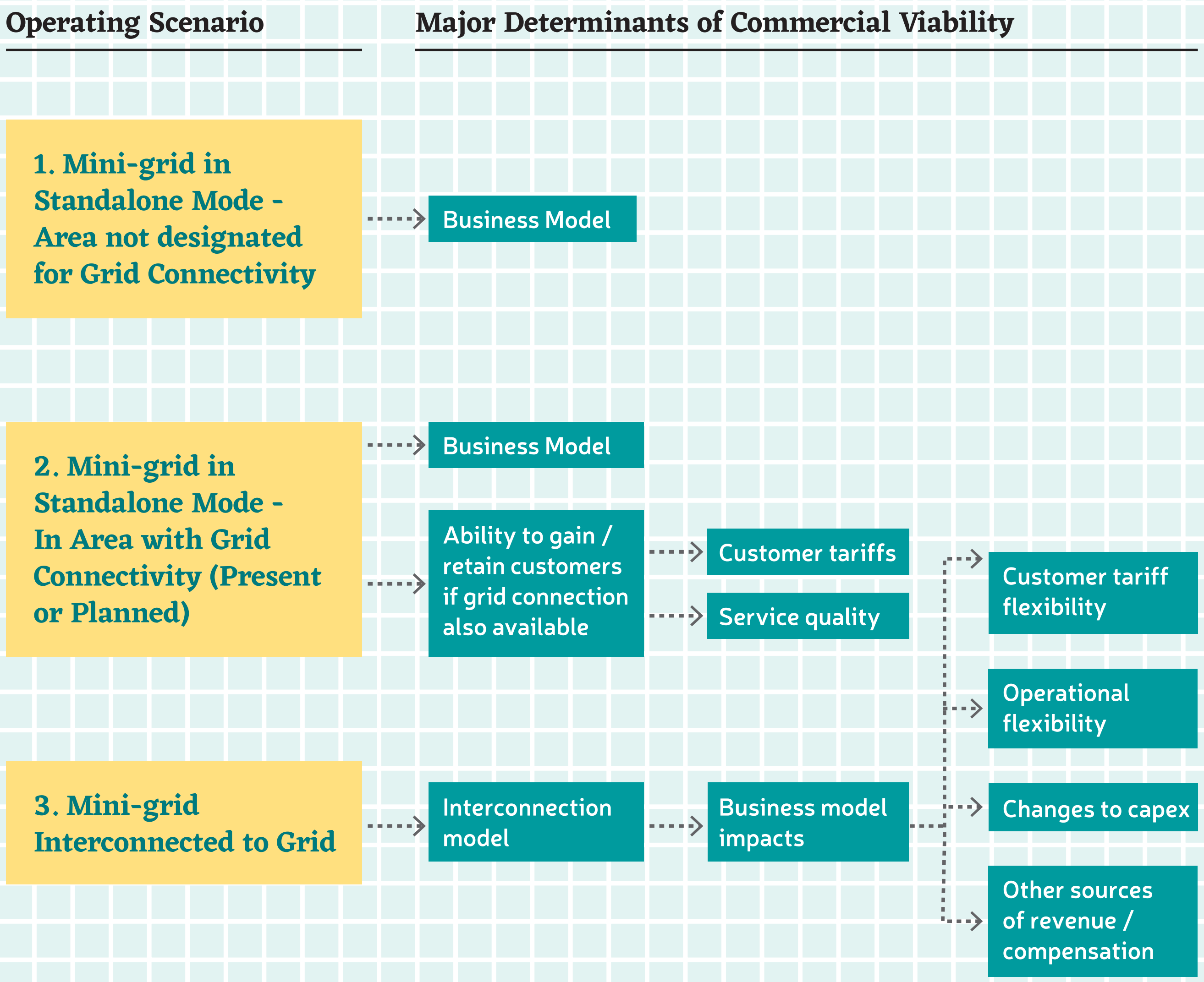


FIGURE 5:
Analysis of Operating Scenarios

Additionally, in some areas where markets already exist for power backup solutions such as diesel generators or battery packs, mini-grids are often better able to compete with those options and can leverage an existing customer base with a willingness to pay for these products and services.

If an ESCO seeks to interconnect its mini-grid to the main grid, the impacts on its business model will naturally be a function of which interconnection model is applied. These impacts, as shown in Figure 5, can be broadly grouped into four categories:

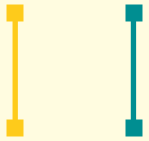
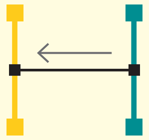
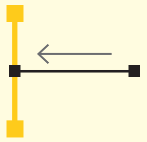
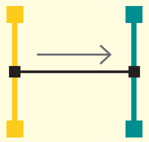
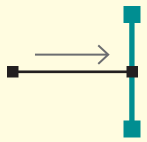
- **Customer tariff flexibility** – does the ESCO retain the ability to set its own customer tariffs, or does the interconnection model result in a requirement to charge only the much lower regulated tariff?
- **Operational flexibility** – under what conditions is the ESCO permitted to sell the power it generates (either directly to customers or to the grid)? If the mini-grid must cease supply in the case of load shedding, this can negatively impact revenue.
- **Changes to capital expenditure (capex)** – these can be either positive or negative depending on the model (see Table 4 below). The magnitude of the change may depend on the degree of infrastructure upgrades required in a given model (see Chapter 4 for further discussion).
- **Other sources of revenue/compensation** – this could include the applicable feed in tariff for power exported to the grid, purchase of assets by the DISCOM (such as the mini-grid PDN), or other fees paid to the ESCO as part of any Franchisee arrangement.[16] Compensation above and beyond the feed in tariff may be critical if this tariff is linked to those defined for larger scale projects that only include generation infrastructure, whereas the mini-grid cost also includes the PDN and operational costs (and does not benefit from the same economies of scale).

3.2 Impact by Interconnection Model

Given the range of commercial impacts described in the previous section, the table below summarises the key features of each model, the associated revenue and cost implications, as well as the economic rationale for each model. In cases where a particular model has not yet been clearly defined in any existing policy or regulation, the important outstanding questions are highlighted.

FOOTNOTES
[16] For example, some Franchisee arrangements cover Metering, Billing, and Collection Services which are paid to the Franchisee as a fixed fee per month per customer by the DISCOM. This structure is currently being used by the Ajmer DISCOM. (http://energy.rajasthan.gov.in/content/dam/raj/energy/avvnl/pdf/News/Draft%20RFP%20MBC%20Services%20Bhilwara%20City.pdf)

TABLE 1: Key features of interconnection models, associated revenue and cost implications

