Making Access Possible

2022

INVESTOR TOOLKIT

Financing the future

Opportunities to finance clean energy for the low-income at scale

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD

UNCDF
Unlocking Public and Private Finance for the Poor

THE MAKING ACCESS POSSIBLE PROGRAMME

Making Access Possible (MAP) is a multi-country initiative to support financial inclusion through a process of evidence-based country diagnostic and stakeholder dialogue, leading to the development of national financial inclusion roadmaps that identify key drivers of financial inclusion and recommended action. Through its design, MAP seeks to strengthen and focus the domestic development dialogue on financial inclusion. The global project seeks to engage with various other international platforms and entities impacting on financial inclusion, using the evidence gathered at the country level. MAP is a diagnostic and programmatic framework to support expanding access to financial services for individuals and micro and small businesses.

The MAP framework was designed to create the space to convene a wide range of stakeholders around an evidence-based country diagnostic exercise and dialogue, leading to the development of national financial inclusion roadmaps. The roadmap identifies key drivers of financial inclusion and includes specific actions that will contribute to greater financial inclusion in the country.

CLEAN ENERGY INVESTING FOR PEOPLE AND PLANET

The UNCDF MAP Note 2 – Clean Energy Investor Toolkit provides insights into the realities of energy and clean energy demand and supply in low-income, emerging markets. It considers the investment case – opportunities and challenges – for expanding energy inclusion to the point where clean energy could fulfil its potential as a transformative mechanism: improving livelihoods (especially of low-income households and MSMEs) and increasing access to opportunities in support of inclusive economic growth, while combatting climate change.

Energy stakeholders – country governments, policymakers, energy suppliers, entrepreneurs, financial services providers, and would-be investors – are provided with both the business case and the infrastructure investment requirements for expanding energy inclusion.

The toolkit is part of the larger body of work on financial inclusion towards inclusive growth and sustainable finance. The findings presented here are drawn from MAP's 2020 five-country study in the Southern African Development Community, which aimed to provide insight into the potential for accelerating uptake of cleaner, off-grid energy solutions, in contribution to the UN Sustainable Development Goals (SDGs) and particularly SDG 7: Affordable and clean energy: ensure access to affordable, reliable, sustainable and modern energy for all by 2030.

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ABOUT THE COVER

The cover design represents the moving cycle of a working system where all parts come together with a common goal. People, data, finances and policy fit together to create business solutions that focus on, and revolve around, the people they are created for.

SUSTAINABLE INVESTMENT TOWARDS

healthier, more inclusive societies

How can country governments, other energy stakeholders and would-be investors in low-income, emerging markets identify the clean energy investment opportunities with the potential to deliver significant and sustainable gains for financiers and poor communities alike?

Investors play a significant role in shaping society: through where they choose to put their money, and the returns they are satisfied with. Increasingly, therefore, the private sector is being held to account for its larger and indirect impact on society and the environment via financing channels.

By investing capital and resources in ventures likely to bring significant, sustainable gains to low-income communities, investors can positively impact those communities – and, by extension, inclusive economic growth.

At the core of the UN SDGs is the intention to address the most pressing social issues of our time, while ensuring the environment is not sacrificed; in particular, SDG 7 calls for universal access to clean and modern sources of energy by 2030. In the SDGs, beside the need for energy to be clean, access to energy is positioned as a basic service and a human development need, with energy inclusion having the potential to challenge existing economic inequities.

Achieving the SDGs in this decade, however, calls for a radical shift in perception by the private sector to view them not as a burden and constraint to growth but as an unprecedented economic opportunity (Malloch-Brown 2017). Part of the challenge for energy investment is that developing countries' nascent energy markets are complex and dynamic, functioning far from constructively.

In addition to capitalising on existing opportunities, therefore, multi-stakeholder teams will actually need to actively steer energy markets towards improved functionality across all segments of the income spectrum.

