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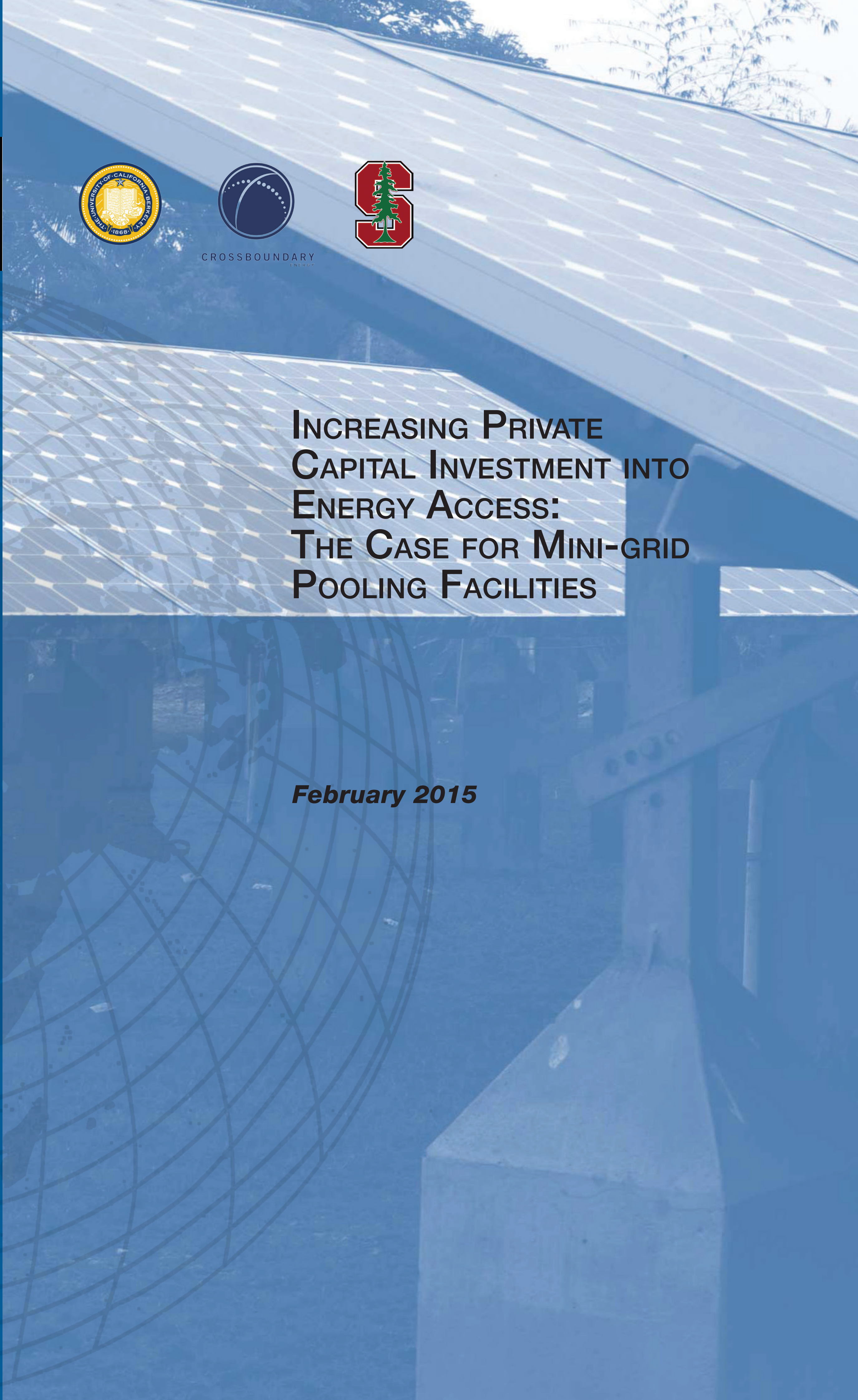

Increasing Private Capital Investment into Energy Access: The Case for Mini-grid Pooling Facilities

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1 Glossary of Terms

ADB	Asian Development Bank
BOO	build-operate-own
BOT	build-operate-transfer
CAREC	Central American Renewable Energy and Cleaner Production Facility
CCFC	Calpine Construction Finance Facility
CDM	Clean Development Mechanism
CER	certified emission reduction
DFI	development finance institution
EIA	environmental impact assessment
GSM	Global System for Mobile Communications
GW	gigawatt
IEEE	Institute of Electrical and Electronics Engineers
IPCC	Intergovernmental Panel on Climate Change
IPO	initial public offering
IPP	independent power producer
ITC	investment tax credit
kW/kWh	kilowatt/kilowatt-hour
MIGA	Multilateral Investment Guarantee Agency
MPF	Mini-grid Pooling Facility
$MtCO_2e$	Megaton of Carbon Dioxide Equivalent
MW	megawatt
MWh	megawatt-hour
MWp	megawatt-peak
O&M	operations and maintenance
OPIC	Overseas Private Investment Corporation
PV	photovoltaic
PPA	power purchase agreement
PPP	public-private partnership
PRG	partial risk guarantee
PRI	political risk insurance
REFIT	renewable energy feed-in tariff
REPP	Renewable Energy Procurement Program
SE4All	Sustainable Energy for All
SHS	Solar Home Systems
SME	small or medium sized enterprise
UN	United Nations
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
W	Watt
WB	World Bank
WEF	World Economic Forum
WHI	Waterhealth International
WSS	water supply & sanitation

2 Executive Summary

EVERY EVENING, NEARLY A THIRD OF OUR planet's population is plunged into darkness. With no access to electric power, much of the world will rely on toxic kerosene lanterns, low-quality dry-cell battery torches, or loud and expensive diesel powered generators. These technologies are not only expensive in the long-run, but are also sources of pollution, damaging household health and global climate. The global lack of universal energy access is perhaps our greatest collective failure; it locks people in poverty, harms their health and causes large scale environmental damage.

One critical solution expected to fill much of the energy gap is the mini-grid: a standalone energy system that provides power to multiple households, employing a range of renewable energy options. However, mini-grids are challenging to finance for two primary reasons: high risk and high transaction cost. To address these barriers and substantially increase the flow of private capital into the sector, new approaches to investment need to be developed. In this report, we provide a framework for such a solution: the Mini-grid Pooling Facility (MPF).

We begin by outlining the current state of access, global financing requirements, and mini-grids as an asset class. Over 65% of off-grid populations are expected to benefit from mini-grids by 2030, and over 30% of total investment into access is expected to be in this asset class, totaling between $4 and $50 Billion annually.

The first barrier to minigrid investment is the scale and complexity of associated risk. Renewable energy mini-grids will primarily be employed in regions with low levels of socioeconomic development, complex business environments, unstable political regimes, and often vague or unsupportive regulatory frameworks. This results in a complex challenge for firm managers and financiers, who have to mitigate, allocate, and eliminate the complex risks that prevent successful and sustainable development, construction, and operation (see section 6 for a detailed risk analysis). While some can be easily (although not inexpensively) managed through insurance products, other risks are hard to quantify, challenging to price, and even more difficult to address.

The second barrier to effective financing of mini-grids is the transaction cost facing potential investors if projects are approached individually. Regardless of size, any individual minigrid project incurs a set of fixed transaction costs including identification, diligence, and platform development expenses, which are described in detail in section 7. These fixed costs are often significant relative to the size of the potential investment often overwhelming the financial viability of an individual project.

We propose a solution that addresses both of these barriers through project and capital pooling. An MPF can strategically select projects into portfolios, thus diversifying risk and increasing capital requirements. By centralizing some fixed expenses, transaction costs can be lowered significantly on a per-project basis, thus increasing returns substantially for potential investors. The MPF can also serve to attract previously unavailable capital, better leverage philanthropic investment, result in lower technology costs, and deliver other benefits (see section 8). While the potential of this approach is substantial, MPF managers must also be conscious of the drawbacks of creating portfolios of mini-grids, and these are outlined in section 8.2. Best practices can also be derived from the case studies we present in this report, which are summarized in the appendix at the end of the report.

We conclude by discussing potential structures for an MPF, including private and public options. It is critical that developers, investors, and researchers work together, conduct the proper analysis, and determine which structure is most appropriate in the working context. While this report does not prescribe any particular approach, we hope that the information provided in these pages serves to inform firm managers, investors, development finance institution leaders, and other relevant stakeholders in this complex decision process. Ultimately it is our hope that effective implementation of the concepts in this paper will contribute to increased energy access for all.

3 Introduction

EVERY EVENING, NEARLY A THIRD OF OUR planet's population is plunged into darkness. With no access to electric power, many will spark toxic kerosene lanterns[1], turn on low-quality dry-cell battery torches[2], or fire up loud and expensive diesel powered generators. Productive work can be difficult in the dim light and children often struggle to study as their parents prepare the family meal over a smoky and inefficient biomass cookstove[3]. Many of these energy sources are also significant contributors to climate change[4] and significant sources of local environmental pollutants[5, 6]. The global lack of universal energy access is perhaps our greatest collective failure; it locks people in poverty, harms their health and causes large scale environmental damage.

To address this issue, the global community has united beneath the banner of Sustainable Energy for All (SE4All), an initiative led by the United Nations (UN). This organization has declared universal access to energy by the year 2030 as one of its three main objectives[7]. However existing planned investment by governments, development finance institutions, and the private sector are insufficient to achieve this goal. With current rates of investment, and a lack of significant participation by the private finance community, almost 1 billion people are projected to remain without electric power in 2030[8].

Much has already been written on the total investment required, the potential roles of different stakeholders, the policy frameworks that need to be developed, and the means by which the public sector can incite greater participation by the private sector[8-16]. However high transaction costs and high project risk remain, and existing mitigation strategies have proven insufficient or unsuited for current business models, leaving investors with little incentive to provide the required levels of capital[17-24]. There remains a need to design and develop financial vehicles and facilities to address these complex cost and risk challenges, and spur greater private and institutional investment into energy access[13, 16].

The various approaches to providing access to electricity face varying levels of complexity and risk, and therefore are perceived differently by investors. Large-scale generation and transmission projects in emerging markets have a long track record of significant private investment (primarily through project finance), and while recent flows have decreased due to the global economic downturn, the financial sector understands these types of projects well[19, 21, 25-27]. Pico products (with energy provision of no more than 100W per customer), such as lanterns and small solar home systems (SHS), have also seen significant support recently in the form of corporate financing (primarily from impact, venture, and institutional investors), as the finance sector begins to better understand the scale of the market and the risks involved in individual business models[28-31]. However, micro- and mini-grids (henceforth referred to solely as "mini-grids" for simplicity) have not seen the same level of growth, primarily because they fall into the "grey space" of financing: they are too small for traditional project finance, and they are not deployed to any significant scale by individual companies with strong balance sheets to warrant corporate finance[23, 32-34]. For the purposes of this report, we consider all power installations with interconnected households, local generation, and local storage to fall under the category of mini-grids.

Some estimate that in order to achieve universal access to electricity, mini-grids will need to serve over 65% of off-grid populations by 2030, or approximately 630 million people[35]. In order to reach such levels of deployment, new models of financing need to be developed. In this report we provide a conceptual framework for the development of a private sector facility to pool and cross-collateralize different sources of capital to support mini-grid portfolios. We begin by discussing the current state of access and approaches to financing and implementing electrification in developing countries. We then qualitatively estimate the risk profile of mini-grids in developing countries, as well as discuss the standard mitigation instruments that are employed today to handle some of these risks. In the third section, we discuss the transaction costs of investing in mini-grid projects, and the opportunities for savings. Then we explore the concept of finance pooling and project bundling, develop several designs for Mini-grid Pooling Facilities (MPFs), and discuss the potential benefits and drawbacks of each approach. We conclude by discussing the opportunities for financiers, entrepreneurs, researchers, and development finance institutions (DFI) to collaboratively increase the understanding of risk and return in this space, as well as develop MPFs for large-scale financing of mini-grids in developing economies.

4 *Energy Access Today*

TODAY, OVER 1.3 BILLION PEOPLE LACK ACCESS to electricity, with another billion only having access to a poor quality, and often intermittent, grid. The vast majority (over 85%) reside in the rural areas of developing countries where access to other basic services including clean water, education, and healthcare, is also limited. In many cases, a lack of socio-economic progress in these areas is correlated to limited access to electricity, although the exact causal links remain unclear[36-39]. The lack of access places significant strain on the limited financial resources of the poor, as they must rely on expensive fuels for lighting and cooking, and third-party vendors for cell-phone charging. For example, a typical phone with an average battery capacity of 5 Wh, costs an average of $0.20/charge in East Africa. This translates to an exorbitant price of $40 per kWh[40-42].

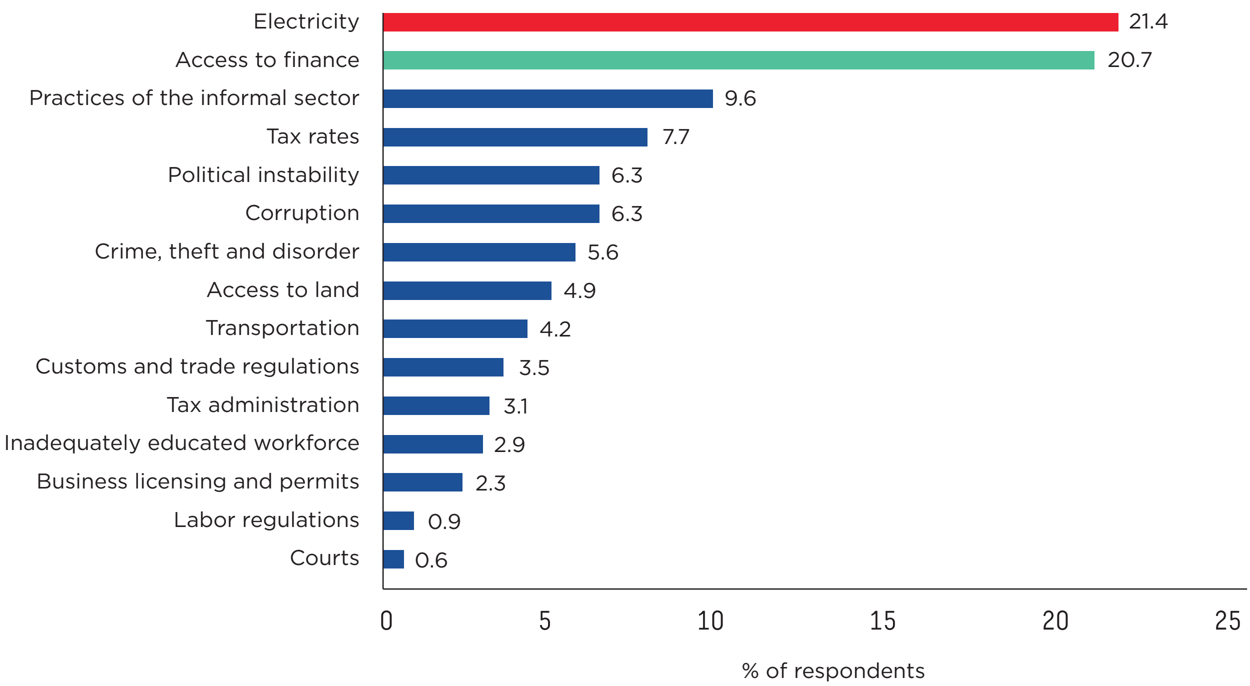
A night vendor in rural Kenya sorting tomatoes with the aid of a solar lantern

photo credit: Peter Alstone

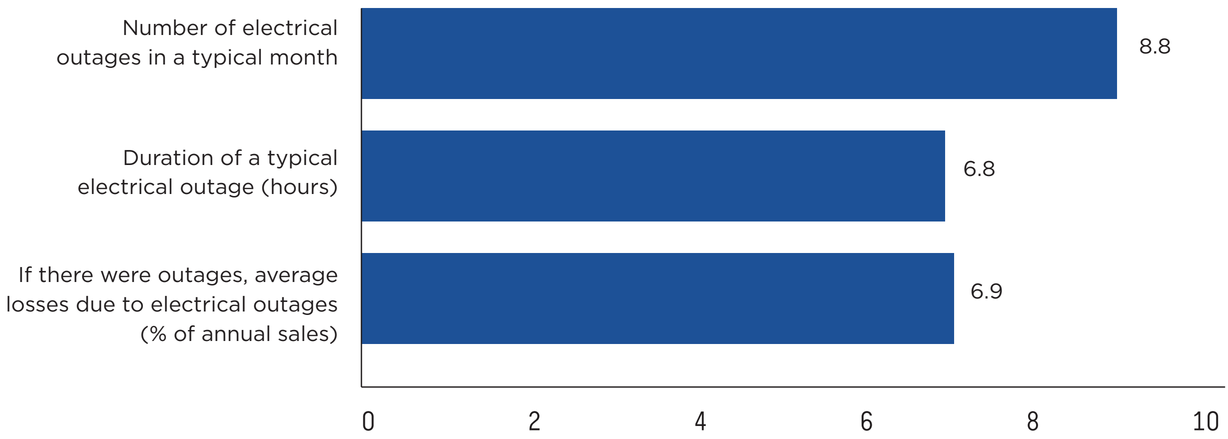
Barriers to accessing national grid infrastructure vary across locations and can be broken down into the following 3 categories of "remoteness": *geographic, political, and economic*[43]. *Geographic* remoteness stems from the high cost and difficulty of extending infrastructure over long distances and challenging terrain to commonly diffuse populations[44]. In the case of many such communities, the expected consumption does not justify the high cost of grid expansion[15]. *Economic* remoteness points to the poverty of populations without access, which precludes them from paying prohibitive interconnection fees or from consuming sufficient energy to justify the high cost of connection[45]. Finally, *political* remoteness refers to the nature of electrification in developing countries, where it is often managed by the public sector[16]. This leads to the marginalization of disadvantaged urban and rural citizens, who may lack the political clout or institutional support to lobby for grid extension[15, 46].