MODEL	SCHEMATIC	REVENUE AND COST IMPLICATIONS	MODEL RATIONALE
Parallel Operation		• Enables separate tariff and billing for mini-grid and grid connections • No incremental costs except in case of state specific standards for all mini-grids; however, avoids the cost of interconnection equipment	• The mini-grid capacity is small enough and/or it has minimal excess generation and/or the feed in tariff is at a level where it does not make economic sense to invest in the equipment required to interconnect and feed power into the grid • If grid supply to the area is unreliable, it is also more likely that the mini-grid will have a steady customer base such that a standalone commercial model continues to be viable
Interconnection with Partial Export		• Enables separate tariff and billing for mini-grid and grid connections • ESCO receives feed in tariff from DISCOM for power exported to the grid • Per UPERC mini-grid regulation, ESCO bears the cost of infrastructure and meters from its system up to the interconnection point, and DISCOM bears the cost of metering at the interconnection point • If ESCO can reliably export any excess generation, this could reduce storage expenditures	• The mini-grid capacity is large enough relative to its aggregate customer demand that it has excess generation that can be monetised • The feed in tariff provides sufficient compensation relative to the cost of generation and cost of interconnection to be borne by the ESCO • ESCO operations will not be subject to frequent interruption, meaning: • intentional islanding is permitted in areas with frequent load shedding, or • grid supply is continuous (but possibly low voltage, etc.) in the area of operations
Interconnection with Full Export		• ESCO receives feed in tariff from DISCOM for power exported to the grid • Per UPERC mini-grid regulation, mini-grid operator bears the cost of infrastructure and meters from its system up to the interconnection point, and DISCOM bears the cost of metering at the interconnection point • If ESCO can reliably export power, this could reduce storage expenditure	• The grid supply is of sufficient quality and reliability that the ESCO does not have a sufficient retail customer base • The feed in tariff provides sufficient compensation relative to the cost of generation and higher cost of interconnection to be borne by the ESCO
Interconnection with Import		• Enables separate tariff and billing for mini-grid and grid connections • ESCO pays DISCOM for initial connection and for power consumed (tariff to be determined) • To be determined whether there would be any subsequent regulation of the retail tariff set by ESCO	• The mini-grid has storage capability (primarily solar PV systems) • The mini-grid has a power deficit relative to its aggregate customer demand. Grid power can be used to supplement mini-grid generation, and in the case of hybrid systems, can offset more expensive sources used to balance intermittent renewables • Grid provides at least minimal supply in the area in which the ESCO operates • The tariff rate for the ESCO is lower than its cost of generation, which could also benefit ESCO customers if cost savings are passed through
Interconnection with Import, Mini-grid PDN		• Neither variant of this model has been included in any final regulations to date, so there are several open questions that would need to be addressed in any forthcoming regulation. ***If DISCOM feeds power into mini-grid PDN:*** • Would DISCOM pay the ESCO for use of its PDN (wheeling charges)? • Would ESCO need power purchase agreement (PPA) with DISCOM (in which ESCO pays DISCOM for bulk power supply)? • Who bears the cost of any required system upgrades? • Who defines retail tariffs? ***If DISCOM purchases PDN and ESCO becomes an IPP:*** • ESCO receives feed in tariff from DISCOM • Per UPERC mini-grid regulation, mini-grid operator bears the cost of infrastructure and meters from its system up to the interconnection point, and DISCOM bears the cost of metering at the interconnection point • ESCO receives the depreciated PDN asset value from DISCOM • Who bears the cost of any required upgrades to the PDN?	• The revenue and cost implications will depend on the share of responsibilities for incremental costs and the magnitude of these costs to enable these models

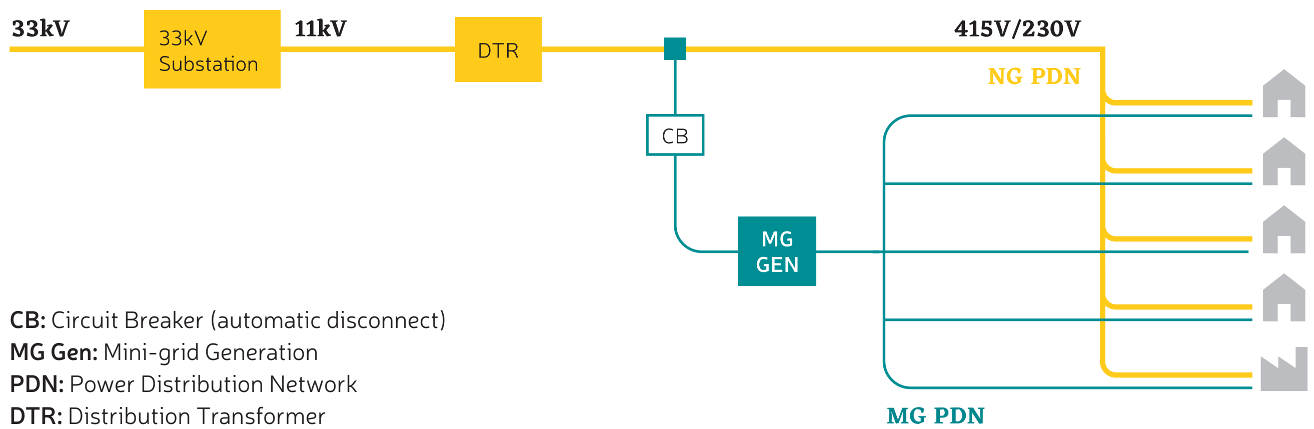
4 Technology and Infrastructure Implications

The literature review and discussions with experts from the mini-grid (and related) sectors in India yielded a wide range of technical considerations for interconnection scenarios that account for the complete mini-grid infrastructure (generation and distribution related assets). These considerations can be more intuitively understood when mapped to the relevant parts of this system. The schematic that follows is a simplified representation of a grid-connected mini-grid system that will be used throughout the rest of this section.

In the schematic, the distribution level national grid (NG)- the section of that network below 33 kilovolts (kV) - is represented by the yellow line from the left. Voltage is stepped down to 11kV at the substation level and then further stepped down by the distribution transformer (DTR) to low tension (LT) levels, which are 415 volts (V) for three phase power and 230V for single phase supply. For simplicity, this network is shown connecting to each of the households and one commercial customer, although in practice not all may have such a grid connection.

The green lines represent the mini-grid system, including the generation assets and the mini-grid PDN which is also linked to all of the households and commercial customer. This scenario reflects the parallel networks that are present in some locations in India. In addition to customer loads, the mini-grid here is also shown interconnecting with the main grid (with an automatic disconnect in place for safety reasons as required by regulation).[17]

FIGURE 6:
Mini-grid and Grid Connection Schematic



CB: Circuit Breaker (automatic disconnect)
MG Gen: Mini-grid Generation
PDN: Power Distribution Network
DTR: Distribution Transformer

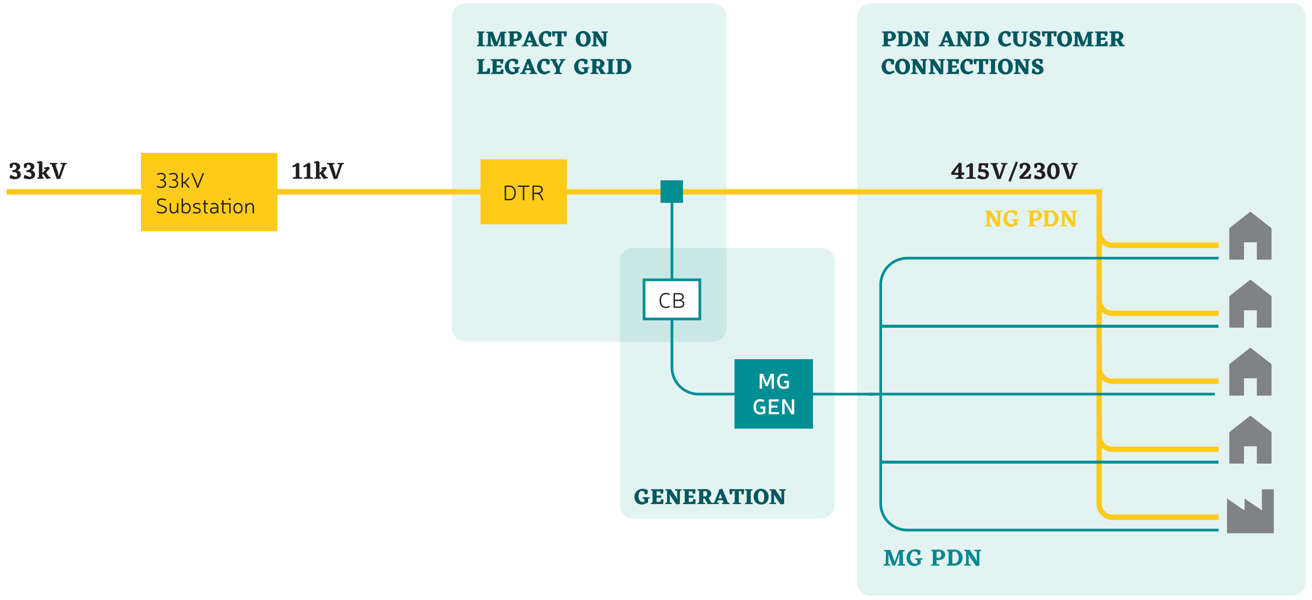


FIGURE 7:
Integrated System Segments

Next, the technical considerations can be grouped into several categories based on which parts of the integrated system are most impacted, although there are clearly interdependencies between all of these parts. The sections that follow will proceed through each of these system categories – linkage to and impact on the legacy grid, generation assets, and PDN and customer connections – to detail the considerations that are relevant to most if not all of the interconnection models to be presented.