IT IS A TALL ORDER TO ASK THAT GOVERNMENTS AND INVESTORS: INCREASING ENERGY ACCESS AND USAGE FOR THE GREATEST NUMBER OF THE LOW-INCOME, AFFORDABLY, SO AS TO CAUSE NO ENVIRONMENTAL DAMAGE (AND EVEN TO REVERSE CLIMATE CHANGE) WHILE CONTRIBUTING TO COUNTRIES' INDUSTRIALISATION, BOOSTING INCLUSIVE ECONOMIC GROWTH, AND BEING VIABLE AND SUSTAINABLE IN A BUSINESS SENSE.

It becomes crucial to draw in broader support in combatting energy exclusion. For this reason, the toolkit highlights the linkage between financial inclusion and energy inclusion, and the investment case for financial services as an enabler of energy market development. As this investor note demonstrates, one of the most important dimensions of understanding access to energy is understanding energy affordability at the household level within the context of poverty, and establishing households' (and MSMEs') access to finance to purchase energy and related products; in this sense the linkage between financial inclusion and energy inclusion becomes very clear.

POWERING COUNTRY GROWTH BY ENABLING *domestic capital and local markets*

The goal in contribution to the UN SDGs, particularly SDG 7, would be to move as many people as possible away from reliance for their household needs such as lighting, heating, cooking, on using solid fuels such as coal and biomass (firewood, animal dung, charcoal) or even modern fuels (LPG, ethanol, paraffin, biogas) and towards reliance on existing or to-be-extended national grid electricity: powered by fossil fuels, where necessary, but increasingly and wherever possible from renewable sources such as hydro, solar or wind.

Where access to the central grid is not possible, decentralised mini-grid solutions would be the next option for consideration (again, as with the national grid, sometimes powered by fossil fuels but preferably renewables, or in hybrid form). Where people still lack access, further decentralised solutions in the form of solar home systems could be an option.

Finally, limited-purpose clean energy products, such as pico-solar products and improved cookstoves, could serve the needs of people across all segments. The big challenge in terms of substantially increasing energy inclusion seems to be tackling the multifaceted challenge of affordability while moving countries steadily closer to an integrated energy mix that favours clean solutions.

Today, industrialisation and catch-up economic growth are imperatives for much of the developing world, and in many developing countries there is also an unprecedented push to achieve energy-related social objectives towards more inclusive growth.

There is also huge pressure globally to switch from fossil fuel-based energy to cleaner, greener, renewable alternatives (in terms of both current and planned energy provision). This process is projected to take decades, though, as existing energy infrastructure investments cannot be written off overnight. Further underlining the need for clean energy is that, in developing countries, high levels of poverty combine with energy exclusion to directly contribute to environmental degradation; low-income communities are heavily dependent on gathering or harvesting biomass (e.g. firewood), often unsustainably, for lighting, heating and cooking, or rely on coal – all of which generates high emission levels from black carbon. Poor communities also experience high exposure and compromised resilience in the face of climate change-related risks and shocks.

IN THE COURSE OF THE PAST 10 YEARS, LEAST DEVELOPED COUNTRIES (LDCS) AND DEVELOPING COUNTRIES ALIKE HAVE MADE SIGNIFICANT PROGRESS IN EXTENDING THE REACH OF THEIR PUBLIC ELECTRICITY GRIDS. NONETHELESS, LARGE PROPORTIONS OF THOSE POPULATIONS, ESPECIALLY IN RURAL OR PERI-URBAN AREAS, STILL LACK ACCESS TO ELECTRICITY.

It is safe to say that, combined with the challenges of climate change, increasing energy inclusion for much of developing Africa presents a 'wicked problem': multifaceted, and difficult to solve. This is because the scale is daunting and the situation will likely take generations to improve (not least because expanding the electricity supply is not straightforward, while demand continues to accelerate as population numbers increase). Also, energy market, policy and technological conditions are dynamic and evolving; these markets have both more and more intersecting facets than those in developed countries; and business models for low-income (especially rural) energy markets are quite unclear using a conventional lens.