A compounding factor is the lack of awareness in remote communities of available and appropriate technologies to meet the needs for access to energy. This technology remoteness is a key issue that must be addressed by any initiative aiming to expand the use of clean energy mini-grids. The supply of electricity to remote areas can be achieved most cost-effectively by making the greatest use of locally-available energy resources. In many under-served developing countries, solar radiation is abundant and can be converted cost-effectively by appropriate photovoltaic systems. Technologies that use other local energy sources - including wind, hydro, biomass and waste - are widely available, though must be matched effectively to local resource availability and consumer needs.

The lack of reliable access to electricity has significant implications on household health, access to modern communication technologies, participation in local governance, education, family nutrition, and the participation of the poor in complex market value chains[5, 35, 41, 47, 48]. Without electricity, the rural poor in agricultural areas are limited in their ability to derive returns from agriculture, as most irrigation systems and value-add processing equipment require electricity to function[49]. There are also significant negative impacts on business operation and growth in areas without access (or with unreliable power). Electricity unavailability can limit production (due to the loss of productive time), increase costs (especially in the case of dependence on own generation)[50], and cause damage to sensitive equipment and products[51]. A quick glance at the World Bank Enterprise Survey dataset points to the strain that businesses feel due to a lack of access[52].



1: Biggest obstacle to business identified by firms in Sub-Saharan Africa (World Bank Enterprise Survey Dataset)



2: Metrics of Electrical System Reliability in Sub-Saharan Africa (World Bank Enterprise Survey Dataset)

5 Financing Access

ACHIEVING UNIVERSAL ACCESS VIA SUSTAINABLE models of decentralized electrification will require significant capital investment, primarily from the private sector, though philanthropic and public sources are often essential to address early market development risks. Bazilian et al., in their review of financing needs for achieving universal access by 2030, cite a gap of $12-$134 billion dollars per year, with most realistic estimates trending towards the high end[9]. While $134 billion may seem an impressive number, this is less than 0.2% of the asset base of institutional investors world-wide[12] and slightly less than 1% of US GDP[53]. To put this into further perspective, the annual sales of Wal-Mart, and 10 other multination corporations (including Royal Dutch Shell, BP, Volkswagen, and Chevron), all exceeded $200 Billion each, in 2013[54].

Unfortunately, the pace and scale of investment into sustainable energy access pales in comparison to the needs of remote populations. In 2013, the most recent year for which investment data is available, only $93 Billion was invested into renewable energy in developing economies as a whole. This amount represented a reduction of almost 15% from the previous year, which in part can be attributed to dropping global solar prices, but most believe is due to significant regulatory uncertainty and risk[55]. Furthermore, the majority of capital flowed into large generation capacity projects, i.e. developments of utility scale solar, wind and hydro, and few targeted remote populations or led to significant expansion of access. Although there seems to be a long term trend of increasing flow of investment capital into renewable energy in developing economies (from 2004-2014), overall, the rate of electrification remains on track to leave nearly a Billion people in the dark by 2030[35, 43].

6 *Mini-grids*

TO ADDRESS ENERGY ACCESS ISSUES IN AREAS where grid extension is not expected, governments, development organizations, and the private sector have turned to decentralized energy systems to fill the gap. The majority of such systems, whether pico-lighting products, household systems, or community mini-grids, typically provide sufficient power for basic lighting, cell phone charging, and small DC appliances. However, only the larger community systems can provide sufficient power for improved agricultural hardware such as water pumps and mills, healthcare centers, and telecommunications infrastructure[15, 41]. As many governments and development finance institutions are beginning to transition their support towards lower carbon intensive projects, RE mini-grids are becoming a more attractive option for remote areas[56].

Until recently, conventional mini-grid designs mainly depended on diesel or gasoline generation, primarily due to the wide availability and affordability of fuel, low upfront capital costs of equipment, and a perception of renewables as unproven or prohibitively expensive technologies. However, recent improvements in the cost and efficiency of renewable energy technologies, increasing diesel prices, and the growing adoption of renewables in utility-scale generation, have contributed to an increasing use of micro-hydro, solar, wind, and biomass technologies in off-grid systems[57, 58]. Mini-grids have typically provided power to a relatively small number of customers, via low-voltage distribution networks, all done independently of the national grid infrastructure. Mini-grids are the only tools in the off-grid energy access repertoire that offer a level of productive power that can be used for energy-intensive income generating activities, at a cost that is much lower than traditional standalone household system alternatives[16]. However, due to the challenges in design, management, and high up-front capital costs, mini-grids have not been commercialized at the same scale as their pico- and household scale counterparts[59].

Still, there are a number of successful companies in the space that are beginning to show the potential for significant private sector participation in the RE mini-grid space. Schnitzer et al. reviewed seven business models, across Southeast Asia, Sub-Saharan Africa, and Latin America, and found that a combination of tariff design and collection mechanisms, proper maintenance, reduction of non-technical losses, load limit compliance, proper response to demand growth, and adequate training are all required for successful operation and growth. The authors identify a series of interactions between technology choice, financing, and customer support which they term 'virtuous cycles' of positive reinforcement and project improvement, and 'vicious cycles' where failures in one part of the program design raises added challenges for other aspects[60].

The Alliance for Rural Electrification also conducted a review of best practices for mini-grids and found that system sizing, component quality (i.e. not always attempting to minimize cost), locally available supporting networks (distributors, microfinance institutions, etc.), and contractual agreements were key to effective business operation[61]. Martinot et al. found that the success of micro-hydro mini-grids in Nepal depended strongly on the accessibility of debt capital from local financial institutions, streamlined licensing for independent power producers (IPPs), favorable tariffs and subsidies, and technical assistance from development institutions[62].

Of the total investment required to provide universal access by 2030, the IEA projects that 36% will be targeted towards mini-grid efforts, or approximately $4-$50 billion annually, with the vast majority coming from RE generation (90%)[10]. While this range of values may seem large, the uncertainty is due to a number of factors, the discussion of which is outside of the scope of this report. For more information, the works of Bazilian et al[8, 9, 14], Craine et al[63], Glemarec[64], and Bhattacharyya[65] provide diverse viewpoints and detailed discussion. The most widely accepted and quoted value lies in the $30-$40 billion range, and that will be the working assumption for the remainder of this report.

The typical installation cost a renewable energy mini-grid in developing countries is highly dependent on the technology used, the location of nearby manufacturing and shipping facilities, local capacity, and the cost of debt capital. Recent reports by the ADB point to a range of values around $4.5 Million/MWp installed, or approximately $1.5 Million per project[66]. Bhattacharyya and Palit suggest a slightly lower value of $1-$3 Million/MWp[67]. Regardless of the specifics, this range can be used as a basis for thinking about average project financing needs.

6.1 Mini-grid Ownership Models

Mini-grids in emerging markets can be financed by a variety of sources of capital, and can be owned and operated by a diverse set of stakeholders. In many regions (particularly Southeast Asia), mini-grids are developed through public-private partnerships (PPPs), although there are cases where the source of a majority of the capital is a single type of institution, whether a private entity, local or national government, or a non-profit/international aid donor[20]. The preponderance of PPP models of ownership derives from the combined benefits of capitalizing on the entrepreneurial skillset of the private sector and the ability of government partners to reduce political, currency, contractual, and other risks[68-70].

6.1.1 Private Models

Notable cases of purely-private models exist across developing regions. Examples include Husk Power, Power Hive, Inensus, Gram Power, Mera Gao Power, as well as national programs like that of Cambodia, where close to 300 private operators own mini-grids that have been funded through primarily private dollars[60, 71, 72]. Much of the energy access community favors private-sector led models due to:

- the ability of private sector actors to better quantify project benefits (and costs) and thus improve pricing and tariff collection
- more efficient operational control and management of attendant risks (i.e. design, procurement, construction, and operation/maintenance)
- a better use of limited capital, as it is evaluated according to economic value created rather than political influence, social measures of impact, or other non-economic factors[23, 73]
- the sustainability of an approach that is driven by market dynamics rather than government subsidies

Researchers like Andersen[74] have shown that large project cost savings can be derived from private ownership. Although the opposite can be true in countries where political risks and government intervention lead to cost overruns, extended construction times, or even expropriation[69, 75]. An analysis of rural private water projects in emerging markets by Rivera et al, also showed private initiatives provided expanded coverage, better quality service delivery, and improvements in overall efficiency[76].

Private models also significantly reduce the restrictions placed on government or institutional developers, such as equipment sourcing, employment requirements, capital origin requirements, etc. Furthermore, private enterprises can employ a variety of proprietary tools that may not be available to the public sector to manage systems, collect payments, monitor performance, and improve service quality. Examples of such tools include management software suites from Powerhive or Simpa Networks, metering technology developed by Lumeter Networks, and the Angaza Design payment platform.

Purely private models for mini-grid implementation, particularly in developing countries, are largely impeded by the unavailability of capital. This is especially true if debt is sourced from local banks or development finance institutions, for whom the small size of the loan, the long term of payback (typically on the scale of 10-20 years), project complexity and uncertainty, and lack of firm credit/financial history do not justify the transactional costs or the risk of investment[32, 34]. Unfamiliarity of traditional financiers with the mini-grid concept also compounds the perceived risk. For equity investors, the risk and uncertainty of individual projects is typically too high, and because projects are illiquid, there is a lack of exit options (although successful exits have been seen in IPPs in Africa in the past)[19, 23]. Furthermore, transaction costs, including diligence and platform development, can be prohibitive for investing in single projects. From the perspective of small or medium sized enterprises (SMEs) that are implementing the projects, the cost of capital can be too high for expected returns, the procedures to receive funding are often too long and overly complicated, and the process requires a level of technical skill that managers may not have[33].

6.1.2 Non-profit/Aid Models

There are a number of non-profit NGOs and aid organizations that own and operate primarily grant-funded mini-grids in emerging markets (DESI Power, Blue Energy, Green Empowerment, Tonibung, EarthSpark International to name a few)[60, 77]. The limited number of actors in the space and their diverse approaches make it challenging to draw generalizable conclusions about the effectiveness of individual models. Successful programs do exist, and point to the ability of non-profits and community groups to utilize their strong local connections to effectively assess local conditions, work closely with community leadership to design systems, and capitalize on social mission to acquire grant capital needed for individual operations[60, 61, 72].

However, many argue that dependency on donor support can significantly affect scale and impact the efficient delivery of services due to the focus of projects on social impact, rather than effective long-term operation and consistent revenue generation[15, 78]. Even for projects where a specially created for-profit entity is developed with donor capital, the same issues can arise due to misguided donor requirements[79], although some successful examples have arisen in recent years[80].

6.1.3 Public Sector (Community or Government Owned) Models

A mini-grid operator standing in front of a 120 kW PV installation on Sagar Island, India

photo credit: Juan Pablo Carvallo Bodelon

Government funding for mini-grids is incredibly limited in comparison to the total amounts of investment required. In part, this is due to strained national budgets, competition amongst development priorities (i.e. water, energy, education, healthcare, etc.), low internal technical capacity, and mixed political agendas. Furthermore, there is often a default predilection amongst government and DFIs for large projects focused on grid extension[21]. Still, many of the mini-grids operating today in the developing world were funded and are operated by national or municipal government. In some cases, communities are able to operate mini-grids for long periods of time, although there is often a strong need for subsidies and continued funding support. Overall, many point to the lack of capacity at a community or local government level as the primary reason for inefficient project operation and failure. However, it is worth noting that public models can benefit from government leadership in select cases, which can serve to reduce political risk and attract capital from DFIs and other sources that require government participation. Similarly to non-profit/aid approaches, best practices can also be drawn from cases where strong community participation and consultation improved performance[15, 60, 61] in public models.

6.1.4 Public Private Partnerships

Public private partnership models are a common means of developing hybrid facilities where government and the private sector enter into a long-term contractual agreement to collaboratively develop a project and best share and allocate risk[69]. The participation of the private sector can range from minimal (in the form of a lease or management contract) to extensive (such as a full utility concession or Build-Own-Operate (BOO) models)[32]. In the latter cases, government may hold an equity stake in the project or retain regulatory power, but would not be involved in operation or management[69, 75].

PPPs are attractive for a number of reasons. First, they allow project sponsors to more easily access public funding, which often comes at lower cost than from commercial banks[73]. PPP models also allow projects to receive alternative sources of financing that might otherwise be unavailable such as sovereign credit guarantees from international finance institutions[69, 75]. Furthermore, government participation can ease negotiation processes for private sponsors, especially if government has an equity stake in the project. Finally, and potentially most importantly, the investment and therefore partial ownership by government can reduce currency convertability, expropriation, and regulatory risk[68, 69]. In many examples, the allocation of risk in properly structured and managed PPPs is more efficient than purely private or public models, and some commonly cited development and operational risks can even be eliminated[75].

Failure in PPPs often arises from the inability of one of the actors to manage an allocated risk, which can occur for any number of reasons. Civil conflict or collapse of government can lead to the loss of a project, even if the private sector sponsors are effective in operation. Government corruption and lack of expertise can also cause basic services projects to fail, as has been the case in many post-conflict countries in Sub-Saharan Africa[81]. Conversely, government can provide all the necessary support, but if the entity tasked with managing a mini-grid is unable to adequately collect tariffs, the project can easily fail. Still PPPs offer one of the best means of efficiently delivering public services with limited public resources, while providing sufficient returns for private sector participation[23].

One example of a successful PPP for the development of RE mini-grids can be seen in Nepal. A large number of small microhydro projects were developed with debt capital from the public sector bank, the support of government subsidies, a favorable tariff regime, and significant technical assistance from development institutions[62]. Interestingly, the initial subsidies were not efficient or effective, but because of a good relationship between the private sector actors and government the subsidy policy was quickly revised to better support implementation[82].

6.2 Mini-grid Adoption Still Too Low

Regardless of the model employed, mini-grid adoption is still too low to meet the needs of populations living without electricity in developing economies. For universal access, developers, financiers, researchers, and other stakeholders need to work together to reduce one of the principal barriers to growth in the sector: availability of capital. In the following sections we assess the risk profile of minigrids in emerging markets and the transaction costs that investors face when supporting such projects. We then provide a framework which can not only reduce and eliminate much of the risk, but can also serve to significantly lower transaction costs and thus make mini-grid investments more attractive to private capital providers.

7 Barrier 1: Diverse Risk in Renewable Energy Mini-grid Projects in Emerging Markets

A NUMBER OF RESEARCHERS HAVE EXPLORED the investment risk of RE in emerging markets, with some focusing on independent power producers and even small-scale decentralized infrastructure. Komendantova et al. assessed investment risks for RE in North Africa and found that investors were most concerned about political stability, risks to personal and business safety, petroleum and fuel cost volatility, the global financial crisis and macroeconomic conditions, and finally the volatility of national investment regimes in countries of interest[18]. In another study, Rolffs found that the majority of surveyed commercial finance institutions perceive the overall risk in emerging markets for energy access products and services as being generally too high[83].

Higher perceived risk results in higher costs of capital, loans with shorter tenors, and higher equity requirements than in developed markets[20]. However, it is unclear as to how much of the perceived risk is accurate, and reflected in the real risk profiles of many emerging markets. In fact, a number of researchers have pointed out that model assumptions and structure can significantly affect the understanding and valuation of risk, and can cause investors to shy away from projects that are in fact bankable. This is especially true for projects where all risk is seen as negative (i.e. all sources of variance), even though some may in fact be upside risk (upside beta, or Ð+, which results in greater returns than expected)[84, 85].

Energy project risk in developing countries depends significantly on location, scale, technology, business model design, and numerous other factors. Centralized grid infrastructure faces different national and local government regulations, force-majeure risks, and consumer attitudes than mini-grids or pico-lighting products. Mega projects in particular, in the hundreds of Megawatts to Gigawatts, face significant construction and cross-phase risks in comparison to smaller efforts. These include significant cost overruns and the potential for loss of political support due to the long construction and development phases (5-10 years, if not longer). Such political buy-in can be incredibly tenuous, especially in post-conflict emerging and developing countries[18].

Emerging market risk profiles typically improve over time, due to institutional reform and socio-economic development. National risk measures are often used to determine cost of capital, which can be seen in the correlation between country risk measures (Euromoney, Institutional Investor Economist Intelligence Unit) and the average cost of commercial capital[86]. However, such macro-level metrics often ignore more localized conditions that may cause the project risk profiles to differ significantly within a country, especially for private-sector decentralized energy projects.

In this section, we will explore the specific risks that face renewable energy mini-grids in emerging markets, discuss the parallels to larger infrastructure, and provide examples of traditional mitigation instruments that have been used to reduce or eliminate certain risks. For clarity, the risks to investment in mini-grids can be divided into the following temporal categories: development phase risk, construction phase risk, operation phase risk, and cross-phase risk.

7.1 Development Phase Risk

7.1.1 Permitting and Licensing

Accessing the proper permits and licenses to construct decentralized energy facilities can be a difficult process, especially in emerging markets with relatively young, evolving institutions and poor regulatory frameworks[27]. In the mini-grid space, a license or permit to operate can be thought of as a ticket of entry into the market, without which legal operation cannot occur. A firm may expend significant resources but still fail to get the adequate permits and licenses to operate. This is a significant risk that prevents many projects from being initiated, let alone constructed or operated[72]. Not only is getting a permit challenging, but it can take significant time during which capital accrues interest, investors can get impatient, and other aspects of project development can suffer. The World Bank Enterprise Survey includes data on the amount of time required to get an operating permit in Sub-Saharan Africa, which can range from only 6 days in Zimbabwe to 57 days in Togo. In Latin America, the numbers are even more staggering, reaching an astronomical 138 days in the Dominican Republic, or 176 days in Argentina[52].

Permits that are required to operate a mini-grid span a variety of regulatory bodies, from the business and finance ministries that manage the establishment of new private business entities within a country, to the environmental ministries that approve safe operation to minimize harm to local ecosystems. Within many developing markets, the process of obtaining the necessary licenses or permits can be delayed or obstructed by corruption within government ministries or regulators. Avoiding or mitigating these risks is unfortunately difficult, and can stall a development process, particularly where the developer is bound by strict corporate governance standards.

In some cases, to streamline the process and mitigate permitting risk, mini-grid developers can partner with government or large DFIs through PPPs. While this can be challenging, especially when government officials lack technical capacity, the potential to reduce unnecessary permitting hurdles can be significant. An alternative is to employ local consultants and technicians with extensive experience with the local permitting process to ensure proper application and processing, however this does not eliminate the licensing risk in its entirety.