4.1

Linkage to and Impact on the Legacy Grid

One of the first and most critical considerations in interconnecting mini-grids with the main grid (in cases where power will flow from the mini-grid to the grid) is how to achieve this integration safely and with minimal impact on the stability of the legacy grid at the point of interconnection.

Safe interconnection typically involves requirements related to six factors that govern power quality and synchronised operation with the grid: harmonics, flicker, direct current (DC) injection, voltage range, frequency range, and anti-islanding protection.[18] International standards set by the Institute of Electrical and Electronics Engineers (IEEE) and International Electrotechnical Commission (IEC) set forth recommendations for these parameters, and Central Electricity Authority (CEA) regulations for interconnection of distributed generation are modelled after these guidelines. However, these standards are not specific to interconnection of mini-grids, and some experts have recommended that international best practices for mini-grid interconnection are still needed.[19]

The location of the point of interconnection can have a material impact on the cost and technical challenges of interconnection from both the mini-grid and utility viewpoint.

The selection of the point of interconnection itself is another important factor. The current CEA guidelines are meant to apply broadly to any interconnection below 33kV but do not specify at which point after the 33kV substation the interconnection should occur – this is left to the DISCOM to determine after conducting an interconnection study. Some states have notified schedules for the point of interconnection based on the generation capacity of rooftop and ground-mounted solar PV systems, while others maintain the DISCOMs' discretion. Due to the lack of a specific directive there are concerns about how DISCOMs would approach these decisions in practice.[20] The location of the point of interconnection can have a material impact on the cost and technical challenges of interconnection from both the mini-grid and utility viewpoint.

Option 1: Interconnection point on the LT Network

Similar to most smaller rooftop solar installations, one option is that mini-grids may seek interconnection to the LT distribution network (415V/230V line for three phase and single phase, respectively). As shown in Figure 8 this would allow interconnection points in closer proximity to the mini-grid, which can reduce transmission losses and lower the cost of interconnection infrastructure. However, to connect to the LT network requires that there is a sufficient power deficit in the area to take the full quantum of exported power, that there is sufficient utility infrastructure to integrate and manage the added generation source at these points, and that rural feeder lines are live. In rural India, the latter two requirements are less likely to be met according to conversations with a range of stakeholders.

FIGURE 8:
Interconnection point on LT grid

Option 2: Interconnection point on the 11kV Network

The other possibility is for the mini-grid to interconnect to the 11kV network as depicted in Figure 9. On one hand, some stakeholders suggested that the utility infrastructure would be more robust at

...the economic rationale for interconnection would also depend on the quantum of power the ESCO expects to export and the applicable feed-in tariff.

the 11kV level to manage integration of the additional generation resource. However, since mini-grids are typically designed to generate and distribute power at LT voltage levels, connecting to the 11kV network would require installation of a step-up transformer to match the grid voltage. In addition, the distance to the interconnection point would be farther than a LT network connection (possibly by several kilometres) and would increase the length of cable required. The cost of such an upgrade could be significant - one expert estimated that a transformer plus 5km of cable could cost up to INR 15 lakhs, not including the value of any transformer and transmission losses. As per UPERC mini-grid regulations, the mini-grid operator would bear this cost, which could leave many such interconnections economically unviable.

FIGURE 9:
Interconnection point at 11kV network

Of course, the economic rationale for interconnection would also depend on the quantum of power the ESCO expects to export and the applicable feed-in tariff.

Finally, a longer-term consideration for grid impacts will be the applicable penetration limits for mini-grids connecting to the main grid, under a scenario where there could be multiple mini-grids seeking to interconnect to the same grid distribution network. This is another area where the mini-grid sector may benefit from the lessons learned (and still in progress) in the grid-connected rooftop solar sector, where several states have defined penetration limits, but experts recommend development of a uniform standard for all of India.[21]

4.2 Mini-grid Generation Assets

The nature of mini-grid generation assets and the resulting equipment requirements for interconnection are closely linked to the synchronisation requirements described in the previous section. In particular, mini-grids that supply alternating current (AC) electrical

power can do so using one of the following generator types (with the exception of hybrid mini-grids, which may have two types):[22]

- induction (asynchronous generators)
- synchronous generators (alternators)
- inverters

While solar PV mini-grids with inverters to generate AC power are the most common mini-grid type in India, there are also numerous installations using sources such as micro-hydro, biomass, and biogas that may use induction or synchronous generators. These distinctions are important because for some generator types, the equipment upgrades required to meet the synchronization requirements of the grid may also significantly impact the economics of interconnection.

In general, interconnection of mini-grid installations using synchronous and induction generators are seen to be relatively more complex than those using inverters, since inverters designed for grid-connected operation can perform many of the protection and synchronization functions required.[23]

4.3 Power Distribution Networks and Customer Loads

The ultimate roles of the mini-grid PDN and the national grid PDN in an interconnected system have both technical and consumer-facing implications since this infrastructure forms the last mile connectivity to the loads in a given area. Following interconnection, one of three scenarios may occur:

- The mini-grid and main grid PDN both continue to serve customer loads in parallel
- The main grid PDN becomes the sole distribution network for the area
- The mini-grid PDN becomes the sole distribution network for the area

In terms of the technical requirements of the PDN, continuing to operate in parallel typically means that the mini-grid PDN does not need to conform to the complete set of technical standards specified in regulation. However, if the objective is for the mini-grid PDN assets to continue to be utilised after interconnection, either by having the mini-grid operator keeping primary responsibility for distribution, using its own network, or by having the DISCOM purchase and utilise the mini-grid PDN, then there may be additional investment required by the mini-grid operator to meet these standards.

Based on review of the existing regulations and discussions with sector experts, there are two major dimensions of what may be termed a "grid compatible" PDN. First, there is typically a set of specifications for the physical infrastructure, such as the construction material and dimensions for poles, the location of poles, and other specifications for meters, junction boxes etc. These requirements can vary by utility, and in the case of the UPERC mini-grid regulation, they refer to the guidelines of the Rural Electrification and Secondary System Planning Organisation (RESSPO) of the Uttar Pradesh Power Corporation Limited (UPPCL) and the CEA (Measures relating to Safety and Electric Supply) Regulations, 2010.

Historically, the perception has been that mini-grid PDNs were constructed to a standard far below that of utilities, which may remain the case for some smaller mini-grids for whom grid connectivity may not be commercially viable. However, a number of enterprises now indicate that their PDNs are built to meet the CEA regulations, and some investors are increasingly encouraging enterprises to follow these standards in order to facilitate future interconnection.

Second, the capacity of the conductors (cables) must match that of the DISCOM network. The conductor size selected for a given PDN is necessarily a function of the total customer load to be served, and this aspect is where mini-grid PDNs and the main grid PDN may differ significantly, even if the rest of the system design is comparable.

Mini-grid operators emphasise energy efficiency, supplying low-wattage equipment such as LED bulbs along with their packages, resulting in household loads that are often below 100 watts (W) per household. In addition, many enterprises indicated that they use devices to limit the load of a given customer connection in case they try to consume beyond the package they have purchased. On the other hand, under the auspices of DDUGJY, the sanctioned household load is 250W or 500W (for below poverty line (BPL) and above poverty line (APL) households).[24] Furthermore, many rural connections are unmetered, with no provisions for load limiting, and so according to experts the actual load for these households may far exceed the sanctioned load in practice.

...a number of enterprises now indicate that their PDNs are built to meet the CEA regulations, and some investors are increasingly encouraging enterprises to follow these standards in order to facilitate future interconnection.

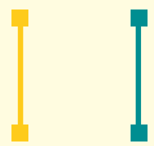
Despite the likely capacity gap between the two PDN systems, a phased investment in the PDN over time for the mini-grid may be a suitable solution. Mini-grid operators can invest upfront in the other infrastructure requirements of the PDN, and later, if they seek to have the PDN used as the primary PDN for both grid power and mini-grid generation, they can upgrade the conductor size in the existing PDN in a matter of days. Experts however cautioned that modifications to other aspects of the PDN, especially the poles, will come at a substantial cost that may render this approach economically unviable.