Finally, contributing to the energy inclusion challenge are the different time horizons and related financing considerations that must be factored in: the pressing need for short- to medium-term improvements by 2030, as well as a long-term just transition to energy inclusion.

ENERGY INVESTING IN LOW-INCOME MARKETS: IS IT EVEN WORTH IT? Challenges aside, there are worthwhile investment cases to be identified in developing countries. Crucially, this requires forming multi-stakeholder partnerships to access the required expertise: engineering/technology, economic, policy and financing. It also requires being intentional about prioritising access to basic services, and being pragmatic about identifying complementary solutions, given that energy markets in the developing world sit at a nexus of grid electrification, off-grid (clean) energy options, environmental concerns and poverty. However, it is within the complexities and nuances of these markets that the exciting opportunities are to be identified; after all, if the investment opportunities were already well known, they would also be less promising. The MAP ongoing research in these markets is shared in this toolkit as a means to arm governments and investors with solid data and insights into real opportunities: to make real progress, in real-economy settings, with real consumers.

Steering energy markets towards better functionality

Within all the complexity, energy inclusion in developing country contexts will be determined ultimately by domestic market consumption and *consumers'* ability, readiness and willingness to pay for services; and so successfully bringing together the multiple pieces of the energy market puzzle, to service all parts of the market regardless of income, is the massive undertaking that is required. Not surprisingly, though, policymakers are often under-equipped to make the necessary decisions and trade-offs; for instance, when it comes to balancing the needs of low-income populations and sometimes-reluctant and sceptical financiers.

A helpful start is probably to acknowledge that energy markets can no longer be designed, as such, in the command-and-control tradition of times past.

Energy markets have historically been highly reliant on regulation to create market conditions under which it made sense to produce, distribute and sell energy, because the sector relies on central production and then distribution over large geographic areas, which in turn requires extensive physical infrastructure investments. It would be irrational, for instance, to have two centralised distribution grids serving exactly the same geographic areas; this would simply double the cost of distribution without increasing supply.

BUT RAPIDLY EVOLVING TECHNOLOGY HAS BEEN CHANGING MARKET CONDITIONS, AND TRADITIONAL ASSUMPTIONS ABOUT ENERGY MARKET DESIGN AND REGULATION NO LONGER HOLD.

CENTRALISED GRID-GENERATED AND GRID-PROVIDED ELECTRICITY CAN INCREASINGLY BE *COMPLEMENTED AND SUPPLEMENTED* BY DECENTRALISED ENERGY PROVISION, ESPECIALLY USING RENEWABLE ENERGY SOURCES (CLEAN, OFF-GRID ENERGY).

The technology and stakeholder shifts in generation and distribution of new, clean energy solutions today in many ways mirror the historic market transformation of the telecoms sector; with the boom of mobile technology, the fixed-line telecom industry in the 1990s saw a shift from highly centralised systems that lacked capacity for adaptation to highly adaptive, customer-centric, distributed network systems; the outcomes included competitive infrastructure markets and better reach and penetration of mobile technology in the population.

Policymakers and regulators, when planning to address a country's energy provision needs, must work out the *rules for participation* in energy production and transmission; this allows for incentives to drive multi-stakeholder decisions and innovation. An important consideration in this regard is the policy choice for national distributed energy systems: between monopoly provision (traditionally based on one source, often fossil fuel) at one end of the continuum and market-based operations that combine an interplay of traditional fuel and newer, cleaner energy options at the other. Considering the trends of decentralised energy production and rapid technological innovation, along with pressing consumer needs for energy and the current large deficits in energy access, it is highly unlikely that monopoly provision will be countries' chosen solution; nevertheless, it is important to understand the distinctive characteristics of market fundamentals, as they will impact a country's energy systems and provision for decades to come.

In short, the traditional model of monopoly provision is based on a mandated national design, and reliant on central planning, public investment and closed access; it allows for limited choices and average cost pricing. By contrast, competitive markets rely on voluntary participation based on a combination of (independent) investment sources, but allow for open access to participate, many choices in terms of the methods of production, and marginal-cost pricing. (However, it should also be noted that deregulation in energy markets has led to its own issues such as vertical integration, which could undermine market competition.)