7.1.2 Design Quality

Community mini-grids in developing countries are designed on an individual basis due to highly specific resource availability (both fuel and system components), load, and socioeconomic conditions[15]. This can result in significant variability in quality across installations, and is a source of investment risk. One mitigation approach is the establishment of international standards or universally accepted methodologies for design. One example is the IEEE standard 1547.4 for the *Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems*, which addresses some of the key aspects of mini-grid design and operation, such as system voltage and frequency, power quality, reliability, load profiling and monitoring, demand response, and the technical requirements for proper interconnection between mini-grids and national grid infrastructure[87].

Component selection can have significant impacts on mini-grid operational lifetime and performance. For example, improper storage selection can lead to excessive replacement expenses throughout system life, and can actually become the driver of overall cost[88]. Until recently, operators were limited in their options (primarily lead-acid battery variants), however with recent decreases in the cost of lithium-ion, sodium sulfur, and other battery technologies, commercial alternatives have begun to enter the market[89-91]. Although the majority have a higher initial capital cost, these new battery technologies have greater cycling lives, more significant gravimetric energy density, and overall improved performance under adverse conditions[92, 93].

7.1.3 Supply and Demand Assessments

Estimating demand for proper system sizing and power purchase agreement (PPA) structuring is critical[19]. Demand should not be assessed solely on existing conditions at the site of the planned installations, but also should be projected into the future based on patterns of consumption, aspirations of the customers, and potential impacts of improved access to electricity on business development, consumption, and other local conditions[16]. However, understanding demand growth is a challenging process. Researchers have found that demand forecasts frequently underestimate the growth in consumption once electricity is introduced in a community[94].

Solar mini-grid systems can be sized to current demand and expanded as community demand grows. The recent advent of new monitoring and control technologies as well as highly efficient micro-inverters has made solar even more adaptable. This adaptability reduces upfront capital costs and the potential for inefficient system operation due to lower-than-optimal demand profiles. The approach of modular and adaptable grid expansion, deemed swarm electrification by some, is currently being explored to determine the technical and economic feasibility for large scale flexible dynamic electrification efforts[95].

System lifetime supply must also be properly assessed in order to ensure consistent operation and avoid the possibility of blackout[96]. For solar PV mini-grids, daily insolation data is available for much of the world, and fairly accurate estimates can be made to properly size PV arrays and components. Systems that operate from wind or hydro require local measurements to be undertaken for a period of at least a year, although with rapidly changing climate, a one year sample may no longer be sufficient to estimate lifetime generation[97]. In the case of biomass mini-grids, supply estimates must hinge on feedstock supply contracts and local market assessments to determine pricing and available quantity. Such surveying is complex and fraught with uncertainty, and a number of biomass mini-grids have struggled due to unexpected changes in the price, quantity, and quality of available feedstock[15, 60].

7.1.4 Incumbent Infrastructure

Local incumbent infrastructure, such as a national grid or existing decentralized facilities, can be a cause of uncertainty and risk for mini-grids. Political pressure can arise from established stakeholders, which can cause delays in permitting or approval, and potentially even lead to a complete dissolution of the project. In the case of design and planning, incumbent infrastructure can also provide uncertainty regarding local demand and potential future interconnection. Mini-grid projects need to be adequately designed for islanding and secure interconnection with centralized generation, which in developing countries is typically unreliable and prone to system failure[21, 72, 98]. In interconnected systems, outages in the network can significantly impede local mini-grid operation, reduce the ability of the operator to plan scheduled maintenance, and last but not least, low power quality can impact the wear and tear on system components, thus shortening installation lifetime and increasing capital and operations and maintenance (O&M) costs (thus decreasing profitability)[21]. System design can accommodate much of the risks of interconnection with unreliable power networks, however cost can increase significantly. Partnering with government through a PPP can also significantly improve the standing of the project and reduce the possibility of loss due to political influence by competitors or incumbents.

A cow walks by power infrastructure near Mai Mahiu, Kenya

photo credit: Peter Alstone

7.2 Construction Phase Risk

During construction, poor contractor performance and negative exogenous factors can significantly impair project completion and success. The project can be delayed, experience significant cost overruns, be abandoned all together due to unfavorable conditions or force majeure, or fail to achieve expected performance[32]. Many of these risks can be mitigated through turnkey contracts with the responsible project construction firm, performance bonds, insurance, liquidated damages clauses, as well as improved design and regulatory support. Rigorous due diligence by project sponsors during the selection of construction partners is also critical[32], particularly in the context of PPPs, where government involvement in the contractor selection process can create governance risks.

The construction phase is a period of cash lock up, meaning that equity and debt payments are not being made until the plant becomes operational. Delays during the construction phase can extend lock up, potentially resulting in fees and other negative consequences. Long cash lock up can also expose a project to other risks (some of which are more common in emerging markets), including force majeure, regulatory risk, or civil conflict[27, 34]. In the case of mini-grids, cash lock up is significantly shorter than for large energy infrastructure projects, however delays during the construction period can still occur (as discussed in this section), and therefore it is critical that all possible construction risk is assessed, mitigated or otherwise properly allocated.

7.2.1 Delay/Non-Completion

The timely execution of the construction phase of a mini-grid is a primary concern for project sponsors. Delays during construction can lead to the failure of the project to adequately service debt, complete contractual agreements for operation with local government or offtake parties, or fulfill equity expectations. In the case of mini-grids, where the project is relatively small and easy to design in comparison to large-scale energy infrastructure, delays during construction are less inevitable[27], and more dependent on location and time. Seasonal variation in weather, issues with the supply of equipment and parts, and lack of skilled labor can all contribute to delays.

As delays can be caused by any number of factors, project sponsors will typically mitigate this risk by entering into turnkey contractual agreements with contractors that have liquidated damages clauses triggered by delay. Qualified contractor selection is also important, as technical capacity varies significantly between firms, especially in the nascent mini-grid space, and low technical capacity can lead to planning mishaps and poor execution[27, 32]. During the selection process it is also key to determine the ability of the construction firm to supply capital in the case of non-compliance, which could be enforced through provision of a surety bond from the firm or insurer. In the case of PPPs, the government can also mitigate some of the construction risk by easing the customs processes and port delays for the importation of system components, or by providing security for contractors in areas where civil conflict can potentially interrupt construction[19, 23].

7.2.2 Cost Overruns

RE mini-grid projects are small installations by nature, which makes cost planning significantly easier on an individual installation basis than for large energy projects. However, in most cases system components have to be imported from international manufacturing hubs. This means delays and damage during transport can result in significant cost overruns. Furthermore, on-site damage due to equipment tampering or force majeure events such as extreme weather can result in further unexpected expenses. These risks can be mitigated through the same approaches as delay/non-completion risks, such as allocating risk to construction contractors or governments[19, 23, 27, 32].

7.3 Operation Phase Risks

The operation phase marks a key point in the project lifecycle, during which the risk of the project shifts from the construction contractor and design engineers, and is passed on to the project company itself (and any contracted operators)[26, 27]. Project "startup" also signals the beginning of debt service and dividend payments to equity (if debt service requirements are met). In the case of RE mini-grids, this period can last anywhere between 15-30 years, or longer if system components are renewed as part of initial contractual agreements between the project company and the offtakers.

A mini-grid in the operation phase can face a number of diverse risks, including customer default, force majeure, political action (such as expropriation), currency exchange risk, and more. Although the sheer number of risks potentially affecting the project is large in comparison to other phases, there are a large number of traditional (and relatively novel) mitigation instruments that can be used to ensure smooth operation, debt service, and dividend distribution.

7.3.1 Default

Default risk is a significant concern for mini-grid projects in emerging markets, due to the volatile macroeconomic and political environment, and a customer base that, on paper, has incredibly limited resources[85]. Overall, consistent consumption that reflects initial demand models is required for mini-grid projects where debt is provided on the basis of an expected regular revenue stream[24], i.e. through project financing rather than corporate loans.

Numerous recent studies show that even the rural poor spend significant portions of their income on cooking, lighting, and other energy needs. For example, the World Resource Institute estimates that over 100 million off-grid households in rural India spend an average of $3.50 a month on energy needs, while those connected to the grid only spend $2.30[99]. In South Sudan, one of the lowest performing countries in terms of socio-economic development, NRECA and the IFC found household spending on energy that averaged more than $10 per household for over 50% of the rural poor[100]. A study conducted in India by Cust et al. found rural and off-grid consumers having a willingness to pay of US $0.32-$0.43 per kWh, or about four times the local grid electricity charges[101]. This amount exceeds the levelized cost of electricity for most off-grid generation options in emerging markets[102-104].

Default on PPAs by a government or local utility offtake entity is a revenue risk that is common in emerging markets. When working with local utilities or large industrial customers, the PPA will typically be developed with non-payment clauses that allow for fines or disruption of service. Many project companies will employ credit enhancement mechanisms sourced from DFIs or local banks to provide debt service to the project company while the offtaker is able to raise capital to repay obligations[32]. When such options are not possible, the project faces the potential of loan default, and assets can be seized by lenders[27]. In some jurisdictions, such as Egypt, PPAs are backed directly through the national central bank, rather than requiring a utility to act as offtaker[20], which mitigates PPA default risk significantly. For PPAs that are signed with a government entity, breach of contract insurance or sovereign guarantees can serve to mitigate default risk even further.

For systems where no PPA exists, and the mini-grid operates as a merchant generator, customer non-payment can be handled through a variety of ways. In the past, stringent collection schedules, use of local collection agents, pre-paid metering, load limiters, and seizure of customer assets were common approaches to reduce default risk[15, 105]. More recently, due to the vast penetration of mobile phones in emerging markets, firms have been using communication technologies and remote sensors/control devices to address non-payment risk[83, 106, 107]. Some of these companies develop payment mechanisms that mimic existing spending on energy products such as kerosene or batteries, thus easing the transition for households who have no previous history with regular utility payments. Rolffs et al., found that companies in Kenya providing such pay-as-you-go services were able to recoup over 40% interest on principal, while still operating within the traditional spending habits of rural poor consumers[83]. Regardless of the means, national policy must allow the firm to legally cut off service or remove equipment due to non-payment[32].

7.3.2 Non-technical Losses

Non-technical losses (theft, poor metering, and poor tariff collection) can also significantly impact project profitability. Non-technical losses are unlike default in that they result from failure on the part of the operators to properly manage and protect the system, rather than due to customer behavior. For large grid infrastructure in emerging markets, commercial/non-technical losses can be as high as 30-40%, while in developed countries, this value is much lower (<10%)[21]. Bakovic et al., in a study focusing on a medium-size distribution utility in Latin America, found that for every 1% improvement in non-technical losses, an additional $1 of revenue would be collected per customer[108]. This risk can be lower for mini-grids and household systems managed by local entrepreneurs, where the local nature of the installation and social pressure can significantly reduce losses and improve the ability of system administrators to collect payments and ensure service delivery[109]. In some cases, systems can be designed with meters on the generation side of individual household feeders, which increases social pressure further by altering the nature of theft: rather than stealing from a utility, you are stealing from your neighbor[96, 107].

7.3.3 Monitoring and Maintenance

Consistent operation and service reliability are critical factors for project revenue collection. Technical losses due to poorly operated and maintained components can reduce profitability of the project and potentially impact planned debt service [21]. At worst complete system malfunction can lead to penalty payments under PPAs or customer default for cause[83]. If the project company sub-contracts O&M to an external provider, it is critical to properly diligence that provider. To mitigate O&M risk, lenders and project sponsors will often include penalty clauses in performance contracts that allow them to fine, or even replace, the firm responsible for operation in order for the project to survive (the latter is also known as a step-in clause)[75].

A small solar installation on Baram Island, Borneo
photo credit: Rebekah Shirley

If the mini-grid is operated by the owner rather than a third party contractor, a number of strategies can be implemented to ensure quality operation and maintenance. One approach that has been accepted by a number of firms involves the use of GSM-enabled sensor and management technology[106, 107]. This works especially well for solar PV where there are no fuel replacement requirements and day to day operation is fairly automated. When sensors communicate impending (or occurring) operational issues, technicians are dispatched to the mini-grid to diagnose and repair. Non-technical losses can be avoided through the installation of local security features (such as fencing, locks, etc), the use of sensors and cut-off switches, and the contracting of security services from a local providers.

7.3.4 Fuel Cost Variability

The availability and stability of competitively priced fuel has been a critical factor in the success of independent power projects in Africa thus far[19]. In the case of pure RE generation such as solar or wind, the financial case for fuel price risk mitigation is strong, as there is no variable fuel cost to consider in long term estimates, and operation and maintenance costs can be much more easily anticipated. For systems that incorporate a hybrid model of generation, where an RE generator is combined with a diesel of biomass fuel to eliminate intermittence, fuel risk re-renters the calculus.

Some have argued that fuel price volatility is not only harmful to individual system performance, but have also pointed to significant impacts on power system planning and national macroeconomic conditions due to fuel volatility and supply interruptions[110]. Researchers suggest that portfolios of diverse generation technologies are the optimal means of mitigating fuel price risk[111]. Alternatively, for mini-grid systems, PPAs and tariffs can be structured around a floating fuel price, rather than a fixed rate, however this can result in greater levels of customer default if fuel, and therefore electricity, prices increase rapidly[27].

7.3.5 Currency Exchange

Currency exchange risk is a primary concern for many project companies that receive debt or equity in a currency different from project revenue. The stability of local currency depends on a number of factors, including global and national macroeconomic conditions, civil conflict and regulation[85]. In an analysis of risk premiums for investments in emerging and developing economies, a group of researchers found that currency risk accounted for over 50% of risk premium for debt and equity capital[17]. The experience of a number of IPPs in Africa has also demonstrated a strong need for currency exchange risk mitigation instruments[19].

The potential for significant changes in exchange rate does not necessarily imply downside risk for mini-grid projects in emerging markets. Fluctuations can have both positive and negative effects on project debt service and equity returns. Inflation in local currency can cause the revenues generated from the local project to be worth less. As a result, debt service can suffer and even cause project default if the fluctuation is significant enough. However, local deflation of currency can cause project revenues to exceed expectations[85].

Currency exchange risk can be viewed through the lens of three types of currency exchange rate fluctuation, each of which requires different mitigation strategies[112]. Creeping fluctuation, or year-to-year change, is generally a common occurrence, especially in emerging markets, and is something that consumers can substantially absorb themselves without any action on the part of the project administrator or developer. In some cases, the pattern of inflation can also be inferred, and instruments can be put into place (like scheduled tariff increases, or indexing the tariff to local inflation) to minimize impact on project revenues.

The second, shock fluctuation, is a sudden change in the value of currency (between 5-10%) that could result from any number of events, both domestically in the project country or due to international fluctuations. Shock fluctuation is a relatively short term occurrence with an expected near-term recovery (within 5 years). For this type of currency devaluation, a number of mitigation instruments could be employed including a debt service reserve accounts (for very short term support) and a stopgap loan (i.e. further financing to pay off lenders during the shortfall, which itself can be repaid in the future when the currency recovers).

The most extreme case is catastrophic fluctuation, where currency value drops precipitously without a foreseeable return to normal levels (not within 5 years). Prime examples of catastrophic fluctuation, typically in the form of hyperinflation, include Angola in the 1990s and Zimbabwe in the late 2000s[113]. This type of currency risk cannot be handled by project developers or insurers, and is the only type of currency risk that can cause complete project failure without opportunity for recovery[112].

In the majority of cases, currency exchange risk can be mitigated by indexing long-term contracts (such as PPAs) to a basket of currencies or to an internationally accepted single currency (such as the US dollar or Euro)[32]. Furthermore, reserve accounts can be established to support projects through periods of short-term inflation as discussed above. Another option to mitigate currency risks is to borrow a portion of debt capital from local financial institutions. However for larger projects capital markets in many emerging economies are not sufficiently liquid to provide the necessary quantities of capital[19, 112]. Alternatively, local government can play a role in shielding enterprises from severe currency fluctuations by establishing a liquidity facility (potentially in partnership with DFIs) which could protect projects from defaulting on debt service due to unexpected cash shortfalls during periods of rapid inflation[112].

7.4 Cross-Phase Risks

7.4.1 Force Majeure (natural and anthropogenic)

Mini-grids in emerging markets face a number of force majeure risks (i.e. unavoidable accidents) that contribute to project failure and loan default. These could occur as a result of natural events, such as extreme weather, volcanic eruption, or earthquakes, or due to unexpected human activities such as terrorism, war, and certain political action[18]. Force majeure events can cause significant disruptions in operations through damage to project infrastructure, interruption of fuel supply, and impacts on supporting networks such as telecommunications, transportation infrastructure, or offtake facilities. Many natural force majeure events are also expected to become more frequent, as climate change increases the volatility of weather cycles[4]. Some have even argued that the incidence of civil conflict may increase as climate change stresses human systems, implying that anthropogenic force majeure events may also increase in frequency[114].

Expropriation is one of the primary force majeure risks cited in the large-scale IPP project finance literature. However, there are no easily found examples of mini-grid expropriation by country governments, even though some governments do have the necessary regulations to seize assets in the case of PPA covenant breach[85, 115]. Still, if deployment were to increase, especially in countries with unstable governments, expropriation could be a reasonable risk, and should be mitigated.

Other commonly mentioned force majeure risks are regime change and political conflict, both of which can result in complete project failure[18, 85]. These risks are especially prevalent in North and Sub-Saharan Africa, where instability has been the rule for the past few decades. While there are limited options for mitigating conflict and security risks in developing countries with unstable leadership regimes, there are cases of project success in the face of national political disruption. For example, a number of wind development projects in Egypt have survived the recent turmoil. This was accomplished through the involvement of the Central Bank, the Egyptian Electricity Regulatory Agency, the New and Renewable Energy Authority, and the World Bank. With their support, the projects were completed even as two regimes were overthrown[20].