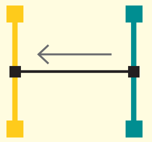
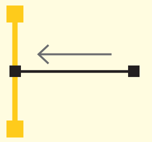
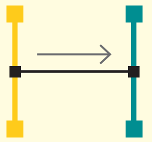
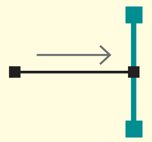
Another consideration linked to the PDN configuration under interconnection is the ability of the mini-grid to serve as a continuing source of power during load shedding.

Another consideration linked to the PDN configuration under interconnection is the ability of the mini-grid to serve as a continuing source of power during load shedding. In cases where the mini-grid PDN continues to operate in parallel to the main grid PDN, with no physical interconnection, then customers with both connections can readily utilise the mini-grid supply when the grid supply is unavailable. If the mini-grid is interconnected and exporting power to the grid, then the need for intentional islanding described in Chapter 2 arises. However, the ability of an intentional island formed by a mini-grid to meet the full customer demand depends on the PDN through which it supplies power:

- If the mini-grid intends to only supply to its customers through its own PDN, then it would operate as under its previous standalone arrangements
- If the mini-grid is supplying power wholly or in part to the main grid PDN, then some form of demand side management (DSM) would need to be applied to grid customer connections to reduce the overall load in the event of a grid outage; the mini-grid generation capacity alone would likely be insufficient to meet the higher grid-connected loads

4.4 Impact by Interconnection Model

MODEL	SCHEMATIC	DESCRIPTION
Parallel Operation		• No major technical or infrastructure requirements from either the mini-grid or the national grid perspective - no physical point of interconnection between the two grids • Regulators may exercise their discretion to place incremental technical requirements on the mini-grid installations (e.g. UPERC mini-grid regulation PDN guidelines)

Interconnection with Partial Export		• Requires installation of equipment and infrastructure to facilitate interconnection • May include equipment to enable mini-grid generator to synchronise with grid as well as infrastructure to physically connect the systems • DISCOM grid may require upgrade to include control systems for managing additional generation source
Interconnection with Full Export		• Requires installation of equipment and infrastructure to facilitate interconnection • May include equipment to enable mini-grid generator to synchronise with grid as well as infrastructure to physically connect the systems and step up voltage to feed into 11kV network • DISCOM grid may require upgrade to include control systems for managing additional generation source
Interconnection with Import		• Minimal – requires the installation of meter and other equipment needed to establish grid connection for the ESCO (assuming storage capability)
Interconnection with Import, Mini-grid PDN		• Requires installation of equipment and infrastructure to facilitate interconnection • May include equipment to enable ESCO to manage dispatch of power supply from the grid and its own generation • ESCO PDN would require upgrade to DISCOM standard conductor size ***OR*** • Requires installation of equipment and infrastructure to facilitate interconnection • May include equipment to enable mini-grid generator to synchronise with grid as well as infrastructure to physically connect the systems and step up voltage to feed into 11kV network • DISCOM grid may require upgrade to include control systems for managing additional generation source • ESCO PDN would require upgrade to DISCOM standard conductor size

FOOTNOTES

[17] A more detailed depiction of the mini-grid system design to enable interconnection is beyond the scope of this report, however it is worth noting that preliminary discussions with stakeholders revealed there may be micro-level system design variations that could be the subject of future research

[18] Magal, A. et al (2014). *Grid Integration of Distributed Solar Photovoltaics (PV) in India.* Prayas (Energy Group)

[19] Greacen (2013)

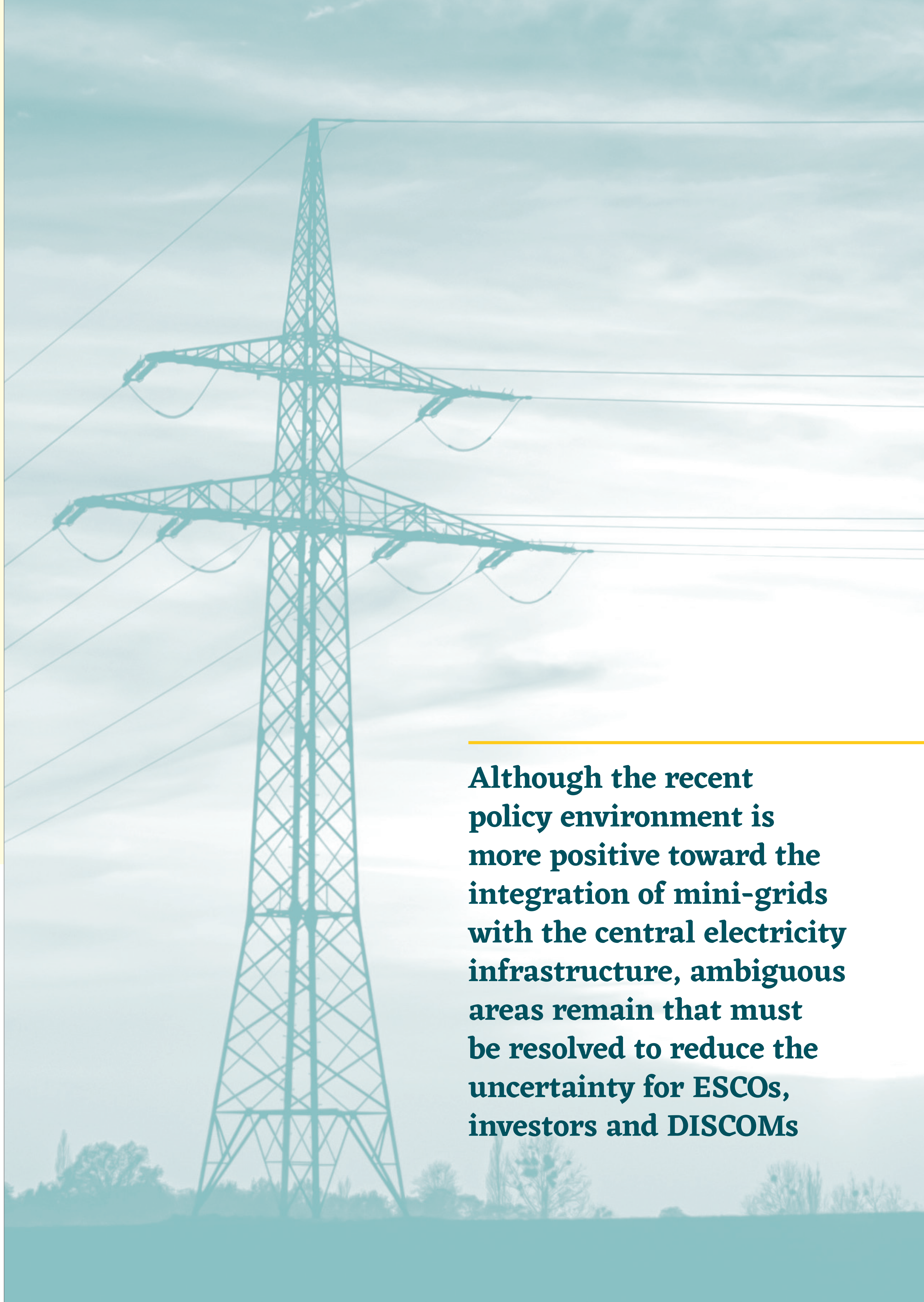
[20] Sharma, BD (2015). "Rooftop Solar PV Power: Potential, Growth, and Issues related to Connectivity and Metering". 7th Capacity Building Program for Officers of the Regulatory Commissions. Available at: http://www.iitk.ac.in/ime/anoops/for15/ppts/Day-3%20IITK/Rooftop%20PV%20-%20Mr.%20B%20D%20Sharma.pdf

[21] BD Sharma (2015).