In terms of steering energy markets toward more rational functioning, key elements the multiple stakeholders need to consider include:

- Licensing options – in order to create licensing categories with the commensurate rules, rights and obligations and fee structures.
- Technology options and fit within the context of the larger landscape of energy provision for the country, including balancing newer, distributed technology options with the main, national grid.
- Financing considerations that match investment appetite, country risk profile, consumer income levels, and energy consumption patterns.
- Regulatory mechanisms that include pricing and tariff design across wholesale and retail, equipment licencing, and the quality of service options (including obligations and responsibilities towards consumers).

Decisions with regard to the above will in turn be based on market size; consumers' livelihoods realities and income levels; appropriateness of technology options linked to geographical terrain including climate factors such as sunlight for solar, wind for turbines, and so on; and the potential for market disaggregation and the flexibility of licensing boundaries.

Given changing market conditions, regulation in the energy space must consider allowing for decentralised production and competition in production, and must explore the effect of variable (marginal-cost) pricing. Again, in terms of regulation that is sufficiently agile to keep up with and even anticipate rapid technological innovation, the energy industry can benefit from lessons learned in the telecoms industry. In particular, energy market regulation should focus on creating a market structure that allows all participants to recover the cost of their significant upfront capital expenditure, while balancing the interplay between larger and smaller companies. Again, comparable to what happened in the telecoms industry, new entrants to the energy market will in some ways be in competition to the national grid and existing government revenue streams – which adds a further, interesting challenge to the unavoidable need for multi-stakeholder partnering.

While cleaner, renewable energy solutions are an option for newly industrialised countries, even in those country settings completely overhauling the national electricity grid is not always feasible – and in the case of the MAP target countries in general and as highlighted by the five study countries in particular is highly unlikely. Furthermore, private renewable energy provision is widely characterised as an altruistic project rooted in the idea that 'green capitalism' can resolve the conditions precipitated by climate change. The MAP data and analysis illustrates that, for a range of reasons, transitioning low-income households (in other words, the majority of the population) to the electricity grid will be a massive challenge – and that transitioning national energy provision towards *clean energy* at any kind of scale is unlikely to be achieved without a coherent national strategy and clearly stated, evidence-based public policy choices around such transitions.

ALTHOUGH ACCESS TO ELECTRICITY IS EXPANDING, AND WILL CONTINUE TO DO SO, JUST IN THE FIVE MAP COUNTRIES STUDIED AROUND 70 MILLION PEOPLE ARE LIKELY TO BE LEFT BEHIND BY 2030.

There are a number of reasons for this, as discussed in this toolkit, including high reliance of grid electricity generation on hydro, the challenge of population growth, grid electricity's lack of affordability in the context of poverty, and an enduring urban–rural divide, which will be difficult to breach before 2030.

FIGURE 1
MAP inclusive growth pillars and relevance for financial inclusion

Source: UNCDF MAP (2020)