The typical approach is to pursue political risk insurance (PRI) or partial risk guarantees (PRG), like those offered by the Multilateral Investment Guarantee Agency (MIGA) and the Overseas Private Investment Corporation (OPIC), which will cover a certain degree of loss in the case of expropriation (up to 90%)[116]. Direct DFI participation beyond providing insurance, such as in-kind contribution, debt provision, or taking an equity stake in the project also provides a political shield which may protect projects from government action, if there is a potential loss of donor support.

In most cases, while these institutions can technically provide risk insurance without sovereign counter guarantees, such mechanisms are often required ensure effectiveness of PRI or PRG in high risk regions[112, 117]. These counter guarantees are challenging to secure for small projects, and require significant time investment, which further increases transaction costs. There are a small number of institutions that provide tailored risk mitigation instruments to SMEs like mini-grids, however they are not able to fill the entire PRI gap for all mini-grid developers[116]. Alternatively, when DFI insurance is not available, independent power producers have looked to government to take an equity stake in the project, thus establishing a greater sense of ownership and reducing the probability of expropriation and other political risk[19, 27, 118]. Developers should be cautious when exploring government equity options, as issues of corruption, or conflicting long-term interests, could cause project failure.

7.4.2 Policy and Regulation

Since mini-grid installations have long lifetimes (20-30 years), the possibility of significant changes to policy or regulatory structure in emerging markets is high[21]. In fact, unfavorable policy and unstable regulatory environments are the most often cited risks for small utilities such as mini-grids in emerging markets[19, 20, 24, 85, 119].

Komendatova et al., in their interviews of multiple experts on renewable energy investment in North Africa, found that close to 50% of experts cited complexity and corruption of bureaucratic processes as a significant barrier and more than 40% cited fluctuations in national regulations, an absence of guarantees, as well as a generally low level of political stability[18]. Gratwick and Eberhard, in their analysis of private IPPs across the African content, found that projects in North Africa were on average more successful than in Sub-Saharan countries due to more robust policy frameworks, and credit enhancements such as sovereign guarantees. It was also noted that supportive policy and political support had buffered the impacts of exogenous stresses such as currency risk and fuel price volatility[19].

Instability in regulation can be as devastating to investor risk perception as unfavorable policy. One excellent example of policy fluctuation leading to investor flight can be seen in South Africa, which announced a national renewable energy feed-in-tariff (REFIT) in 2009. Subsequently the policy was scrapped, and a competitive bidding process, known as the Renewable Energy Procurement Program (REPP) was introduced. However, although the replacement program incorporated a number of the features from the REFIT plans, and used the original tariff prices from REFIT to establish competitive price ceilings, investor confusion and distrust ensued, and according to experts locally, interest in the sector waned[20].

In fact, tariff policy fluctuation is cited as one of the primary regulatory concerns of small project developers and utility companies[112]. Tariff reform can occur due to changes in governance, the development of more complex regulations, political pressure, and influence from interest groups and lobbies. In some cases, tariff regulations can change for the better and be more supportive of decentralized power production[82], while in other cases, they can make operations become highly uncompetitive and unprofitable[112].

Overall, policy frameworks need to be deeply enshrined in enforceable legislation, which clearly defines the roles and responsibilities of all actors, the terms of partnerships, and the protections afforded to private investors in social infrastructure. Furthermore, long-term political commitment to a project or program is also critical. Political favor in emerging markets is a prime criteria for success, and projects that are not supported by leadership often find themselves hampered by corruption, red tape, and long slowdowns in permitting and approval. Conversely, political interference can also have a detrimental impact, for example in situations where politicians may seek to reduce energy costs for consumers through poorly planned reductions in tariffs. In areas where the political regime is in constant shift, finding long-term investors, especially institutional ones, is a significant barrier to investment[12].

Risk mitigation in this space can be challenging, as it may require altering the path of government on key issues for national development. Project sponsors will often look to significant bilateral and multilateral donors to support the project in some capacity, as this places pressure on country government to continually support an initiative as to avoid potential loss of other funding. Government can also take an equity stake in the project, this creating further incentives to develop favorable policy such as licensing and tariff frameworks, long-term coherent power sector planning, and transparent procurement and concession processes[19].

This issue has been considered in some detail by the Climate Policy Initiative in consultation with UNEP. The conclusion is that a targeted form of policy risk insurance may be an effective way to address this key market barrier. The relative significance of policy risk in relation to other constraints is still under debate and has not yet been the main focus for relevant insurance providers[120]. However, this situation is gradually shifting, with some facilities now in place to help protect relevant investors against such policy reversals.

7.4.3 Breach of Contract

Project financing for mini-grids will most often revolve around a large number of contracts with other private companies and with country or local government. In developing countries contract enforceability for the energy sector can be a more significant concern than for other public services. According to the MIGA Political Risk Survey, breach of contract ranks as the top concern for international investors, along with regulatory risk (discussed in the previous section)[121]. Gratwick and Eberhard found that contractual breach by local government was one the principal reasons for project failure or increased costs and losses to investors. In the cases where this risk was appropriately mitigated, it was done through the support of bilateral and multilateral institutions with strong ties to national government. In fact, out of all of the IPPs investigated, those that involved DFI investment did not experience any contract changes[19]. There are also a number of firms (such as OPIC, MIGA, and private entities) that provide insurance products that cover breach of contract, although this will typically only apply to sovereign contracts (i.e. contractual agreements formed with country government or public utilities, rather than private parties).

Lack of clarity or definition in contracts, as opposed to breach of contract, can also result in project failure. Financial responsibility for different risks, and adequate allocation of such financial responsibility, is key for ensuring success. Furthermore, from the standpoint of financiers, clearly defined iron-clad contracts are key[20]. This applies to offtake agreements and PPAs, performance contracts with operators, construction contracts with responsible firms, etc.

7.4.4 Local Competition

Traditionally, electrical power provision has been viewed as a market with natural monopolies, where the costs of developing infrastructure are high and prohibitive for most actors, and the duplication of infrastructure is highly inefficient[69, 122]. Decentralized energy in emerging markets however can change this dynamic significantly and bring in the efficiencies of the free market that are essentially unavailable in traditional power sectors. However, incumbent infrastructure can pose a number of risk to entering mini-grid developers such as political pressure for issuance of concessions, funding support of unfavorable regulations, and corruption and bribery leading to preferential treatment. Additionally, rapid growth in the off-grid energy sector in a country can create other forms of competition for providers of similar services: i.e. a community may choose to back out of a mini-grid project if community members are offered less expensive household solutions more quickly.

Mitigation of competition risks is challenging, especially in countries with established energy sectors with strong political power. Still, political will can be swayed by coalitions of early-stage companies or non-profit/trade organizations that lobby on their behalf, such as the Kenya Renewable Energy Association[123] or Prayas Energy Group in Pune, India[124]. Alternatively, having strong DFI support can also impact government attitudes and support levels.

7.4.5 Technology

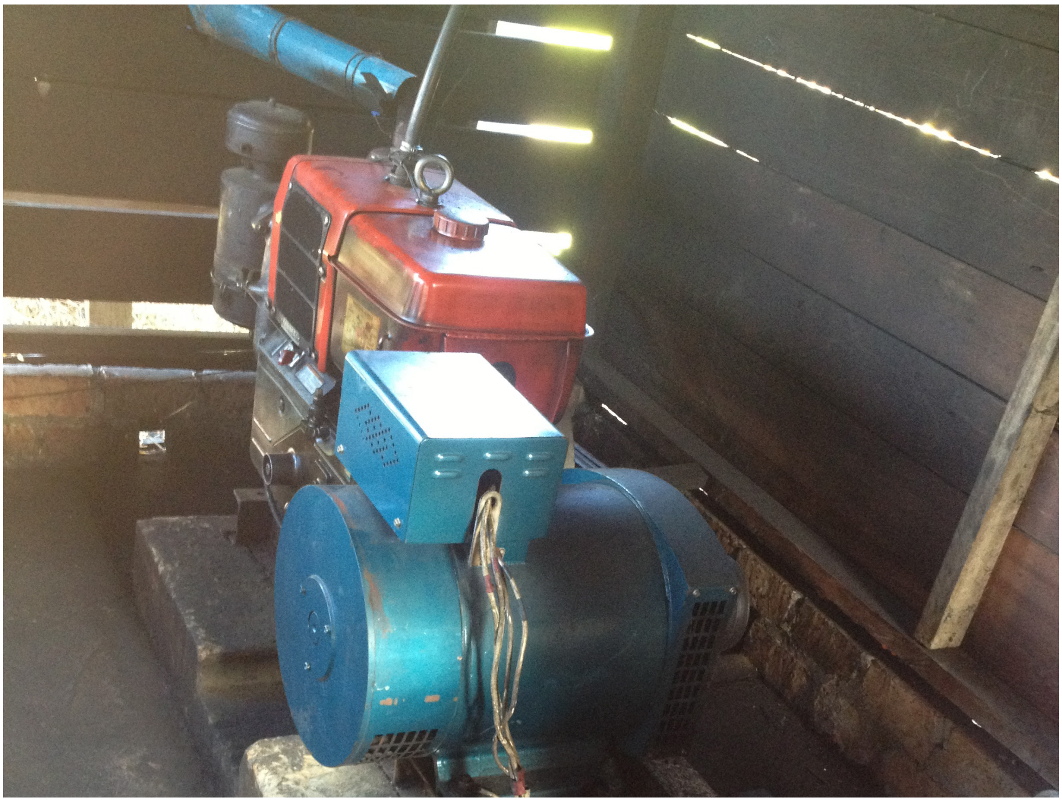
Renewable energy mini-grid technologies employed today vary in their cumulative levels of deployment, thus creating some uncertainty regarding their performance. This is especially true for new equipment and approaches (such as hybrid systems and GSM-enabled monitoring and payment infrastructure) that have yet to demonstrate a long track record of consistent and effective operation[83, 106, 107, 125].

However, the majority of components, such as PV panels, charge-controllers, lead-acid batteries and other storage technologies, etc. have been used in the field for decades. Technical experts can easily model their useful lifetimes and failure rates in various environmental and use conditions. Such modeling is even required for traditional diesel-generator mini-grids, which can significantly vary in performance due to load conditions, operating temperature, O&M practices, and quality of diesel fuel. Fuel consumption can more than double if operating conditions are not optimized, leading to increased costs and thus lower returns to investors[104]. In the cases where new technology is being employed, pilot testing is typically required to demonstrate viability to investors, and in most cases, a long-term warranty will be mandatory for investor confidence. Alternatively, performance contracts can be signed by technology providers, construction firms, or operators that designate an expected service quality, and any deviation results in fees or item replacement[27].

7.4.6 Environmental Degradation

Finally, the last significant risk for mini-grid projects in emerging markets is that of environmental degradation. This is especially true for projects being developed in sensitive ecological areas, or those that use potentially toxic components such as petroleum fuels, lead-acid battery storage, etc[126-128]. Most governments require public sector projects to complete

Environmental Impact Assessments (EIAs), and these will typically outline expected environmental impacts and appropriate mitigation measures[15]. Project companies can also design a reserve account for handling pay-



A typical diesel generator used for household power on Baram Island, Borneo

photo credit: Rebekah Shirley

ments for restoration projects in the case of unexpected environmental impact. Finally, project developers can seek support from organizations such as OPIC that provide funding and technical expertise to complete feasibility studies and impact assessments[129].

8 Barrier 2: Mini-grid Project Transaction Costs in Developing Economies

THE OTHER CRITICAL BARRIER TO FINANCING mini-grids is the transaction cost involved in providing financing to eligible projects. While individual mini-grid projects require relatively small amounts of capital (typically in the range of $1.5 Million per project, or $4.5 Million per MWp)[66, 130], investment into a mini-grid project must also incur a set of transaction costs. These transaction costs can be separated into:

- Identification costs
- Evaluation/Diligence costs
- Platform costs

Each of these costs can be considered fixed for any individual mini-grid investment. For instance, the drafting of a Power Purchase Agreement is always required, and can result in legal fees of up to $25,000. Yet the marginal benefit of the investment is variable as a function of the size of the transaction. Given the large fixed component, the marginal cost of evaluating mini-grid transactions on an individual basis generally exceeds their marginal benefit. More simply put, projects are often so small that the cost incurred in the investment process may exceed any possible return from that investment.

This manifests in the reluctance of many investors, service providers and instruments such as insurance to consider any transaction below a certain size. Distinct projects have to overcome many of the same steps as large projects. For financial institutions and project developers, the cost of assembling these elements and evaluating the risk on a project by project basis can be quite onerous. This results in potentially bankable projects being ignored due to the high transaction costs[12].

There is no generalizable or aggregate data on the actual fixed transaction costs of a mini-grid transaction. Kariuki et al. note that formal banks are often reluctant to extend loans to small projects, and the procedures to access such loans are long and complex, making it more difficult for developers to access them[33]. Singer, in her discussion of the development of E+Co, an early stage investment fund for decentralized energy in emerging markets, also found the same challenges, noting that large investors were often hesitant due to “the small size of the transactions” proposed[131].

At a practical level, a review of the investment landscape reveals indicators of the role of transaction costs. Many commercial banks, institutional investors, and other large sources of debt and equity employ minimum investment limits, as their transaction costs for financing mini-grids are similar to large energy infrastructure projects, without the associated returns or associated fees[32]. Local financial institutions often avoid small projects due to the fixed nature of their internal transaction costs, often limited by their technical capacity, access to data, and use of specialized techniques like credit scoring[132]. These institutions are also often unable to capture the benefits of economies of scale with one off investments to small projects such as mini-grids[133].

Provider	Description	Transaction size
Overseas Private Investment Corporation	*Political Risk Insurance*	No minimum transaction size for PRI. “Transaction size range from a minimum of $350,000 to a maximum of $250 million” for loans[134, 135].
Multilateral Investment Guarantee Agency	*Political Risk Insurance*	MIGA does not have an official minimum transaction size. However, of 880 projects recorded since 1990, only 37 are listed as under US$1m. The average transaction size is US$60m[136].
International Finance Corporation	*Development Finance Institution*	IFC investments typically range from $1 million to $100 million. Of the 2,000 publically available deals since 1994, only 45 are listed as under US$1m[137, 138].
European Bank for Reconstruction and Development	*Development Finance Institution*	“A minimum amount of Đ5 million, although this can be smaller in some countries”[139].
The Abraaj Group	*Private Equity Firm*	Average investment size of US$37.5m (200 investments for a portfolio of US$7.5bn[140].
Actis	*Private Equity Firm*	Minimum investment size of US$50m[141].
Vital Capital	*Impact Investor*	Average investment size of US$25m, and a smallest active investment of US$5m[142].

Even where there is not a strict minimum transaction size, the average size of typical investments by known players demonstrates that a substantial opportunity to deploy capital is required to justify diligence costs. The table below contains a sample of minimum and average transaction sizes for capital providers focused on developing markets.

This section will describe the major categories of transaction cost observed in the market for mini-grids. Although developers, governments, and other stakeholders also incur some degree of transaction cost, especially if their business model includes the provision of other services, this section will focus only on the transaction costs borne by a potential investor.

8.1 Identification costs

A small community in Borneo with substantial unexploited hydropower potential

photo credit: Rebekah Shirley

Identification costs are incurred to find bankable mini-grid investments. Investors cannot easily consult an index or register in a database of projects. Instead they must invest time and expertise to source potential projects on a case by case basis. This can include attending conferences and specialized events, sourcing information from professional consulting firms, or even actively contacting and visiting firms on an individual basis. While there are only a few prominent developers in the news, the number of active firms is substantial, and many effective actors are largely unknown outside of their region. This type of search incurs significant costs on a per project basis, which are likely to be the same regardless of the eventual size of the investment. In fact, smaller projects may be more difficult to identify as they attract less attention from stakeholders who would refer the project. Finally, identification of effective projects requires a level of internal expertise that many investment firms lack. Developing such expertise in-house can include a substantial cost as well.

8.2 Diligence costs

Diligence costs are the most important fixed cost. To responsibly finance an individual mini-grid project, an investor must conduct diligence on each of the aforementioned areas of risk. An investor needs to diligence the technical capacity of the implementer, off-taker creditworthiness, operational approach and any contextual risks such as political disruption. If conducted internally by the investor, this approach requires a significant allocation of time. Often an investor may also engage professional assistance to advise on aspects of technical and financial feasibility as well as the wider risk environment.

For instance, financing any individual mini-grid requires review of the project's legal documentation. At a minimum these documents might include a power purchase agreement, installation and commissioning agreements and operations, maintenance agreements and a land use agreement. If these documents already exist then they will generally need to be reviewed by independent counsel. Often both local project country and international counsel will review each document. Standardized and template PPAs are one approach to reducing such transaction costs. However given the current absence of widely accepted bankable PPAs for mini-grid projects, the requirement for review of each agreement remains. The fixed cost of review by counsel can be substantial and is required to make any individual project bankable.

Little public information exists to generalize diligence costs for mini-grid investments. A number of tenders have been shared publicly, however it is unknown whether or not the diligence was done properly, or within budget. For example, the ADB issued a call for diligence on mini-grid investments in India, with a total of $75,000[143]. In a report conducted by the Sustainable Business Institute, diligence costs are estimated at 30,000 to 150,000 Euro per project[144]. Experience from other sectors can provide further insight, pointing to a similar range of values. For example, an FAO report on SME forestry investments in emerging markets suggests that diligence costs average approximately $100,000 per investment [145].

Last but not least, it is important to note that the aforementioned values assume a level of internal capacity on the part of the firm conducting the diligence. In reality, firms must invest much more capital on developing appropriate internal expertise. Many of the risks that affect mini-grid investments are challenging to quantify, with a dearth of publicly available data to input into analytic models. In most cases, strong connections with local stakeholders and substantial personal experience operating in the space are required to begin to unpack the challenges for each project. When firms engage in one-off investments in such projects, there is little incentive to develop such significant capacity.

8.3 Platform development costs

Any mini-grid transaction also requires the development of legal, accounting and insurance infrastructure. Some elements of this infrastructure may have already been prepared by the project sponsor and in that instance the requirement will be for diligence rather than assembly. Either through assembly or review these instruments incur a fixed establishment cost.