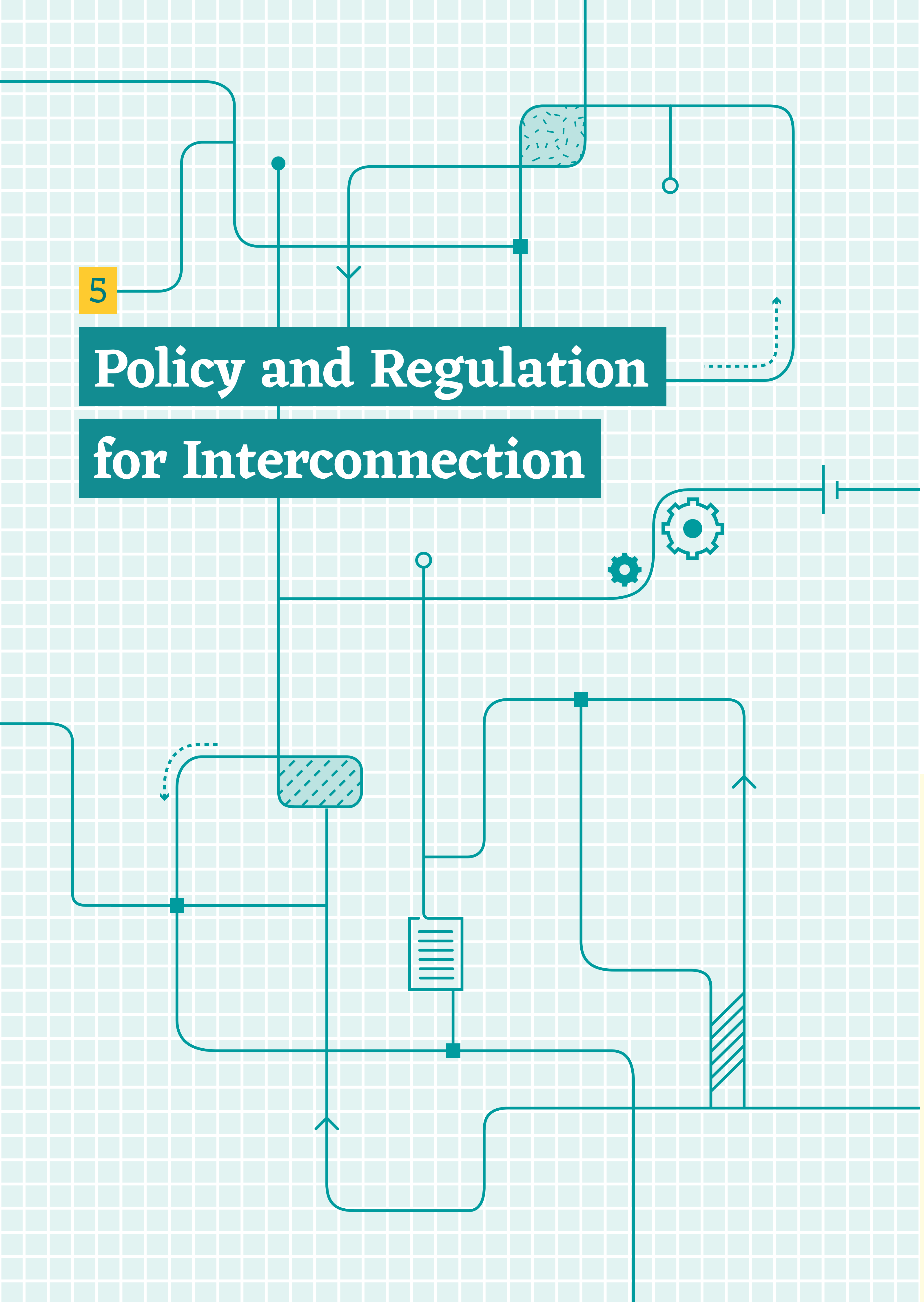
[22] Greacen (2013)

[23] The details of the system requirements for synchronization of various generator types is beyond the scope of this report. For more information, see Greacen (2013).

[24] http://ddugjy.gov.in/mis/portal/memo/DDUGJY_Guidelines.pdf



Although the recent policy environment is more positive toward the integration of mini-grids with the central electricity infrastructure, ambiguous areas remain that must be resolved to reduce the uncertainty for ESCOs, investors and DISCOMs



5

Policy and Regulation for Interconnection

National policies, programmes, and regulations that apply to the mini-grid sector fall under the jurisdiction of both the Ministry of Power (MoP) and the Ministry of New and Renewable Energy (MNRE), with state level implementation guided by their counterpart state regulators and state nodal agencies. Additionally, the central guidelines for tariff setting and technical guidelines are provided by the Central Electricity Regulatory Commission (CERC) and Central Electricity Authority (CEA), respectively.

The visibility of mini-grids in national and state policy conversations has risen considerably in the past year, with a number of important developments at the national and state level that have brought mini-grids to a more prominent role in the national conversation around rural electrification. The table below provides a brief overview of important policy and regulatory developments impacting the sector.

TABLE 2:
Relevant Policies and Regulations for Mini-grid Interconnection

POLICY / REGULATION	KEY FEATURES
The CEA (Technical Standards for connectivity of the Distributed Generation Resources) Regulations, 2013	• Establish requirements for any generation resource connecting to the grid at voltage levels below 33kV
National Tariff Policy Amendment[25] (January 2016)	• Focus on risk of grid reaching an area where a mini-grid operates prior to the end of its payback period • States need to develop regulatory framework for "compulsory purchase of power into the grid from such microgrids"

UPNEDA Mini-grid Policy[26] (February 2016)	▪ First dedicated mini-grid policy in India ▪ Includes any mini-grid projects up to 500kW in capacity ▪ Two options for establishing mini-grid projects – either subsidised (30% viability gap funding) or unsubsidised. ◊ Under the subsidy option, there are retail tariff, service level, and distribution network specifications that must be followed. ◊ Unsubsidised projects are given more flexibility and may charge retail tariffs based on mutual consent with customers. ▪ Two exit options for mini-grid: export of all power to the main grid (with possibility of ESCO becoming distribution franchisee) or sale of the mini-grid assets to the DISCOM
UPERC (Mini-grid Renewable Energy Generation and Supply) Regulations, (April 2016)	▪ Further details a range of operational models for mini-grids and the main grids where they co-exist – either parallel operation or interconnected ▪ Feed in tariff for power exported based on UPERC (Captive and Renewable Energy Generating Plants) Regulations, 2014.[27] ▪ Technical requirements ▪ Asset sale options for the mini-grid PDN
MNRE National Policy for Renewable Energy Based Mini and Micro Grids[28] (Draft Version, June 2016)	▪ Intended as framework to guide development of state mini-grid policies, programmes, and regulations ▪ Similar framework for operating models of interconnection as UPERC regulation plus additional scenarios for use of mini-grid PDN by DISCOM (purchase or by paying wheeling charges) ▪ Suggests consideration of intentional islanding, with discretion left to DISCOM to determine adequacy of control and safety features

5.1

Assessment of the Current Policy and Regulatory Scenario

This report presents a series of interconnection options that include models which may suit both near term and longer term visions for integration of decentralised and centralised infrastructure.

These developments have signalled an increased willingness of policy makers and regulators to allow mini-grids to become more integrated with the expanding electricity grid and do provide a measure of additional confidence to mini-grid operators and investors. However, several aspects remain unresolved that leave areas of uncertainty for ESCOs, investors, as well as DISCOMs.

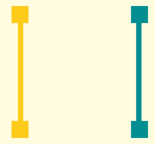
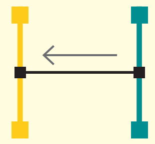
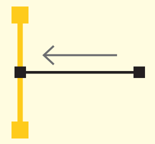
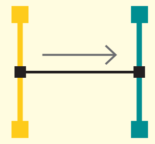
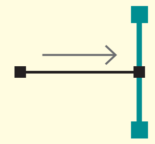
First, it is important that a range of interconnection models are permitted that can allow for the optimal arrangement from both the ESCO, DISCOM, and customer perspective in a given area. This report presents a series of interconnection options that include models which may suit both near term and longer term visions for integration of decentralised and centralised infrastructure.

Longer term exit options that allow the ESCO to export some or all of the mini-grid power generation to the grid and to sell its PDN assets are important when the grid supply improves significantly.

But in the near term, when it is realistic to expect that gaps in grid supply to rural areas will remain, some mini-grid operators indicated that a more attractive option for both ESCO and DISCOM business models would be to simply allow the ESCO to purchase power from the grid as a bulk customer. Keeping a range of options open allows the models of interconnection adopt to changing conditions.

Table 3 below reviews each model against the existing policy and regulatory support at the central and/or state level.