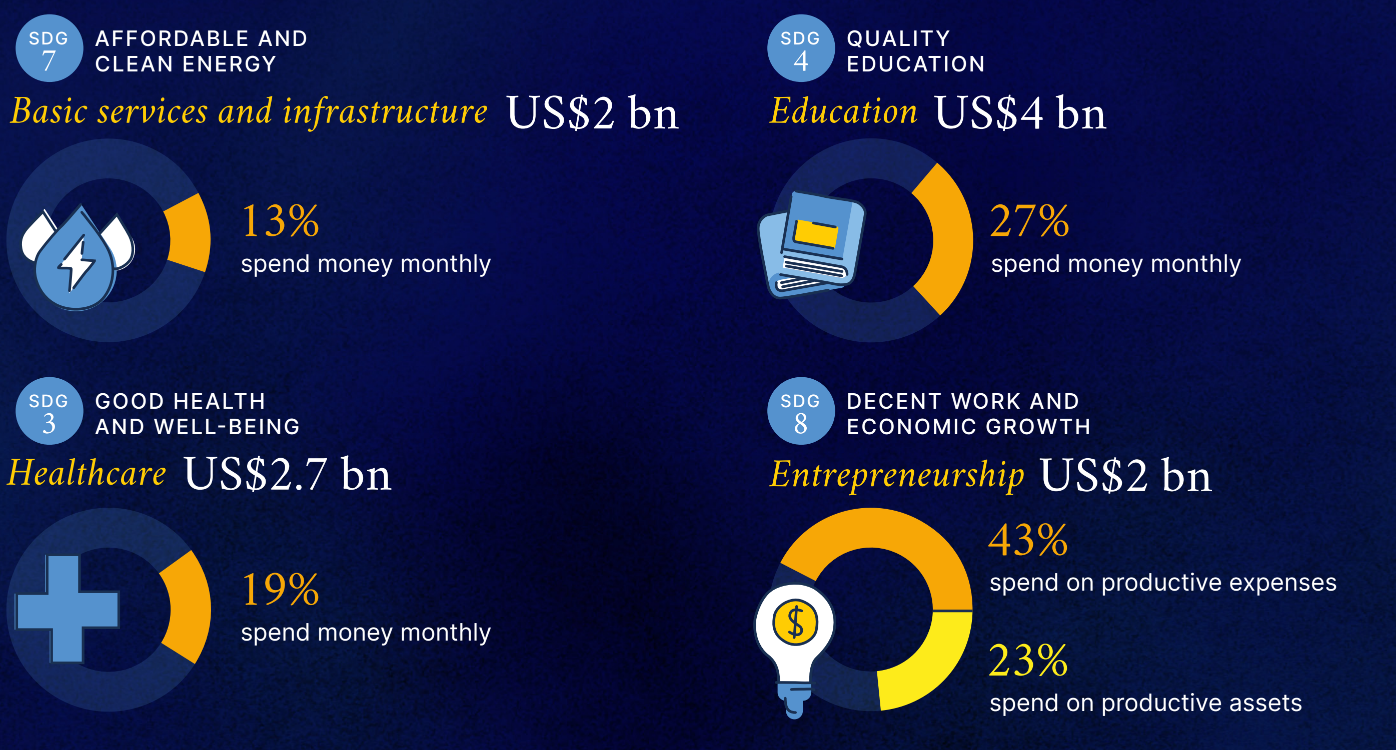
In short, though, the research is clear that neither grid electricity nor completely clean energy solutions alone will get us to the 2030 goals; and that, post-2030, although grid electricity will reach the majority of the market in most cases, this could take decades. This creates opportunities for the other categories of energy provision. Evidence-based trade-offs, pragmatism and complementarity will be important in combatting energy exclusion.

Why financial inclusion is integral to energy inclusion

The MAP financial inclusion focus areas are congruent with the nine pillars supporting inclusive growth (see Figure 1), especially in terms of what MAP terms 'the four crucial needs': education, access to basic services, healthcare services, and entrepreneurship (with focus area 3 on Figure 1 including *energy access*). Universal access to basic infrastructure and services is crucial if a country is to improve participation in economic activity by all who live there, with access to energy and energy products – and in particular affordable, reliable, sustainable and modern energy, as per SDG 7 – being in many ways fundamental to the other crucial needs.

MAP's research confirms these crucial needs are the areas households tend to prioritise in their own spending – often through accessing financial services – whether formal or informal. (Financing, with its ability to increase resilience, facilitate savings, enable credit and increase uptake of more efficient payments services, thus has a key role to play in achieving the SDGs, including SDG 7.) Quantifying expenditure in the largely informal markets in which low-income households operate makes it possible to highlight the investment case for the provision of specific services (as MAP did in the case of Myanmar); despite individual household expenditure being typically modest, total aggregate expenditure by households and individuals on the four crucial needs was calculated to be around USD 10.7 billion per year, including around USD 2 billion a year just on energy (see Figure 2).