8.3.1 Corporate structure

Mini-grids may be financed by domestic or international capital. Structures for domestic investment are relatively simple. However establishing a viable mechanism for cross-border investment generally requires substantial legal and accounting work. A bankable structure must be legally compliant and also tax efficient. At its simplest, an international transaction will need to resolve the most efficient means of transferring capital from the investor country to the project location. However, the most tax efficient structures often utilize domiciles of convenience and feeder jurisdictions. In addition, the establishment of new corporate vehicles to facilitate investment often requires upfront and ongoing administrative fees. Both simple and complex structures create a significant establishment and ongoing fixed cost that must be incurred whenever a cross-border transaction occurs. In Mauritius, for example – a common domicile for Africa-focused funds – the establishment of an investment vehicle can cost $15,000, while the annual cost and fees associated with the entity's management can cost $25,000 to $30,000.

8.3.2 Risk Mitigation

To make a mini-grid investment bankable investors will seek to mitigate any risks identified through the diligence process. Political risk insurance is a common requirement from both international debt and equity providers. Investors may also seek other common forms of insurance including against physical damage of the asset, breach of contract by an offtaker and surety bonds on project implementers. However, insurers must also conduct their own diligence and incur expenditure in structuring the insurance package. Due to these fixed costs many providers of common insurance will not consider transactions below a minimum size (as shown in the table above). Those that do, will pass on the costs of this diligence in higher rates.

9 Project Bundling – the role of a pooling facility

THE PREVIOUS SECTIONS OUTLINE THE FACTORS that make mini-grids challenging to finance with private capital. First, the projects have a complex risk profile. Although many of the risks can be mitigated once identified and evaluated, the size of any individual mini-grid investment is not sufficient to justify the transaction costs involved in mitigation. In addition, the illiquid market means an investor must incur significant cost to identify each investment.

Thus far most investors have shied away from supporting individual mini-grid projects. In a recent meeting of the World Economic Forum in Kenya, this issue was discussed at length, and the following was suggested:

> *"Given the significant risks profile of decentralized energy projects, a proposal was made that* ***a risk sharing facility could be created to help banks enter a market of decentralized projects.*** *Through pooling, the same facility could be used for several transactions and especially for early-stage risk sharing. The pool would rely on agreed credit assessment / eligibility criteria, with a wholesaling approach… and with domestic banks originating the business[146]."*

The WEF conclusion points to an unfortunate reality of financing mini-grids in emerging markets: significant time and capital are required to adequately mitigate and allocate all of the risks for each installation. Each individual project is simply too small to absorb the fixed costs of an isolated and bespoke transaction. In addition, there is simply insufficient awareness (particularly, but not only, in developing countries) of the potential for investment in mini-grid applications – it was acknowledged by participants at the WEF meeting that external intervention will be the most effective way to trigger this market in the short-medium term.

This challenge can be addressed by aggregation. Specifically, the bundling of standardized projects into an aggregated facility can:

- reduce transaction costs for developers and investors
- aggregate projects across diverse regions to reduce portfolio risk and bring the projects into a risk/return profile that individual projects did not meet,
- establish standards and common practices across projects that ease diligence and ensure long term viability and performance,
- improve operations by collecting operation and customer data across a large sample of projects,
- offer streamlined due diligence and in-depth risk analysis to potential investors.

In the following sections we outline the basis for Mini-grid Pooling Facilities (MPFs). We evaluate the potential benefits and drawbacks of pooling facilities, and provide a number of potential structures that can serve as guidelines for facility developers. Overall, the strategy to effectively utilize the MPF would be to take advantage of scale and expertise to maximize returns for investors, facilitate the flow of capital into energy access, and optimize the value chain of products to provide the best service to consumers at the lowest possible cost.

9.1 Benefits

There are many potential benefits of employing MPFs to support mini-grid investment.

- Use of standardization to reduce transaction costs and improve the viability of individual investments
- Unlock institutional capital by increasing scale of investment
- Reduce investor risk by diversifying across multiple projects
- Reduce costs through wholesale purchasing of equipment and services
- Increased ability to layer complementing forms of capital
- Collect aggregate data on project performance, increase the possibility of refinancing individual projects with lower cost capital
- Ability to attract carbon finance through programmatic credits
- Take advantage of sure-shot installations to finance less bankable (but potentially more socially impactful) projects

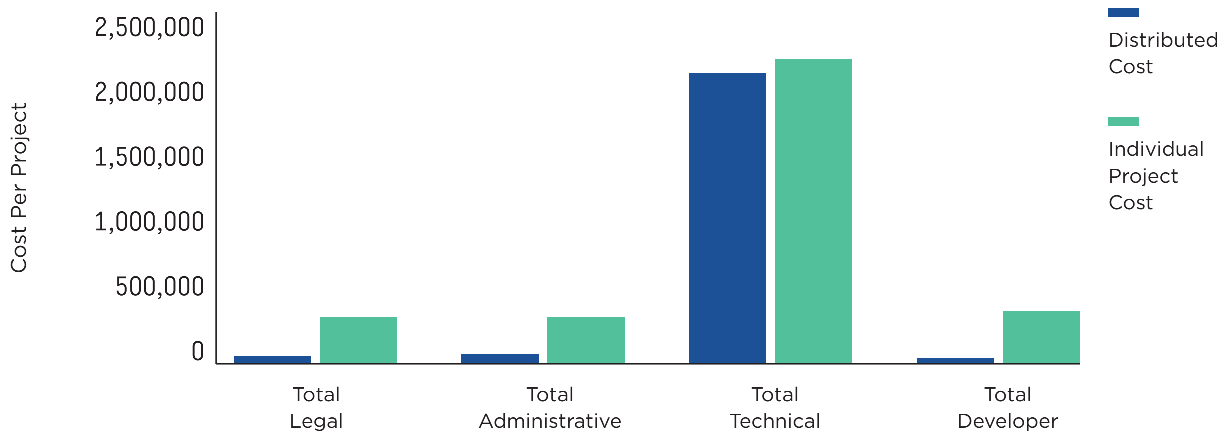
This section explores each of these benefits in turn.

9.1.1 Reduced transaction costs

By aggregating a standardized set of projects, the individual transaction costs required for each project can be dramatically reduced. To illustrate this we have prepared a model of a simplified portfolio of 10 mini-grid investments. In this simplified illustration we assessed four categories of cost that any mini-grid project must incur to be bankable:

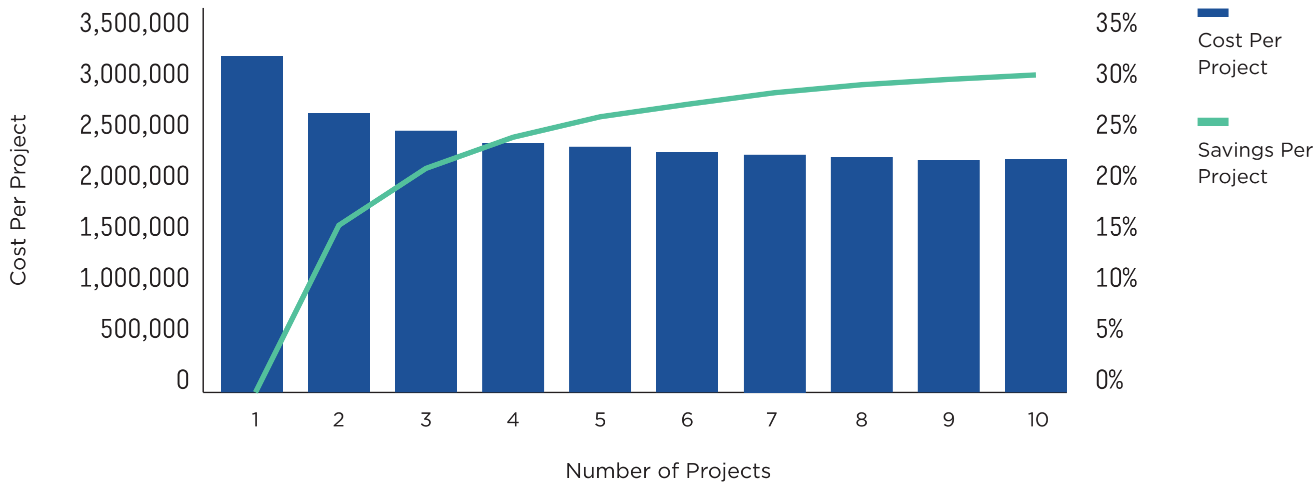
- Legal: Including estimated costs of drafting or reviewing a power purchase or investment agreement, and assembly of the corporate structure
- Administrative: Including estimated fixed establishment costs for obtaining Political Risk Insurance and debt through a Development Finance Institution
- Technical: The technical costs include the construction cost of each project but also other fixed costs such as establishment of an asset management capability and diligence of both technology and a potential implementer
- Developer: The cost of a small team of three staff working full time to implement a project.

Each of these categories of establishment costs is depicted in the figure below. Legal, administrative, some technical, and developer establishment costs can be spread across a portfolio of projects, while our model assumes additional minor discounts in technical costs based on greater volume orders of solar equipment for project construction.



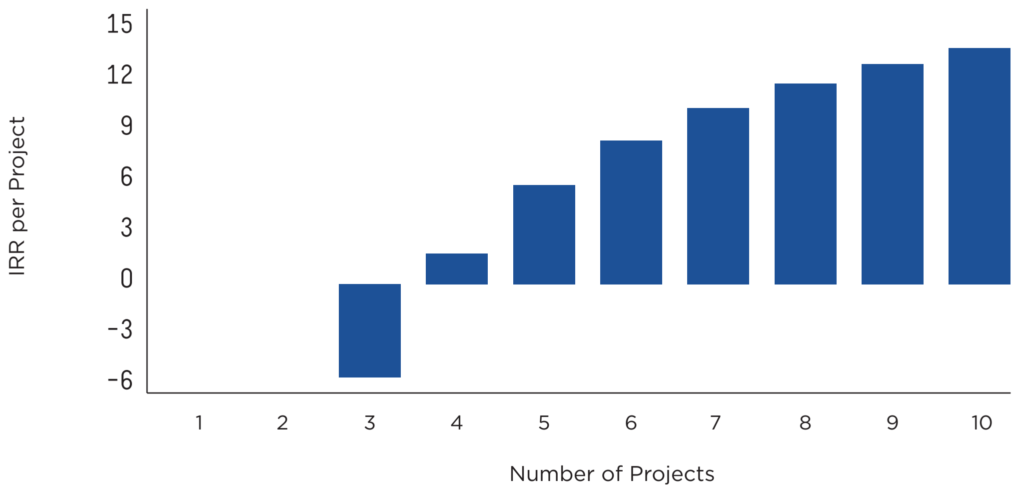
3: Compiled Establishment Costs: Individual versus Distributed (10 projects in portfolio) Cost

By spreading the fixed establishment costs across the portfolio of 10 projects, the cost of any one project is decreased. In our model this generates immediate savings, reducing the cost of each project by 16% for a portfolio of two investments and by 31% for a portfolio of 10 investments.

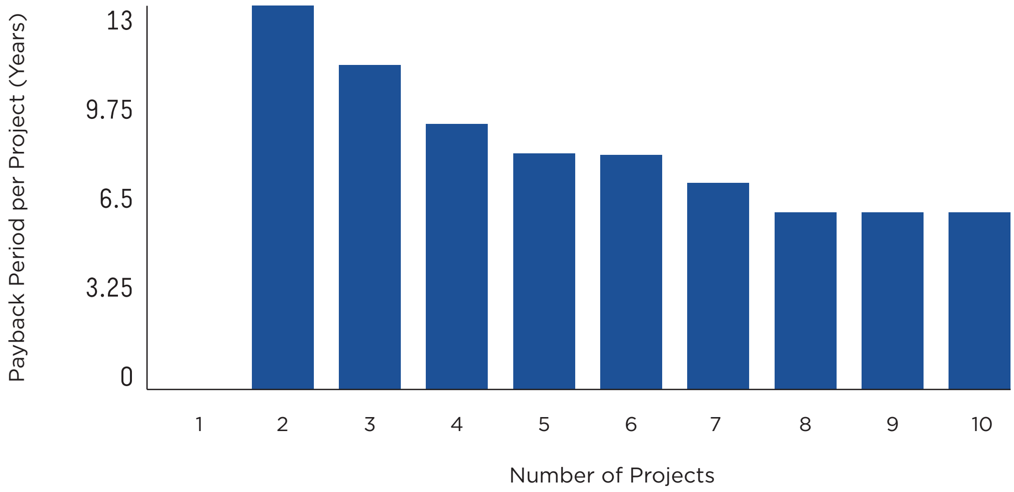


4: Establishment Cost and Savings per Additional Project Added to Portfolio

Our model demonstrates that pooling mini-grids can have a dramatic impact on the viability of individual projects. As the pool of shared fixed costs increases, the marginal benefit of each mini-grid becomes greater than the marginal cost. With each additional project, the number of years before achieving positive cash flow is reduced, from over 10 years for 1 medium-scale project to 6 years per project for a portfolio of 10, allowing energy installations to generate profitable returns for a greater portion of the asset's overall lifetime. As a result, the IRR of each project increases.



5: IRR per Project (%)



6: Payback Period per Project

This simplified model portfolio of projects demonstrates the significant impact that pooling can have on the viability of mini-grid projects by sharing transaction costs across the portfolio. Successful aggregation of these projects will be crucial to making them financeable.

9.1.2 Access to institutional capital

Transaction costs have a very pragmatic manifestation in the minimum investment sizes of most institutional investors. Mini-grid portfolios would allow an MPF to attract these investors by increasing the overall capital requirements to levels that justify their internal diligence work[34]. Pooling will facilitate access to larger amounts of international equity capital, compensating for the low availability of local venture and angel investors, which in turn can attract more commercial and institutional debt[20].

Eventually MPFs may be able to reach sufficient scale to attract institutional investors who cannot invest in individual mini-grids currently as they are below their minimum threshold for deployment of capital. These institutional investors include insurance companies, pension funds, and sovereign wealth funds. Mini-grid portfolios are a good fit for these investors as they typically look for stable, inflation-linked return investments with long lifetimes and low correlations to other investments in their portfolios. Aggregated decentralized energy projects are particularly bankable because they offer consistent and predictable cash flows, especially if adequate due diligence is conducted or if a state-backed PPA is signed with a local utility or offtaker[12].

A number of institutional funds have shown interest in clean energy investments, even in emerging markets. Norway's sovereign wealth fund, is a prime example, investing more than 3 billion in clean-tech firms in China, India, Brazil, and other emerging markets. ATP in Denmark has recently formed their own clean energy fund, albeit for developed country projects, which other pension funds are expected to join. Many US-based funds also make clean energy a priority, such as CalSTERS and CalPERS, who actively search for clean energy projects through direct investments and through their SRI screenings and overlays[12].

At this time, institutional investors have approximately 71 trillion dollars in assets, or approximately 7-70 times the amount of total investment needed to provide universal productive energy access to the world's populations[9, 10, 12]. In the case of a DFI-managed MPF, the aforementioned green bond program can be employed to attract institutional investors, while alternative MPF models can simply issue long-term debt backed by DFI or commercial bank guarantees[12]. Institutional investors would most probably enter in as senior debt, on pari passu with commercial banks in the waterfall of accounts, although some may seek an equity stake.

9.1.3 Portfolio Theory: Diversification of risk

An aggregated group of mini-grid projects may also offer investors the same return but a lower level of risk than an individual mini-grid project. Modern Portfolio Theory argues that efficiency is maximized at the lowest possible level of risk for a particular return, or the greatest return possible for a given risk profile. This implies that any portfolio that has the same returns across a large number of projects will inherently reduce risk over the investment in any one project in particular[111, 147]. The risks associated with any individual mini-grid project can be separated into diversifiable specific risks that are particular to that project and non-diversifiable systematic risks that are shared by all mini-grid projects. Financing portfolios of assets rather than individual projects provides opportunities for diversification and hedging of risk (thus an overall reduction in variance). An MPF can pool together projects with different kinds of diversifiable risk. This might mean pooling projects in different countries, with different implementers and different forms of customers. By investing in a pool of projects, investors can reduce their exposure to project specific risks. This allows investors to access returns but with a lower level of exposure to specific project risks. In this way a MPF could substantially reduce investor risk.

The fundamentals of portfolio theory, best explained by Harry Markowitz in the mid-20th century, express that the variance of a portfolio of investments, one of the quantitative ways to measure risk, can be written as a function of the quantity invested in each security, the variance of each security, and the correlation between securities[148]. This theoretical understanding of portfolio investment assumes that an individual who is judging the expected risk of a portfolio will have sufficient information regarding the potential risks (or variance) of each security, and will thus be able to make informed investment decisions. However, in the case of investing in decentralized energy infrastructure in emerging markets, such information is far from perfect, sometimes false, and largely unavailable. Furthermore, taking qualitative information, such as insider commentary on the state of ethnic tension in a country, and converting it into the concrete quantitative risks to a power generation facility, is still a polemic topic without universally accepted methodology. Still, Markowitz's fundamental theory remains true regardless of the available data: the success or failure of your assets does not depend on a single entity succeeding or failing, but on the complex interplay between the individual securities, and how each security also relates to the greater macro-environment.

It is arguable that traditional insurance or guarantee instruments provide a means to allocate risk rather than diversify it. However, diversification can be a valuable addition that may even reduce the pricing of such instruments. Pollio, as part of his paper, *Project Finance and International Energy Development,* states: "within a total risk framework it makes far better sense to structure the project portfolio in such a way so as to achieve a lower relative level of risk than to rely on financial vehicles to achieve the same result"[73].

Aggregating mini-grid assets allows a MPF to diversify many common forms of risk. The most easily diversified risks are those that are completely specific to each individual project. This might include local weather events, damage or theft. However an MPF might also be structured to diversify risk across groups of projects that share common characteristics such as a technology. For example, **currency** risk might be diversified by grouping projects with revenue in different currencies[85, 112]. The MPF could even select projects into a portfolio based on the optimal levels of anticorrelation of local currencies for each project. Mini-grids with revenues in local currency that are expected to experience inflation with respect to the debt currency could be grouped with projects that are expected to face deflation. Alternatively, the same risk can be eliminated if the portfolio is of sufficient size, and banking partners can provide a hedge to the MPF.