TABLE 3:
Existing Support for Interconnection Models

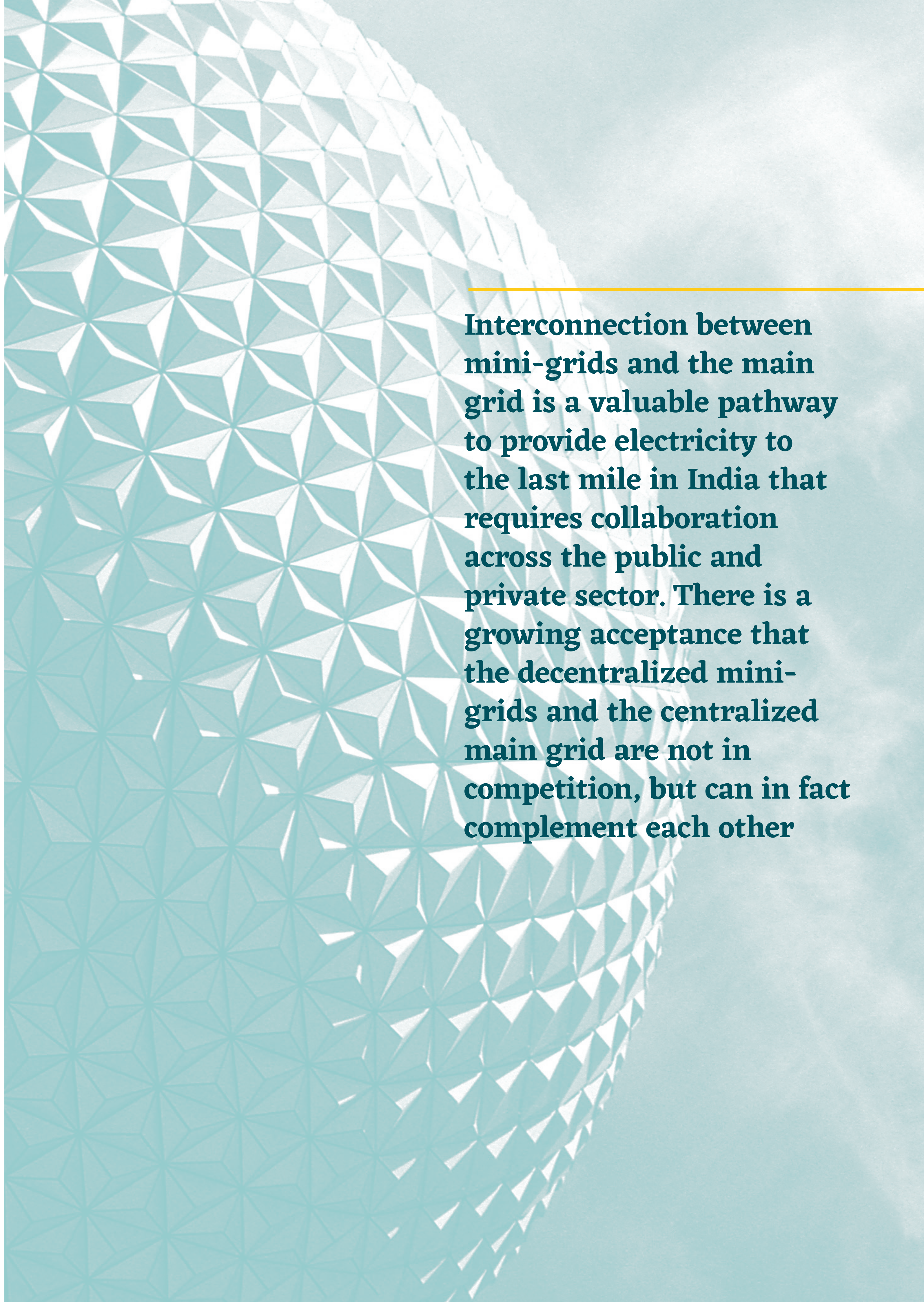
MODEL	SCHEMATIC	DESCRIPTION
Parallel Operation		▪ Model is an option under UPERC mini-grid regulation and draft national mini-grid policy
Interconnection with Partial Export		▪ Model is an option under UPERC mini-grid regulation and draft national mini-grid policy
Interconnection with Full Export		▪ Model is an option under UPERC mini-grid regulation and draft national mini-grid policy ▪ Represents the arrangement envisioned under the NTP Amendment
Interconnection with Import		▪ Model is not explicitly mentioned in any of the mini-grid regulations, however some precedent for import of power mentioned in 2009 DDG guidelines[29]
Interconnection with Import, Mini-grid PDN		▪ Model suggested for consideration under draft national mini-grid policy but not included in any current state mini-grid regulations ▪ Model suggested for consideration under draft national mini-grid policy ▪ Could result from a combination of IPP model permitted under UPERC mini-grid regulation and provisions for subsequent asset purchase by DISCOM

Second, there are a number of implementation level details that require further clarity in order for interconnections to be operationalised successfully at the ground level:

- Technical and/or procedural uncertainty regarding the selection of the interconnection point for a mini-grid and ability to create an intentional island[30]
- Detailed equipment and infrastructure guidelines that are tailored to decentralised infrastructure
- Distribution franchisee frameworks that may allow ESCOs to be compensated for the full range of services provided, and if applicable, to have some financial guarantee of payment from the DISCOM
- The applicable feed in tariff and other compensation mechanisms for ESCOs who interconnect their mini-grids (absent compensation that allows ESCOs to recoup their higher per unit capital costs, models intended to serve as full or partial exit options for mini-grids will be commercially unviable)

FOOTNOTES

[25] http://powermin.nic.in/sites/default/files/webform/notices/Tariff_Policy-Resolution_Dated_28012016.pdf
[26] http://upneda.org.in/sites/default/files/all/section/Mini%20Grid%20Policy%202016.pdf
[27] http://www.uperc.org/App_File/NotifiedCREREGULATIONS2014-rar1212015104022AM.rar
[28] http://mnre.gov.in/file-manager/UserFiles/draft-national-Mini_Micro-Grid-Policy.pdf
[29] From Section 16.2.v: "If grid power reaches the village before 5 years then the power produced from the DDG project can be exported to the grid and imported from the grid, as and when required." Source: http://www.ddugjy.gov.in/mis/portal/DDG/Guidelines-for-DDG.pdf
[30] For further details on requirements for intentional islanding see: Greacen et al (2013) or Magal et al (2014)



Interconnection between mini-grids and the main grid is a valuable pathway to provide electricity to the last mile in India that requires collaboration across the public and private sector. There is a growing acceptance that the decentralized mini-grids and the centralized main grid are not in competition, but can in fact complement each other

6 Conclusions and Recommendations

6.1 Summary

This report presents several pathways to enable interconnection of mini-grids with the main grid as a means of building an integrated electricity system in India that can provide reliable, quality power to historically underserved populations. These models of collaboration between decentralised and centralised infrastructure as well as the private and public sectors represent a new perspective on the role of these two scales of electricity access infrastructure. Historically positioned as competitors, there is a growing acknowledgment of the ways these two systems can instead work together as complements.

However, for these benefits to come to fruition, it is important for all of the critical stakeholders in the electricity access system to come to a common agreement regarding several points:

- Building utility infrastructure to the last mile alone does not guarantee the sustained and reliable electricity access needed to support the household, community, and small business needs of rural communities – although it is an important first step.
- The ESCOs that have successfully built rural mini-grid operations can play a vital role as the local level counterparts in many electrified rural areas, providing the needed maintenance and support services in a way that few other sector actors are equipped or willing to do.
- Power supply from the grid will also become necessary in the future as communities increase their energy consumption over time and can complement distributed renewable sources of generation.

This report presents several pathways to enable interconnection of mini-grids with the main grid as a means of building an integrated electricity system in India that can provide reliable, quality power to historically underserved populations.