Another example relevant to developing economies might be to use pooling to reduce risk created by **seasonal boom and bust cycles** tied to agricultural production. These fluctuations have a strong impact on household cash availability in remote off-grid areas where mini-grids are expected to be installed. MPF managers can design portfolios with seasonality in mind and minimize potential revenue risks from customer default during economic downturn by taking advantage of the anticorrelation of crop harvests across the world.

A final example is that **anthropogenic force majeure** risks might be diversified within a portfolio. While the statistical basis for such an approach is much less sound than with currency or fuel price, MPF managers with a strong understanding of country politics and security conditions could select portfolios with uncorrelated political risk, as to minimize the impact of any one adverse event. Ideally mini-grids would be developed in countries with no common terrorist group activity, affiliations between political subversive groups, or macroeconomic dependence. For example, developing two mini-grids in Sudan and South Sudan within the same portfolio would increase risk rather than decrease it, as the financial viability of one nation strongly depends on the security in the other. However, developing a mini-grid in South Sudan concurrently with another in Malaysia could reduce the overall portfolio risk if compared to developing each individually.

As mentioned previously, it is possible that when mini-grids are developed in close proximity, socioeconomic development can cause beneficial spillover effects that can boost consumption, demand, and ability to pay[35]. However, the clustering model developed by Frearson and Tuckwell can face significant correlated political, currency, force majeure, and other country specific risks. We believe that this can easily be resolved through the division of mini-grid clusters across portfolios. Separating the installations across a number of portfolios with distinct investors, i.e. to ensure that no single investor faces a greater level of risk, would still take advantage of the benefits described by Frearson and Tuckwell without the increase in downside risk. Thus, for example, a loss of a single cluster of mini-grids due to a volcanic eruption would not significantly impact the returns of any single portfolio, while the potential upside risk if they prosper and cause regional economic growth can be absorbed by all.

9.1.4 Procurement and supply chain advantages

Pooling mini-grids allows hardware and services to be procured in bulk at discounted rates[16, 149]. Purchasing at the portfolio level result in significant cost savings[26]. With less expensive components and services, projects can be delivered at lower cost.

Bulk purchasing can also be used to reduce perceived technology risk by employing the same components across all installations within a given portfolio (although note that this will reduce the diversification of risk). Furthermore, component standardization can allow for standardized design methodologies across diverse installations that also reduce risk, improve efficiency, streamline design and construction, and further drive down costs[16]. For MPFs where external contractors are used to construct the mini-grids, capacity building can be structured around a standardized set of equipment, further improving build quality. For vertically integrated MPFs, capacity building costs can be reduced if component and technology standardization are employed.

Beyond just hardware and services MPFs can also with mini-grid value chain partners to streamline processes including importation, delivery, implementation, and end of life[16]. This can be accomplished by developing vertically integrated networks, or by providing suppliers a consistent source of revenue and providing performance incentives to collaborate more efficiently. An MPF could employ supply chain analysis methodologies to determine significant barriers, elaborate activities to reduce those barriers, and in the case of regulatory or political issues, work with the coalition of suppliers to impact policymaking at the local or national levels. Overall, this can have significant effects on strengthening the entire off-grid energy delivery sector, by reducing component prices, increasing production volumes, and growing the visibility of the market as a whole. This could be seen in the case of third-party solar finance in the US (see Appendix Case Studies).

9.1.5 Ability to layer complementing forms of capital

MPFs also offer the opportunity to layer capital into mini-grid projects in more innovative ways. With increased scale it becomes feasible to expand beyond simple equity and debt and consider opportunities to apply other forms of capital to mini-grids.

There is the potential to access mezzanine financing to alter the return profile of mini-grid investments to access other investor classes. Mezzanine capital structured as unsecured debt or preferred stock with specified payments can provide another layer of capital. This might be used to reduce equity requirements and increase the return profile.

Pooling also allows for innovative applications of philanthropic capital. The social impacts of extending energy access to impoverished populations can draw in significant impact-first capital, which can be used to cross-collateralize and de-risk a portion of the portfolio. As Jacqueline Novogratz states in her paper, *Meeting Urgent Needs with Patient Capital*,

"(public sector) solutions may require a combination of high risk philanthropic capital at the onset to test new innovations (as in the case of WHI and water); and increasing levels of higher-return capital to enable the enterprise to scale effectively"[150]*.*

Philanthropic capital could hold a first-loss position in the case of poor microgrid performance or catastrophic risk. Similarly, it can be employed to service debt prior to the operation phase of the microgrid (i.e. start payments at the onset of construction) thus reducing the cost of debt capital [34]. It might also be used as low interest debt to support high risk initial portfolios, prior to accepted proof-of-concept. After a few years (3-5) of recorded operating history, the capital can be refinanced with long-term commercial debt and reinvested in other portfolios.

9.1.6 Access to Empirical Data

MPFs offer implementers the opportunity to collect performance data on projects in a manner previously unavailable to mini-grid installers. The size and diversity of the sample can serve to develop a much deeper understanding of the asset class and potential efficiencies. If MPFs share information, cross-business model generalizations about uncertainty and risk can be derived, and future investments can be done more efficiently with significantly reduced cost of capital. Furthermore, aggregate performance data can be used to improve the management of existing systems, and for citing of future installations. With the use of standardized design models, aggregate data can be used to improve system sizing, demand estimates, and PPA structure.

9.1.7 Carbon Finance

Finally, pooling microgrids would allow MPF managers to access carbon finance, an option typically unavailable to microgrid developers due to the high per-unit cost of certification[151]. MPFs would allow managers to employ approaches to programmatic crediting (i.e. registering a program of projects, rather than each individual project) to abate some of these costs[152].

Carbon finance is emerging as a potential source of capital for renewable energy projects, especially in developing economies where incumbent generation technologies and electricity sector expansion plans are based around high-emission technologies such as coal, diesel, or heavy fuel oil.

However, the current market for trading of Certified Emission Reductions (CERs) is highly dependent on international agreements, especially the status of the Clean Development Mechanism (CDM), as well as the performance of voluntary carbon markets around the world. Still, the value of the entire international carbon market is about $30 Billion, with CERs contributing about half of that total[152]. In China alone, the current CDM pipeline of proposed projects includes close to 48 GW of renewable energy capacity, of which 15 GW have already been registered (the majority being hydroelectric power [26 GW] and wind [19.8 GW])[152].

One concern about carbon finance is the ability of an applicant to demonstrate a viable baseline estimate, or prove additionality. "If a host country already has policies in place to promote renewable energy...then it could be hard to prove that the project would not have occurred without the CDM"[152]. This poses an interesting dilemma for project developers: one requires a supporting policy framework to attract investors, but one of the possible sources of capital or collateral is less available in countries with progressive policy. To some degree, this Catch 22 has been reduced by the decision of the CDM Executive Board to not consider such policies as business as usual if implemented after November 2001[152].

Another often discussed barrier is that carbon markets are largely underdeveloped, or unstable, and that carbon prices are not high enough to provide real value. However, recent trends in emissions trading are shedding some light on this issue and providing some evidence for optimism. The California Carbon Market, launched in 2012, currently trades at an average of approximately $12 per ton CO_2e, with highs of over $20 per ton[153]. At this time, coverage is gradually increasing, to reach 85% of all state polluters by 2015. In 2013 and early 2014, nine new carbon markets were launched, including China's, which is the second largest in the world, covering over a billion tons of CO_2e[154], and expected to be the largest when the national program launches after 2016. The EU market is still the leader in the world today, with over two billion tons traded. In total 35 countries house emissions trading schemes, now valued at approximately $30 billion[154].

9.1.8 Low-Hanging Fruit and Challenging Projects

An MPF can increase portfolio social benefits by clustering low-impact/high-return projects (such as commercial/industrial mini-grids) with high-impact/low-return projects (such as community electrification projects). Inclusion of high-impact mini-grids in the portfolio can also attract a greater level of socially-minded investors such as philanthropic venture funds, impact investors, and corporations with social responsibility

A community meeting to discuss the village's 2 kW PV system in Orissa, India

photo credit: Juan Pablo Carvallo Bodelon

mandates. Such bundling can still reduce the overall uncertainty of a portfolio while delivering greater social benefits than if only low-impact/high return projects were included[16, 34, 147].

9.2 Drawbacks

The need for greater private investment into mini-grids in developing countries has been recognized by investors for some time. Pooling facilities can certainly provide a cost-effective mechanism to achieve this as-yet elusive goal. However, as with any such solution, the guidelines to achieve success must be clearly understood in advance. While there are distinct benefits that can be derived from risk hedging, expanding scale, and employing standardized technologies, practices and contracts, there are a number of potential drawbacks and risks that need to be acknowledged and properly managed in order to avoid any negative consequences.

9.2.1 Correlated Risk

Improper structuring of a portfolio can lead to unintended correlated risks, potentially jeopardizing debt service and equity dividend payments. MPF teams must adequately assess the risk profile of each mini-grid, supporting supply chains, and regulatory systems to determine sources of risk and adequate allocation and mitigation strategies. Projects with significant correlated risk should not be placed in the same portfolio.

Some of the MPF benefits listed above can also easily turn into drawbacks due to improper management. For example, the bulk purchasing of system components can save significant amounts from the capital costs of each mini-grid. However, if the MPF partners with a technology provider that delivers a poor-quality product, the technology risk across portfolios, or within a portfolio, will go up significantly. The systematic failure of a single component in all mini-grids within a portfolio can cause significant disruption in tariff payment and potential delays in debt service.

Furthermore, the standardization that inherently occurs within a pooling facility can also lead administrators to limit the customization of individual projects that may be necessary for a diverse set of markets and project locations. It is critical that managers combine a focus on local conditions with the right quantity of standardized contracts, technologies, and design methodologies.

9.2.2 Complexity

Managing multiple mini-grid portfolios, while leading to greater scale and capital requirements, can result in a level of complexity that becomes difficult to manage even for experienced administrators. Complexity can lead to a poor understanding of the magnitude and correlation of risk, reduced management capacity, and an inability to accurately assess portfolios for bankability. Furthermore, an overly complex structure can lead to a loss of transparency that can cause investor flight, even if all capital is accounted for.

A prime example of portfolio complexity directly leading to failure is that of the Enron Corporation. First, Enron's trading business involved complex long-term contracts with a plethora of high risk international partners. Second, they employed Level 3 *Fair-Value Measurements* based on internally generated asset price estimates for both internal and external reporting, significantly skewing their accounting[155]. Third, Enron employed special purpose entities for the majority of projects, leading to reduced transparency in accounting, limiting the possibility for third-party oversight and increasing the potential for fraud. Finally, Enron improperly allowed projects to share cash flows and risks, without the explicit knowledge or consent of debt holders. The accounting approaches managers employed misrepresented these transactions, and caused a significant divergence between reported values and economic reality[156].

10 MPF Structures and Stakeholders

CONSIDERING THE POTENTIAL BENEFITS and drawbacks of pooling facilities, we elaborate three potential MPF structures to guide developers. The effectiveness of these structures will depend highly on the types of capital provided, the skillset of MPF managers, and the market development in target countries. For example, a vertically integrated MPF (**design 2**) may be more effective in countries where local technical capacity is low and mini-grid installation partners are largely unavailable.

A single MPF can employ different structures for individual portfolios, which may increase transaction costs but can also ensure greater returns if each is properly administered. Portfolio structure will largely depend on the stakeholders involved, existing regulatory frameworks, available debt and associated restrictions, and the interests of equity providers. Individual portfolios may be tied to a specific implementation technology (such as solar PV generation) or a specific funding opportunity (grant availability for medical center electrification. We do not presume that the following frameworks are exhaustive, and suggest further analysis by researchers and sponsors to determine the most efficient allocation of risk and responsibility.

10.1 Stakeholders

The primary participating stakeholders in all of the designs developed are: the MPF itself, Impact Investors and Venture Capital **(equity)**, Commercial Banking Institutions **(debt)**, Development Finance Institutions **(debt, equity, or risk mitigation instruments)**, Institutional Investors **(debt)**, National and Local Government **(grants, debt, or equity)**, Philanthropic Organizations **(grants, debt, or equity)**, Technology Providers, Mini-grid Installers and O&M Providers, and Consumers (households, industrial, commercial, government). The table below summarizes the potential roles and contributions of each, as well as the potential risks that each actor can absorb or mitigate most effectively.

Stakeholder	Role and Contribution	Optimal Risk Allocation
MPF	The MPF arranges financing for all systems; acts as the intermediary between government, technology providers, installers, and customers; contribute initial equity; assures that all mini-grids meet MPF standardization and quality rules	Permitting; Design Quality; Fuel cost Variability; Default; Currency Exchange; Environmental Degradation
Impact Investor/ Venture Capital	Source of equity; hold positions as board members and drive MPF planning	Permitting; Fuel cost Variability; Default; Currency Exchange;
Commercial Banking Institution	Source of debt and some risk mitigation instruments	Default (especially for government, industrial and commercial offtakers); Currency Exchange; Policy and Regulation; Breach of Contract (through credit guarantees)
Development Finance Institution	Source of debt, equity, and risk mitigation instruments; strong source of support for MPFs due to their pools of available capital and political influence in emerging markets.	Permitting; Incumbent Infrastructure; Currency Exchange; Force Majeure; Policy and Regulation; Breach of Contract; Local Competition; Environmental Degradation
Institutional Investor	Source of debt	Default; Currency Exchange
National and Local Government	Develop and enforce regulation of mini-grids; potential source of low-cost debt or equity capital and grants; can provide some risk mitigation	Incumbent Infrastructure; Supply and Demand Assessments; Non-technical Losses; Default (for government offtakers); Currency Exchange; Force Majeure; Policy and Regulation; Breach of Contract; Local Competition
Philanthropic Organization	Source of grants, low-cost debt, or equity; capital can be used to hold a first-loss position in case of default	Default; Currency Exchange;
Technology Provider	Source of bulk technology orders	Technology
Mini-grid Installer and O&M Provider	The installer is responsible for the and a portion of the risk associated with the operation phase	Design Quality; Supply and Demand Assessments; Delay/Non-Completion; Cost Overruns; Default; Non-technical Losses; Operation and Maintenance; Environmental Degradation
Consumer	The consumer can be an individual household (in the case of community installations); an industrial or commercial offtaker; or government	Default (where a PPA contract is signed)

10.2 Structure

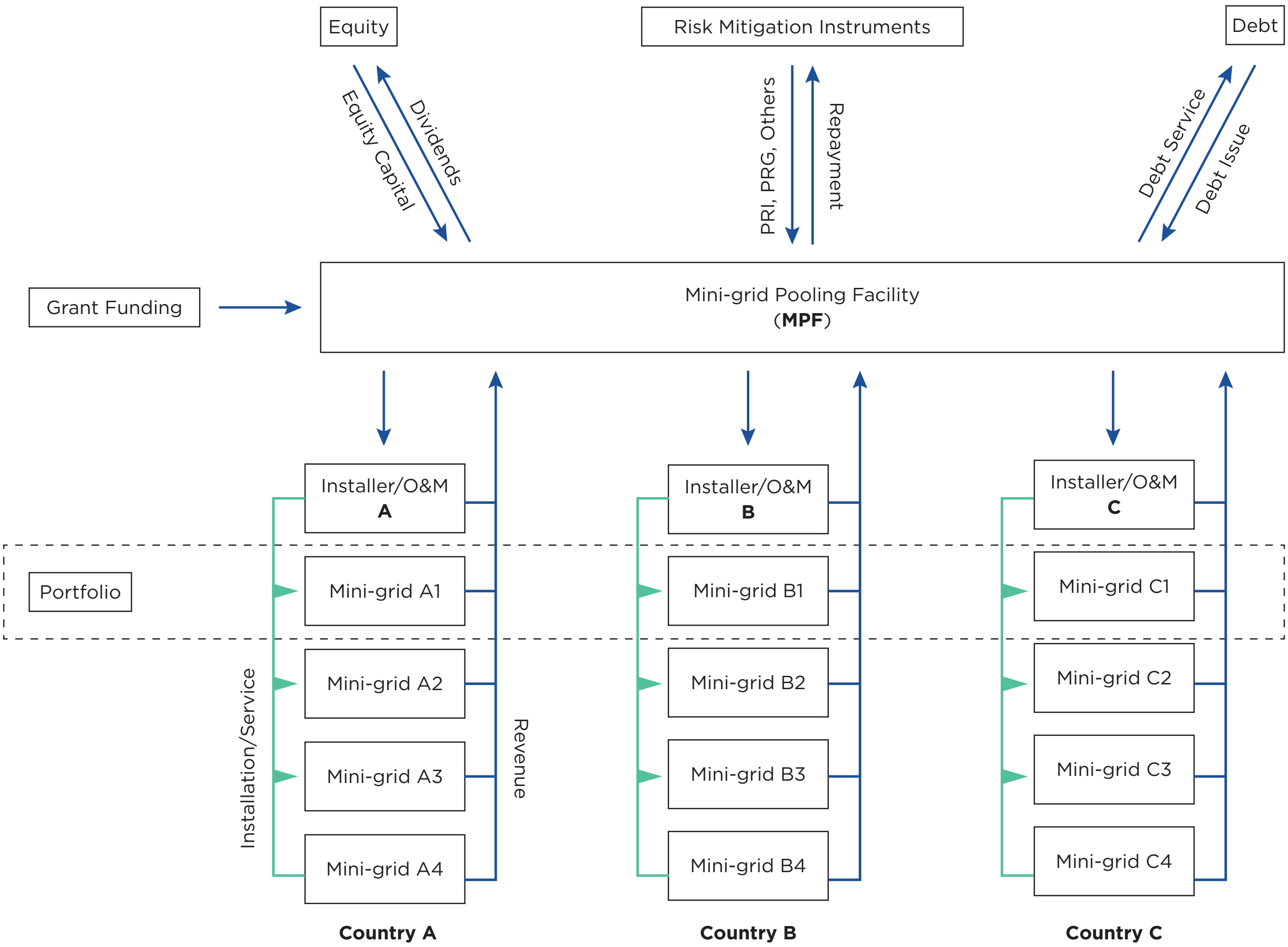
Initially, we foresee the majority of capital being sourced from philanthropic organizations, venture and impact financiers, development finance institutions, and governments. As the sector develops further and MPFs are able to provide adequate performance data, commercial banking institutions and institutional investors (insurance companies, pension funds, sovereign wealth funds, etc.) will become more prominent. However, there are already cases where energy access projects received significant support from Western commercial finance institutions, so it is possible that progressive banks will enter the market early. For example, Bank of America and Merrill Lynch (along with Soros Economic Development Fund, ICM, and Novozymes) entered into a multi-million dollar agreement with CleanStar Ventures to develop a bioethanol value chain in Mozambique. The agreement is based around the pre-sale of Certified Emission Reductions, rather than an established performance history[157].

It is possible that an MPF may attempt to securitize a mini-grid portfolio, in part to allow equity exit and ease of transfer. Securitization could also permit the use of crowd funding to raise capital, if regulations permit it. While securitization of high risk assets has negative connotations at this time (due to the subprime mortgage crisis of the mid 2000's)[158], this approach could be implemented by MPFs with sufficient operating history and data on performance and risk.

The three MPF designs proposed in this section are: *Independent* **(design 1)**, *Vertically Integrated Independent* **(design 2)**, and *DFI-Managed* **(design 3)**. For all three cases, the facility will have to rapidly and efficiently assess bankability of projects, interface with local/state government and bilateral/multilateral funding agencies, and clearly communicate project risks and returns to investors. The facility operations and management staff will have to be composed of highly qualified personnel with a deep understanding of the technologies involved, the local resource availability and consumer characteristics, the potential financial vehicles available, and the regulatory structures and subtle variations in policy across countries[16]. MPFs will have to employ highly capable financial managers with experience in emerging market investing, venture capital, DFI lending, and other related topics.

The MPF, or a national level subsidiary, would serve as the sole owner of the mini-grid projects in its portfolios to ensure standardization, minimize unnecessary risk, and avoid complications of seniority in the waterfall of accounts[27]. The majority of the operation phase risk would be allocated to the installer/operator through performance contracts. Details of ownership structure would depend on concession agreements with government and IPP policies in each country. While there are various ownership options that an MPF could employ, the two most reasonable approaches would be: Build-Operate-Own (BOO) and Build-Operate-Transfer (BOT). Both models involve private participation in the construction and operation of a project, however they differ in the duration of the private operation phase. BOO models retain private operators for the project's lifetime, while BOT contracts include a transfer clause that shifts ownership to a government institution after a predetermined period of time. Depending on the stipulations of the agreement, a BOT concession can conclude through the purchase of the installations by a government, or simply through a transfer of ownership[23, 69].

10.2.1 The Independent MPF



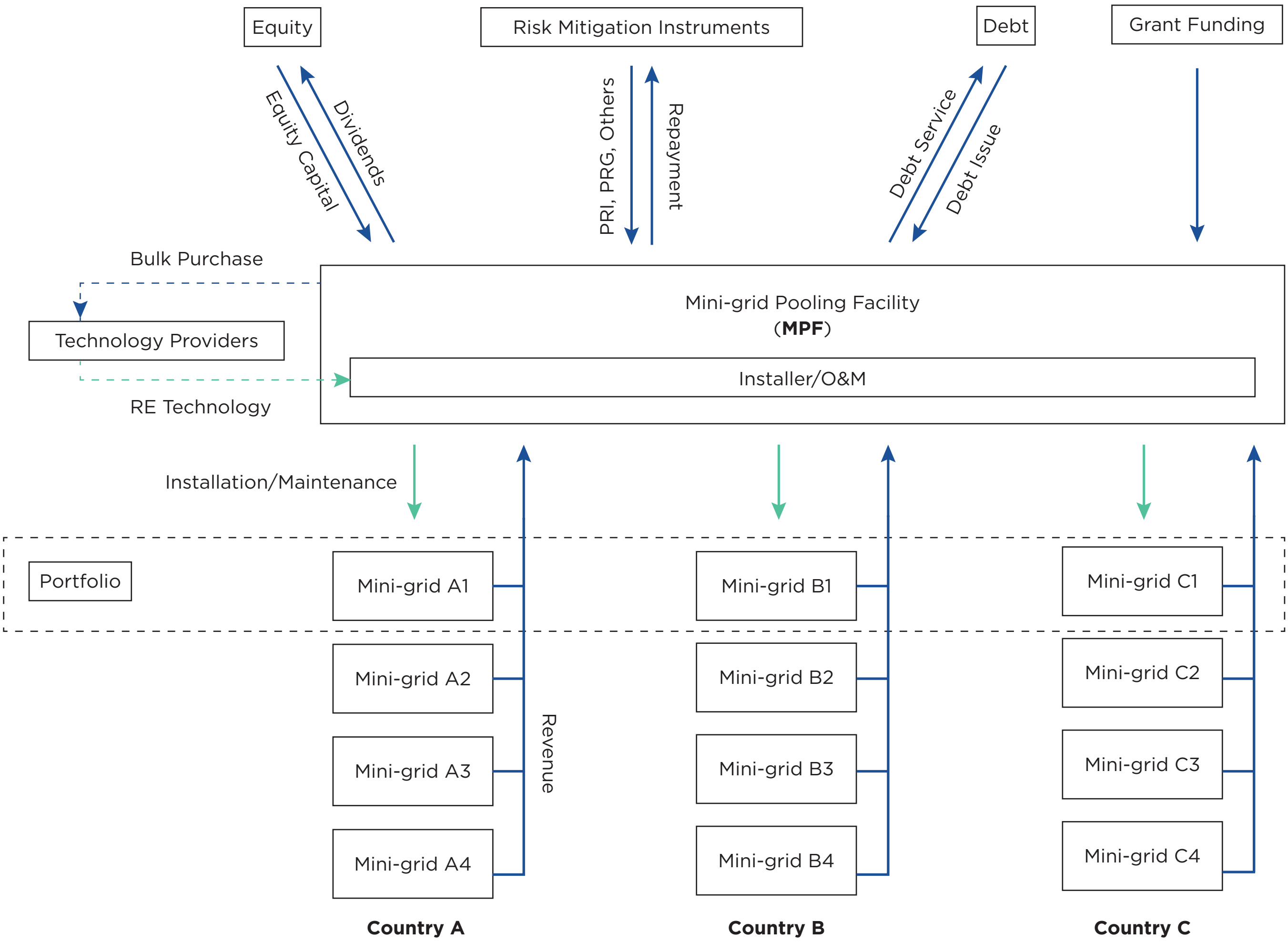
MPF Facility Design 1: The Independent MPF

In the independent MPF model, the MPF would contract all installation and operation to third-party installers/O&M providers that are based in target countries. For each mini-grid, the MPF would sign performance contracts for every stage of construction and operation, preferably with guarantees through central government in case of contract breach. The MPF would source the projects (either through internal research or from installer leads), and then elaborate system designs in partnership with installers to best suit local conditions. Local installers/O&M providers would go through a vetting process akin to that of Sungevity in the United States, which conducts rigorous due diligence and quality assurance reviews of all installers included in their program[159]. To ensure quality even further, the MPF should inspect each installation to ensure compliance to imposed standards.

The installer/O&M provider will be tasked with managing multiple mini-grids and collecting payments. All capital would flow into a single country account managed by the MPF, where a waterfall payment would occur. O&M payments would occur first, followed by a deposit into an O&M reserve account for emergency equipment replacement or repair. Remaining capital would be transferred to the MPF where debt would be serviced, based on an agreed upon seniority structure. Finally, equity dividend payments would be made to portfolio investors.

10.2.2 The Vertically Integrated Independent MPF

The vertically integrated independent MPF shares many of the same characteristics with the independent MPF. However, whereas the independent MPF outsources installation and O&M to third party partners, the vertically integrated MPF does not. All installation and O&M is done by subsidiaries of the MPF based in target countries that employ local experts and are registered as business entities in country. While increasing transaction costs, this approach allows for even greater control and standardization, as well as greater flexibility with technology purchasing. However, the risk allocation in this approach is not ideal, as the MPF must take on construction and operation phase risks.



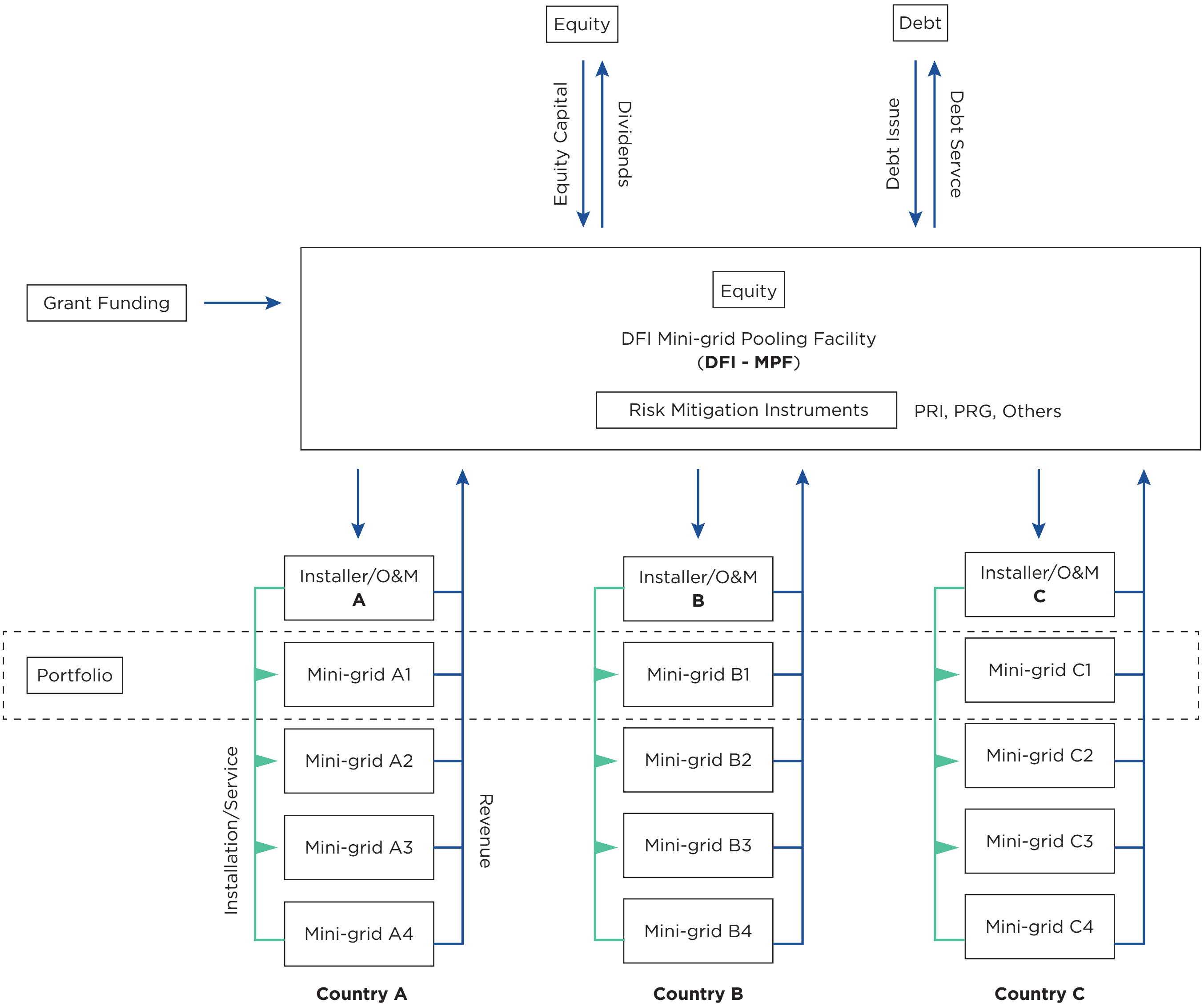
MPF Facility Design 2: The Vertically Integrated Independent MPF

10.2.3 The DFI-Managed MPF

In the case of a DFI-managed MPF, an entity like the World Bank or ADB would create a facility to channel internal funds (sourced through bonds or country commitments) into microgrid installations. The facility would act as a revolving fund without a cap, and continuously raise capital to develop further mini-grids. The DFI-managed MPF would not be vertically integrated, and would partner with local installers/O&M providers to handle construction and operation.

A DFI-managed MPF could issue bonds to finance MPF portfolios. An example to consider is that of the green bonds, implemented most famously by the World Bank, and replicated by a number of institutions.

Green bonds are a debt instrument targeted at socially minded investors that allows private sector participation in the development of projects that mitigate or provide adaptation support for climate change. Green bonds take advantage of the shift of many corporations towards triple-bottom line business models and CSR investing[160]. Green bonds can be issued by institutions that provide debt financing to projects as a means to raise capital, and come with all the benefits of regular bonds: regular returns, credit risk, and size. Typically the institution issuing the bonds conducts rigorous due diligence[160, 161].



MPF Facility Design 3: The DFI-Managed MPF

In the case of the World Bank program, the bonds process was highly standardized. World Bank specialists would conduct evaluations, based on a predetermined rubric, to assess the carbon emission implications of a given project. This rigorous methodology was familiar to private sector investors as it was representative of the traditional World Bank process of appraising and implementing projects. Furthermore, the green bond program allowed investors to support projects in countries that they were personally unfamiliar with, without the high transaction and due diligence costs[160].

Green bonds have not only been largely successful, but have also provided investors relatively competitive returns. For example, the 30% oversubscribed green bonds program in Massachusetts issued bonds at 3.20% to 3.85% for a 20 year bond with an 8 year call option. Electricite de France issued green bonds at a 2.25% rate, for 7.5 year terms[162]. Similar bonds, such as the US Treasury's Clean RE Bonds, the European Investment Bank's Climate Awareness Bonds, or the World Bank's Climate Investment Funds have also been effective at raising capital to fund renewable energy projects across the world. While the majority of RE green bond issue has occurred in developed countries, with sufficient planning and due diligence, the concept can be transitioned to emerging markets to support large portfolios of decentralized mini-grids.

11 *Conclusions*

WE BELIEVE THAT THE MPF MODEL can prove a viable solution to the mini-grid financing gap. While there are still significant gaps in knowledge, early investment by philanthropic, venture, and impact capital can pave the path towards the participation of large-scale commercial finance institutions. To incentivize the participation of all potential stakeholders, we suggest that private sector investors and public development agencies seek to collaborate with the academic community to scale-up the level of financing in this area and so move towards the targets outlined by the IEA and the UN's Sustainable Energy for All initiative. This involves working together to: (a) better understand, the impacts of electrification from the perspectives of households, communities, and small and medium sized enterprises, (b) design and develop innovative technology and applications to minimize the various operation phase risks of mini-grids, (c) develop models to better estimate future household or community demand (market potential for mini-grids)and (d) evaluate further the effectiveness and usability of Mini-grid Pooling Facilities to develop decentralized, commercially viable and hence sustainable power projects.

To facilitate this, the development finance and government institutions have a key role to play. They can collectively facilitate the sustained growth of the mini-grid sector by (a) assisting national governments in the development of supportive policy frameworks, (b) increasing investment into quality assurance programs for off-grid products, such as Lighting Global[163], and (c) improving the procedures for accessing and providing risk mitigation instruments.

Following the announcement by the IEA and other authorities regarding the potential for clean energy mini-grid applications, there is now widespread interest to develop this expected market opportunity and bring about fundamental improvements to the quality of life in many remote areas. However, there is still very little evidence of any scale-up of mini-grid activity. This is due primarily to the absence of a financing mechanism that can address the risks perceived by private investors. The key barrier is the limited size of each mini-grid investment. Introduction of the proposed MPF, with appropriate policy frameworks and quality assurance measures, can directly address this issue. By working closely together with the relevant researchers and development agencies, private investors can introduce facilities that will finally enable the scalability of mini-grid installations to meet their full global potential.

12 Author Profiles

Mr. Dimitry Gershenson is a third-year PhD student at UC Berkeley's Energy and Resources Group. During the production of this report, he was a Graduate Student Researcher at the Renewable and Appropriate Energy Laboratory and a National Science Foundation Graduate Fellow. His research focused on decentralized electrification in East Africa, finance and investment for energy access, and the second-life applications of retired electric vehicle batteries. Prior to graduate school Dimitry worked in advocacy for clean energy and served as a Peace Corps Volunteer in Honduras. He received his Bachelors at Rutgers University, where he studied Natural Resource Management and Spanish.

Mr. Matt Tilleard is Managing Partner of CrossBoundary, a leading frontier market advisory firm with operations in Africa and Asia. The firm recently launched an energy financing platform, CrossBoundary Energy, which invests in, owns, and operates renewable energy solutions for African enterprises. Prior to CrossBoundary, Mr. Tilleard worked at The Boston Consulting Group and the United Nations. Mr. Tilleard holds a Master of Public Administration from the Harvard Kennedy School of Government and a Master of Business Administration from the Stanford Graduate School of Business, where he studied as a Fulbright Scholar.

Mr. Jake Cusack is Managing Partner of CrossBoundary, a leading frontier market advisory firm with operations in Africa and Asia. The firm recently launched an energy financing platform, CrossBoundary Energy, which invests in, owns, and operates renewable energy solutions for African enterprises. Prior to CrossBoundary, Mr. Cusack worked at Abraaj Capital, an emerging market private equity firm, and served as a Marine Corps officer, receiving the Bronze Star for actions in Iraq. Mr. Cusack holds a Master of Public Administration and a Master of Business Administration from the Harvard Kennedy School of Government and Harvard Business School.

Mr. Dean Cooper is Energy Finance Programme Manager within the Division of Technology, Industry & Economics (DTIE) at the United National Environment Programme (UNEP), based in Paris. Dean works with the public and private sectors to build sustainable clean technology markets, using public sector funds to attract private finance and thereby scale up investment in low-carbon applications, particularly in developing countries.