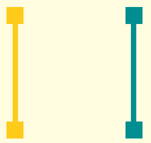
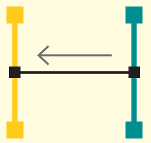
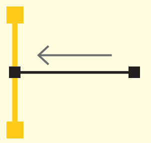
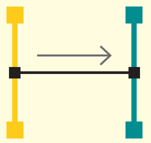
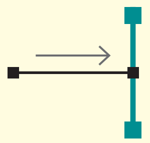
Then, to move toward an environment of cooperation, the concerns of two critical constituencies will need to be addressed:

- From the perspective of DISCOMs and other stakeholders of the legacy grid, they will require assurances that mini-grid infrastructure is sufficiently robust to meet any current and future technical requirements for safe and reliable interconnection, and they need to be clear about their roles, responsibilities, and capacity to sanction any interconnection requests.
- From the perspective of ESCOs, they will require an additional level of clarity around the ways they can be compensated for the full cost of their infrastructure and services under any

interconnection scenario, which are unlikely to be met by charging the regulated tariff, or receiving a customary feed in tariff for any exported generation alone.

The following table summarises several key dimensions of the interconnection models presented in this report. Providing a range of options can allow ESCOs and DISCOMs to implement the model that is most suitable for a given context.

TABLE 4:
Summary of Interconnection Models

MODEL	SCHEMATIC	POLICY OR REGULATORY CLARITY	ESCO CAPEX CHANGE	RETAIL TARIFF FLEXIBILITY	POTENTIAL FOR OTHER REVENUE / COMPENSATION TO ESCO		
					FEED-IN TARIFF	ASSET PURCHASE	FRANCHISEE AGREEMENT
Parallel Operation		✓	Unchanged	✓	N/A	N/A	✓ *
Interconnection with Partial Export		✓	Depends ↑/↓	✓	✓	N/A	✓ *
Interconnection with Full Export		✓	Depends ↑/↓	N/A	✓	✓	✓ *
Interconnection with Import		Uncertain	Likely unchanged	Uncertain	N/A	N/A	Uncertain
Interconnection with Import, Mini-grid PDN		Uncertain	↑	Uncertain	Uncertain	Uncertain	Uncertain

** Per the UPERC mini-grid regulation, the ESCO may seek to become a Franchisee of the DISCOM as long as the mini-grid was established before the grid is extended to a given area. This option is not specified in cases where the mini-grid is established in areas that are already electrified.*

6.2 Recommendations

Given these objectives, there are four recommended areas for action for a range of system stakeholders to support a move toward further operational mini-grid interconnections and ultimately, an integrated multi-scale electricity system.

1. Further private sector partnerships between technology and equipment providers and ESCOs

Rationale:

- Some stakeholders expressed a desire for larger corporates to enter the mini-grid space, but few, if any, of these companies plan to establish the local operational capacity required; rather, they prefer to act more like equipment suppliers to the rural ESCOs which is more in line with their comparative advantage.
- These partnerships can support ***technology innovation*** in a nascent area in India, where some of the technologies required to enable the full range of interconnection models are not yet widely available. For instance, one team planning a pilot interconnection noted that more advanced wireless technologies for demand side management were not yet available off the shelf, which could facilitate the type of automated load management required if intentional islanding is permitted in the future.
- Innovation targeted to the equipment needs of mini-grid systems could also help bring down the capital costs associated with interconnection (and with mini-grids more generally).
- Partnering ESCOs with larger corporates can also help bolster the confidence of policy makers and regulators in the quality
- of mini-grid infrastructure, who strongly prefer the idea of integrating existing infrastructure where possible if the grid arrives.
- Ecosystem level actors can play a key role in bringing together these organisations to identify the infrastructure and technology pain points of ESCOs and potential partners who can address these needs. The Smart Power for Rural Development initiative
- of the Rockefeller Foundation is one such platform that can facilitate these interactions.

...there are four recommended areas for action for a range of system stakeholders to support a move toward further operational mini-grid interconnections and ultimately, an integrated multi-scale electricity system.

2. Business model innovation among ESCOs and a shift in the conversation around compensation for interconnected mini-grids

Rationale:

- A common point of tension between the public and private sector is related to tariff levels – both for retail tariffs as well as feed in tariffs for power exported to the grid. For instance, the cost of generation for most ESCOs is significantly higher than most established feed in tariffs because this cost includes not only generation related assets but also the distribution infrastructure and operational costs, as well as the fact that they do not benefit from the economies of scale of much larger installations.[31]

- Despite general policy directives for state electricity regulatory commissions (SERCs) to set cost-reflective tariffs, it is unlikely that they would be willing to fix feed in tariffs for mini-grids at a significant premium to other sources of renewable generation.
- Therefore, to address the concerns of ESCOs, the total compensation could be split into components that are already used in various policies and regulations: a feed in tariff for exported power, compensation for the PDN (subject to meeting minimum standards), and a per customer per month fee for metering, billing, and collection (MBC) services, as appropriate for a given model of interconnection. This structure would require clear and well-documented implementation processes, but starting from established compensation mechanisms may be more readily a cceptable to policy makers and regulators.
- Along those lines, ESCOs and other sector participants could actively engage with the Forum of Regulators to revisit the possible frameworks for becoming rural Distribution Franchisees on terms that would be mutually agreeable to both ESCOs and DISCOMs.[32] It is also likely that ESCOs would want a guarantor in place for any franchising model in which they are to be paid by the DISCOM.
- The scope for these franchising business models in rural areas is substantial and could represent a beneficial ***business model innovation*** for some ESCOs, subject to having reliable and sufficient compensation arrangements.
- ***It is also critical that financing providers are active participants in discussions around these innovations and the shape of any related policy and regulatory reforms.*** If banks, investors, and other financing providers are on board as partners who can trust revenue streams from these arrangements and factor them into their financing decisions, then the ability of ESCOs to continue to play a role in the bolstering last mile electricity access will be enhanced.

These two levers alone can strongly influence the overall incentives for public and private sector collaboration in the electricity access space.