For 7 years prior to joining UNEP, Dean headed Parallax, a small development business based in South Africa and the UK, which worked to bring sustainable clean-energy solutions to remote communities in Southern Africa. Before Parallax, Dean worked at the UK Energy Agency to help manage the UK's Best Practice Programme and was then appointed Head of Co-operation with Developing Countries within the European Commission's Energy Directorate. After 4 years in Brussels, Dean was seconded to the Department of Minerals and Energy in South Africa to build EU/SA energy development co-operation, and then to Botswana, to develop closer links with the Southern Africa Development Community (SADC) Secretariat. He has a 1st Class degree from the University of York and an MBA (distinction) from Warwick Business School.

Dr. Ashby H.B. Monk is the Executive Director of the Global Projects Center in the School of Engineering at Stanford University and is a Senior Research Associate at the Smith School of Enterprise and Environment at the University of Oxford. His current research is on the design and governance of institutional investors, with particular focus on innovative investment models, vehicles and access points to innovation.

Ashby has published in leading academic journals and is co-author (with Gordon Clark and Adam Dixon) of a monograph on sovereign wealth funds published by Princeton University Press (2013) and is co-editor of a book on risk management published by Oxford University Press (2009). His research and writing is regularly featured in The Economist, The New York Times, Wall Street Journal, Financial Times, Institutional Investor, Reuters, Forbes, and on National Public Radio among a variety of other media outlets.

Outside of the academy, Ashby is Head of Organizational Strategy for the Chief Investment Officer of the Regents of the University of California. He received his DPhil from Oxford University, holds a Master's in International Economics from the University of Paris I - Pantheon Sorbonne, and a BA in Economics from Princeton University.

Dr. Daniel M. Kammen is the Class of 1935 Distinguished Professor of Energy at the University of California, Berkeley, with parallel appointments in the Energy and Resources Group, the Goldman School of Public Policy, and the department of Nuclear Engineering.

Kammen is the founding director of the Renewable and Appropriate Energy Laboratory (RAEL; http://rael.berkeley.edu), and Director of the Transportation Sustainability Research Center. He has founded or is on the board of over 10 companies, and has served the State of California and US federal government in expert and advisory capacities. Dr. Kammen is also the first energy fellow of the Environment and Climate Partnership for the Americas (ECPA) initiative, and served as the first Chief Technical Specialist for Renewable Energy and Energy Efficiency at the World Bank.

Dr. Kammen was educated in physics at Cornell (BA 1984) and Harvard (MA 1986; PhD 1988), and held postdoctoral positions at the California Institute of Technology and Harvard. He was an Assistant Professor and Chair of the Science, Technology and Environmental Policy Program at the Woodrow Wilson School at Princeton University before moving to the University of California, Berkeley. He has authored or co-authored 12 books, written more than 300 peer-reviewed journal publications, and has testified more than 40 times to U.S. state and federal congressional briefings, and has provided various governments with more than 50 technical reports.

13 Case Studies

The Carbon Trust

The Carbon Trust is an example of a private initiative developed around channeling greater levels of public capital into socially and environmentally responsible enterprises. Although not an example of project pooling, the Carbon Trust exhibits a number of best practices that can be applied to the facility suggested in this paper[20].

The Carbon Trust is a leader in RE finance in the UK and internationally. Founded in 2001, the Carbon Trust is a union of international organizations interested in improving their operations to reduce carbon emissions and minimize environmental degradation. They provide advisory and consulting services and invest in technologies and projects that fit their mission. In the past 13 years, they have invested a total of £60 million in 23 companies. Of those, there have been 16 venture early-stage investments, 3 of which have led to successful exits, including a fuel cell company, a tidal generator technology developer, and a network optimization solutions provider for telecoms. The estimated impacts of the Carbon Trust, according to their 2012-2013 annual report, are (a) an estimated carbon saving of 53.5 MtCO2e and (b) a cost savings to beneficiary organizations of £5 billion[164].

Four primary reasons that the Carbon Trust has been successful can be applied to the development of an MPF. First and foremost, it is essential to have **a skilled and interdisciplinary management team** that has a thorough understanding of relevant technologies and innovation, financial vehicles and relevant market risks, and the political environment in which each project operates. Second, a **governance structure** needs to be developed that allocates risk and responsibility appropriately across all stakeholders (i.e. Carbon Trust provides expertise and finance, but does not implement RE projects). **Large scale** is required, with long-term investment strategies that attract institutional investors and large commercial finance institutions. Finally, projects should be designed and implemented around **standardized approaches** tailored to highly specific local conditions[20, 164].

Asian Development Bank (ADB) Independent Aggregator Facility

A recent report (2013) published by the Asian Development Bank (ADB), written by Lyndon Frearson and Michael Tuckwell, discusses the potential of using independent mini-grid aggregator facilities on a country-by-country basis. The structure and design of the proposed concept comes the closest to the idea described in this document, but has a number of notable differences[16].

Frearson and Tuckwell suggest that dedicated "independent aggregator" facilities should be developed to support and fund "clustered, mutually supportive [mini-grid] systems". Their model takes advantage of the potential productive and socio-economic impacts of mini-grids to improve local conditions and thus lead to greater customer demand, as well as ability and willingness to pay. The authors very appropriately stipulate that a mini-grid deployment program led by any individual actor within the value chain is limited by the barriers that that actor faces. They suggest that an independent aggregator facility can not only adequately allocate risk and responsibility, but also fill in the gaps between Suppliers, Finance, and Consumers, thus improving overall efficiency, reducing costs, and attracting greater levels of capital. Such facilities would have deep technical capacity, understanding of necessary financial instruments, and a fundamental knowledge of local conditions. The facility would serve as a conduit for both public and private capital[16].

> *"Such an approach can allow the* ***financial risk of all the individual systems to be pooled*** *and spread across multiple low revenue assets,* ***internal cost sharing*** *to take place across the asset base and potentially even cross-subsidization, and* ***consolidation and rationalization of resources*** *for the operation, maintenance and management of systems. It also provides an opportunity to facilitate* ***greater integration*** *between the enterprises supplying and operating systems and local communities and their economies"* [16].

While the benefits of the aggregator are clear, the potential for increased correlated political, currency, fuel price, and force majeure risk is higher when the facility bundles within one country. These risks can outweigh the cost reduction benefits of local aggregation. Still, a MPF could take advantage of "mutually supportive systems" by having **portfolios that overlap geographically**, thus taking advantage of the aforementioned benefits while diversifying risk across independent exclusive portfolios (discussed further in the paper).

The ADB aggregator model also fails to explore opportunities for successful **vertical integration** of the facility with service providers (i.e. mini-grid installers). While they appropriately suggest that each stakeholder has comparative advantage, there is potential for cost savings and risk reduction by having internal installers rather than qualified external contractors, as can be seen in the third-party solar financing case study further in this document.

Third-Party Solar Financing in the United States

One of the best examples of privately managed successful distributed RE project pooling can be seen in the case of third-party financing for commercial and residential solar in the United States. While a relatively new phenomenon, such models of ownership (pioneered by Sungevity, Solar City, and SunEdison) have transformed the US market. For example, solar leasing, a third-party ownership model, is responsible for over 70% of residential solar installations in the largest markets in the US (i.e. California, Arizona, and Colorado)[165.]

The majority of third-party financed options for residential solar remove the up-front cost barrier for consumers by providing either a standardized PPA, whereby a consumer pays for the electricity he or she consumes at a preset rate for a specified time period (typically 15-20 years), or through a lease structure, whereby the consumer leases the system at a fixed monthly price, and the energy generated is subtracted from the monthly bill[166-168].

Capital is typically sourced from a mix of commercial bank or institutional investor loans, venture capital, securitization, bonds, and in some cases, initial public offerings (IPOs)[167, 169]. Other approaches of sourcing capital, such as crowd funding (one example being the CA-based Mosaic) allow individuals to buy shares in a solar project and receive financial returns on their investment. In the case of Mosaic, the ROI averages 4.5%[170].

Third-party ownership brings down the cost of each installation by aggregating customers, allowing for larger scale, and therefore cheaper wholesale equipment costs for the installer. This approach also significantly mitigates technology risk, and the complex decision making that consumers would otherwise have to undergo (i.e.. higher transaction costs) to select the best system for their household – a commonly cited complaint[167]. By aggregating consumers, firms also reduce transaction costs for all parties involved, especially when standardized PPAs and contracts are used. In many cases, further cost reductions are possible through vertical integration with manufacturers and installers, advanced logistics and design platforms that allow for rapid site analysis, and through distribution partnerships with other firms such as Home Depot or Best Buy[149, 171].

However, third-party financing in the US did not emerge without significant political effort. The models all depend on significant support from federal government and state government, through federal tax regulations like the investment tax credit (ITC) and accelerated depreciation allowances, as well as a number of enabling regulations, such as net metering, electricity market deregulation, exemptions from regulations by local public utility commissions, renewable energy certificates, feed-in tariffs, and state-level rebates[149, 169]. In fact, even as third party financing blooms in the US, the volatility of the regulatory environment, and resultant investor trepidation, have been cited as significant barriers to greater expansion of the sector[149, 169].

Furthermore, in the case of most third-party financing schemes in the US, the initial credit requirements can be prohibitive for low income households[167, 172]. While third-party financing has drawn in more of the US population than traditional ownership models, especially from medium-income households, low-income households are still unable to secure financing due to the perceived risks. In recent years, however, there have been a number of successful initiatives targeting third-party ownership models at low-income populations. One example of successful third-party financed solar for poor consumers has been developed in Colorado using a mix of private and public capital. Even though consumers are low-income (earning less than 60% of local median income of 36,480), the project is expected to receive a net profit over the course of the 25 year long project.

The reasons for the project's effectiveness can also be translated as guidelines for structuring an MPF. The project in Colorado was successful because it revolved around a **competitive bidding** process for developers and employed a request for proposals with a **highly structured set of contracts** for procurement, technology selection, labor quality, and the levels of supervision required. All systems were also installed with **security features** to avoid theft, as well as **metering and communications equipment** to improve monitoring and O&M. Unlike most third-party financing where

PPAs are structured around a fixed price tariff, the PPAs for this project hedged against currency risk by **gradually increasing tariff to match inflation**[172].

E+Co

E+Co, a financing facility for off-grid energy companies in emerging markets, was formed in 1994 with the intent to provide a combination of early-stage patient capital and capacity building to improve management and operations. The long-term goal was to provide the necessary tools and capital to enterprises to demonstrate a successful business model, and then seek later-stage financing from third parties. Nick Parker, one of the chairs of E+Co's board during its 18 years of operation, described the organization as a provider of "venture debt". This meant that, as capital was provided to early stage companies, E+Co partners would become board members, mentors, and advisors to each company, supporting the growth process[131]. E+Co was named Sustainable Investor of the Year in 2008 by the IFC/Financial Times Sustainable Finance Awards[173].

Out of many investment sub-facilities developed by E+Co, a number have been cited as successful. One was the $17 million Central American Renewable Energy and Cleaner (CAREC) Production Facility, which supported a number of projects across Central America with mezzanine debt and loan guarantees. CAREC focused on supporting sub-5 MW projects by directly providing various forms of debt capital (subordinated, convertible, and other quasi-equity structures) (<25%), attracting commercial and development bank debt, channeling further financing through carbon credits, and providing a loan guarantee from the USAID Development Credit Authority[174].

E+Co's founders had faith in the overall success of their portfolio, even in the face of significant heterogeneity of investments. They saw it as an opportunity to reduce risk and offset the losses of some projects (which potentially had higher environmental or social benefits) with the success of others. In *innovations*, the CEO of E+CO Christine Eibs Singer wrote "This is another portfolio lesson learned in our Port Authority days, when the investments and revenues of profit centers like the John F. Kennedy Airport and the World Trade Center offset the losses of the PATH transit system and industrial parks"[131].

In their exploration of investor attitudes and risk perception, the founders of E+Co discovered that the primary concerns were: the poverty of the end-consumer and lack of ability to pay, the stability and political risk in target countries, the lack of data regarding technology quality, the small size of individual projects and associated revenue streams, and last but not least, the weakness of the overall market. However, they also saw investors and programs repeatedly investing in individual "winners" through "character investing", rather than seeking out balanced portfolios131.

At the time of E+Co's restructuring, the fund had close to $35 million of debt placed in companies, with $12.5 million of previous debt obligations had already been serviced. The decision to split the lending and capacity building arms of the company remains somewhat opaque, however the founder Christine Eibs Singer credited investor attitudes as the main reason to restructure. "It apparently was easier for donors to fund separate technical assistance or EDS entities to see what our experience was showing: the efficient integration of service plus capital"[131].

Critics of E+Co disagree regarding the efficiency of combining technical assistance with financing under a single facility, however lessons can still be drawn from individual E+Co projects to show how E+Co was able to pool diverse projects and sources of finance to support off-grid clean energy projects. For example, E+Co sub-facilities like CAREC were successful because of the **appropriate scale**, successful integration of various sources of **capital with diverse agendas**, the use of **non-traditional sources of capital** such as carbon credits, and the combination of pooling and **traditional risk mitigation instruments** like PRI and loan guarantee facilities administered by DFIs.

Water and Sanitation Project Pooling

Further insight about project pooling can be drawn from the experiences of emerging market water and sanitation development, which shares many of the characteristics of decentralized electrification: challenging remote environments, poor consumers, lack of credit rating of projects, lack of incumbent infrastructure, difficult financing due to small size, and high heterogeneity between projects[32].

Water and sanitation also has historically received low levels of private participation. Baietti and Raymond, in their World Bank Report titled *Finacing Water Supply and Sanitation Investments Utilizing Mitigation Instruments,* state:

> *"The small share of private participation in the water supply and sanitation (WSS) sector and the extremely low level of risk mitigation*

instruments underscore (a) the specific nature of the risks affecting the sector; (b) the lack of adequate project preparation (and thus of bankable projects); (c) the difficult access of water investments to financial markets; and (d) the constraints and limitations among the various risk mitigation instruments, which render them inadequate to respond in a significant way to the challenges of the water sector[112]."

However, water programs or facilities that provide a bundle of projects based on offtake agreements with local government or local utilities are viewed as less risky and more attractive to investors[112]. Such pools have been financed through debt facilities created by government that channel international loan funds through local financial intermediaries (such as small commercial banks or micro-lending institutions), which have the backing of sovereign counter guarantees. However, this approach is limited to the amount of public funding available, as well as the interest of government to invest limited financial resources in a project for remote communities with a less influential constituency[43]. In limited cases, more mature and experienced utilities have worked together with development finance institutions to issue bonds to support pooled projects, a model that can be employed to source debt capital for future MPFs with established track records of debt service[32].

Calpine Corporation

The final case of project pooling that we will explore is that of Calpine Corporation in the United States. Some would cite the bankruptcy of Calpine in 2005 as a reason to not draw lessons from their experience, which would ignore the many factors that led to their collapse (including a near-universal replication of their financing model, significant improvements in natural gas combined-cycle generation efficiency, a spike in natural gas prices, the collapse of Enron, and the California energy crisis)[175, 176]. Still, we believe that their award-winning approach to financing a large swath of merchant power plants in the US starting in the early 2000s can provide insights into novel financing mechanisms for a of portfolio risky assets.

In 1999, Calpine decided to pursue an aggressive expansion strategy, with a goal to triple generating capacity within 5 years, at a cost of almost $6 billion. After substantial internal deliberation, the leadership team decided to develop a new subsidiary that would only incur approximately $1 billion of initial debt (a much easier proposition than borrowing the entire amount). They thus formed the Calpine Construction Finance Company (CCFC) that borrowed capital through a secured revolving construction facility. The tenor of the initial debt was only 4 years, with the expectation that at the end of the tenor all developed plants could be refinanced with longer term debt, and the initial debt capital could be re-borrowed to invest in other generation assets. Calpine addressed the construction risks by agreeing to fund as much extra equity as necessary to complete the plants on time. This approach was also attractive because financing a small number of plants in the initial push still reduced transaction costs when compared to individual project financing. The initial concept was also that, as more and more plants came online and demonstrated bankability, the cost of capital would decrease over time26.

Of the many aspects of the financial model that Calpine developed, a number can be applied to the structuring of an MPF. **Appropriate scale** is required to provide necessary returns to service debt, allow for reinvestment in new assets, and pay out of dividends to equity without exceeding commercial investor risk comfort levels. **Technological standardization** is key to not only reducing risk, but also driving down costs through bulk purchasing. The **vertical integration** of O&M to develop a highly technically capable internal team can reduce costs even further. Finally, significant learning curve efficiencies can be derived from having a single **experienced management team** develop portfolios of projects, rather than having individual teams work on each project individually[26].

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About the UNEP Division of Technology, Industry and Economics

Set up in 1975, three years after UNEP was created, the Division of Technology, Industry and Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: climate change, harmful substances and hazardous waste, resource efficiency.

DTIE is also actively contributing to the Green Economy Initiative launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

The Office of the Director, located in Paris, coordinates activities through:

> **The International Environmental Technology Centre – IETC** (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.

> **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.

> **Chemicals** (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.

> **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.

> **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.

> **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.

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Mini-grids are viewed as one of the key elements in securing universal energy access in the developing world. However, current levels of investment into renewable decentralized energy are insufficient to reach the development goals identified by initiatives such as the UN's Sustainable Energy for All. In order to reach such levels of deployment, new models of financing need to be designed.

In this report, we provide a conceptual framework for the development of a private sector facility to pool and cross-collateralize diverse capital to support international mini-grid portfolios. We begin by discussing the current status of electrification initiatives in developing countries, and the approaches adopted to access finance for their implementation. We then argue that two key barriers exist to the effective financing of mini-grids. First, mini-grids in emerging markets have a complex risk profile that is difficult to mitigate at the individual project level. Furthermore, individual mini-grid projects are so small that their fixed transaction costs reduce their financial viability.

As a solution to these barriers we propose the Mini-grid Pooling Facility (MPF) concept. The remainder of the report focuses on the key topics of finance pooling and project bundling, the conceptual development of multiple designs for bundling facilities, and a discussion of the benefits and drawbacks of each design. We conclude by discussing the opportunities for public and private financiers to work together with academic researchers, development finance institutions, and entrepreneurs to expand the understanding of the risks and returns in the mini-grid space, and collaboratively implement the Mini-grid Pooling Facility concept.

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