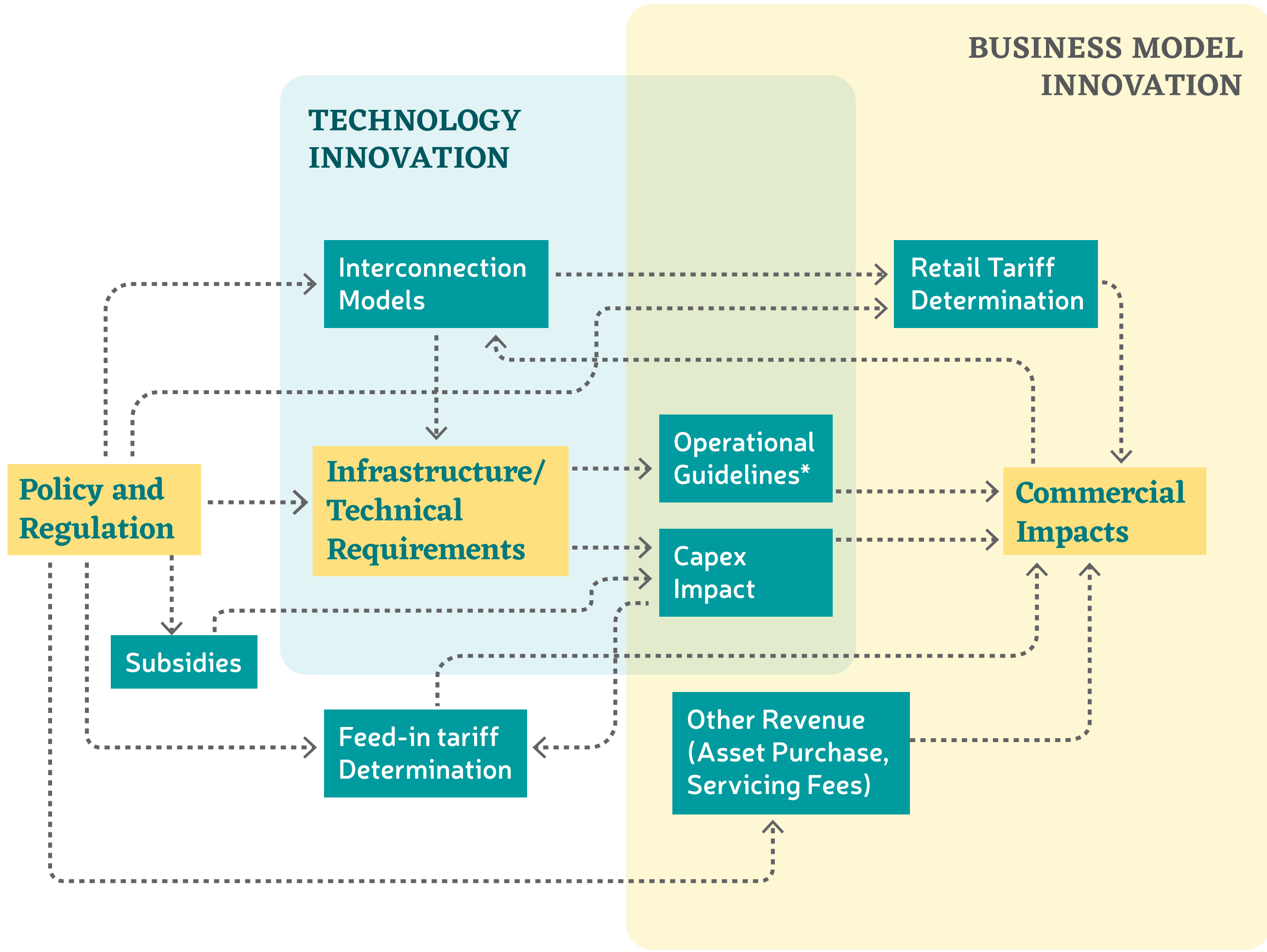


FIGURE 10:
Influence of Technology and Business Model Innovation

3. Sector-wide experimentation and learning around interconnection pilots

Rationale:

- In several expert consultations, the need for detailed implementation guidelines for the interconnection models was emphasised, with clarity on processes, roles, and responsibilities. They noted the importance of clearly specifying the role of local level government officials who are most closely involved in implementation at the ground level.
- Although some literature is available on the general technical requirements for interconnection of renewable energy minigrids, there are bound to be areas of uncertainty around local level approvals, equipment costs and availability, and other points of friction for the interconnection process that may only emerge from practical experience.
- There are select ongoing or completed interconnections in India, and the lessons from these experiences (and hopefully others to

come) can form an important knowledge base for the sector.[33] Procedures for intentional islanding and the associated technology could also be piloted along with relevant models to inform future guidelines customised for Indian conditions.
- Involving grid stakeholders in several working demonstrations of mini-grid interconnections will also go a long way to building confidence among DISCOMs and regulators who might otherwise remain sceptical of the practical feasibility of this option.

4. Establish national guidelines for intentional islanding of interconnected mini-grids

Rationale:
- As described in this report, the ability for an interconnected mini-grid to continue to supply power during the frequent and unpredictable periods of load shedding in rural areas can enable greater supply reliability for customers and provide more consistent revenue for the ESCO.
- Under the existing CEA guidelines for interconnection of distributed generation sources, this option is not currently permitted.
- The draft national mini-grid policy references the possibility of intentional islanding, but it provides only an open-ended statement leaving it the decision to the DISCOM's discretion.
- In the absence of a clear guidance from CEA, it is unlikely that this option would be permitted, and formal guidelines would also ensure this option can be implemented safely and consistently.
- International standards for intentional islanding exist (IEEE standard 1547.4-2011), and any pilot installations (Recommendation 3) testing this option could inform whether these standards require customisation for Indian conditions.

6.3 Conclusion

This report summarizes the findings from extensive consultations with stakeholders across the mini-grid and grid spectrum and a review of the literature on interconnection in India and globally. Rather than go into the full technical details and requirements of interconnection, the intention of this report is to provide an accessible overview of the various important considerations related to interconnection, from policy to regulation to commercial impacts to infrastructure requirements. This overview is targeted to a broader, non-technical audience that is familiar with the concept of interconnection but seeks a more in-depth treatment of the topic. Ultimately, this enhanced understanding can motivate a

The recommendations in this report are intended to address several gaps which if resolved, have the potential to accelerate the move toward integration of mini-grids and the grid in a way that is beneficial to both the public and private sector entities involved in electricity provision, and most of all, to the many customers whose energy aspirations remain to be fulfilled.

more detailed conversation among the many stakeholders whose participation is necessary to move toward an integrated electricity system with both centralised and decentralised supply.

From a macro perspective, the focus is on understanding the benefits of integration of the two scales of infrastructure, toward a more robust electricity system that can better serve the millions of Indian households and businesses currently lacking reliable power supply. From a micro perspective, the focus is on the various ways in which this integration can happen – including an assessment of the various models of interconnection through the lenses of commercial impacts, technology and infrastructure impacts, and the existing policy and regulatory environment.

What is clear from these perspectives is that moving toward this integrated system requires a collaborative effort across ecosystem actors, with attention to a package of solutions that considers the concerns, incentives and capabilities of all key stakeholders. The recommendations in this report are intended to address several gaps which if resolved, have the potential to accelerate the move toward integration of mini-grids and the grid in a way that is beneficial to both the public and private sector entities involved in electricity provision, and most of all, to the many customers whose energy aspirations remain to be fulfilled.

FOOTNOTES

[31] For instance, the applicable feed in tariff under the UPERC mini-grid regulation is based on the UPERC (Captive and Renewable Energy Generating Plants) Regulations, 2014. Stakeholder interviews confirmed these rates are far below the cost of generation, especially for solar plants. Source: http://www.uperc.org/App_File/NotifiedCREREGULATIONS2014-rar1212015104022AM.rar

[32] One example is the Metering, Billing, and Collection Services arrangement used by Ajmer Vidyut Vitaran Nigam Limited (AVVNL) in Bhilwara, Rajasthan. The franchisee in this case receives a fixed fee per month per customer for these services.

[33] Examples include: Avani Bio Energy, which operates biomass gasifier power plants in Uttarakhand which export power to the grid as IPPs (http://www.samhita.org/social-organisation/avani-bio-energy/) and an Ashden India Renewable Energy Collective project that seeks to integrate a hybrid micro-hydro and solar PV plant with the grid in Assam (http://wisions.net/projects/hybridisation-of-an-existing-micro-hydro-plant-with-solar-pv-and-integratio).

About the organisations

ASHA IMPACT

Asha Impact is a platform for business leaders and philanthropists to address critical development challenges by leveraging their expertise, capital and networks to make impact investments in high-quality social enterprises with scalable business models to deliver basic products and services to underserved populations. Asha Impact also has a not-for-profit trust that works with government and civil society to influence public policy based on lessons from inclusive business models in the areas of affordable housing, financial inclusion, energy access, education and employment. The organisation was founded in 2014 by Vikram Gandhi and Pramod Bhasin, who have decades of financing and operating experience building successful companies, and includes many of India's top business leaders as its investors and trustees.
Website: www.ashaimpact.com

THE ROCKEFELLER FOUNDATION

The Rockefeller Foundation's mission is to promote the well-being of humanity throughout the world through dual goals: advancing inclusive economies that expand opportunities for more broadly shared prosperity, and building resilience by helping people, communities and institutions prepare for, withstand, and emerge stronger from acute shocks and chronic stresses. It works on four focus areas—advance health, revalue ecosystems, secure livelihoods, and transform cities—to address the root causes of emerging challenges and create systemic change. Together with partners and grantees, The Rockefeller Foundation strives to catalyze and scale transformative innovations.
Website: www.rockefellerfoundation.org/about-us

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage renewable energy, energy efficiency and the adoption of sustainable transport solutions. Shakti works collaboratively with national, state and local decision-makers to craft sound energy policies to build India's new energy economy and bring together experts from every sector — industry, academia, law, finance, civil society, think tanks, and more — to drive this change. Shakti supports high-quality research and providing policy makers with specific and practical policy recommendations for an energy secure future.
Website: www.shaktifoundation.in

OKAPI RESEARCH AND ADVISORY

Okapi is an India-based research and consulting group focused on institutional design for complex goals in changing times. We work closely with public and private sector leaders to identify opportunities for catalytic interventions and develop blueprints for harnessing policy, market, and community dynamics to achieve social and environmental impact. Okapi's practice draws extensively on academic social science research for insights and innovative approaches to the challenges our clients face: from regulatory design and public investment prioritisation to deepening innovation ecosystems or integrating social and financial goals in organisational processes. Okapi was founded in July 2012 and is incubated by IIT Madras.
Website: www.okapia.co