FIGURE 2
Annual household spend: basic services and infrastructure, including energy, Myanmar



Source: UNCDF calculated using FinScope Myanmar 2018

IT IS NOT ONLY BENEFICIAL, IT IS ACTUALLY ESSENTIAL THAT GOVERNMENTS AND THE FINANCIAL SECTOR LEVERAGE EXISTING HOUSEHOLD SPEND TO FUND INCREASED ENERGY ACCESS AND USAGE.

The energy business model over the medium and longer term is premised on this, because micro-level capital generation enables macro-level activities and investments. Increasing consumers' levels of energy usage and growing the market for clean energy is likely to be achieved through identifying ways to make a range of energy solutions more affordable to consumers, including via financing.

While developing countries do have basic services infrastructure, they have very clear urban–rural divides. Infrastructure is usually more concentrated and better developed in urban areas as a result of both barriers to infrastructure expansion and the weaker business case for serving rural areas; the capital costs for expanding and maintaining infrastructure exceed the revenue potential from areas where poor consumers translate to lower revenue. Accordingly, urban populations have higher grid electricity access rates, as traditional electrification programmes targeted more accessible and densely populated towns and cities.

MAP classifies this urban–rural divide as the 'citadel economy' – where those in urban areas are relatively 'safe' within the citadel walls, while those in the outer reaches (beyond the walls) are largely left to fend for themselves. The analogy takes on more meaning when one realises that in LDCs – including the five countries studied (Malawi, Mozambique, Madagascar, Lesotho and Eswatini) – the *majority* of the population is rurally based. Financial inclusion thus has an important role to play in interventions to increase energy inclusion; while government and private sector investment is clearly still required, financial inclusion co-opts households into the rollout and accessibility of energy infrastructure and access to energy.

Access to energy and access to finance can be mutually reinforcing

In Africa, off-grid solar energy has tapped around 17% of the addressable market overall and has been promoted largely by private actors, who have raised close to USD 700 million in grant, social impact and commercial capital to fund rapid growth. According to a 2018 report from GOGLA (an off-grid solar energy industry body), some 130 million devices are now deployed worldwide, of which the bulk are in Sub-Saharan Africa, with special concentrations in East Africa.

This concentration is no surprise: the growth of clean, off-grid energy solutions, especially for the low-income, has been closely linked to digital financial innovation; the spread of mobile money enabled energy providers' collection of remote, cheap micro-payments from consumers in a process known as pay-as-you-go (PAYGO). However, even more interestingly, the appeal of this real-sector innovation has had the effect of 'pulling' excluded people into opening mobile money accounts; according to the Consultative Group to Assist the Poor (CGAP), some 30% to 50% of PAYGO users had not, prior to that, been mobile money customers.

A combination of micro-payments and microfinance has been helpful as a proof of concept, demonstrating the symbiosis that is emerging between financial inclusion and new technology. The reality, though, is that such examples of increased access to clean energy fall far short of the transformative solutions needed: mass energy access on a scale sufficient to drive countries' industrialisation and inclusive growth.

Given the realities of the energy markets in most MAP countries, including the five study countries, and the gap between the intended 2030 goals and what has been practically achieved, supply-side interventions alone will be inadequate to combat energy exclusion. Although regulatory support will help, if supply and regulatory efforts are to achieve impact they will need to be based on a deep and granular understanding of consumers' energy-related choices, behaviour and needs.

Employing multi-stakeholder expertise towards coherent investment initiatives

The increasingly multi-stakeholder and decentralised options for energy production and distribution that have become possible due to technological advances allow for increased use of off-grid clean energy options to *complement* grid-distributed and centrally produced electricity. It makes sense then that funding such energy production and distribution will also be characterised by multi-stakeholder partnerships and decentralised approaches. The MAP multi-stakeholder approach attempts to engage with both the energy-related technology shifts and related financing and distribution options, especially at the household level.

The stakeholder and institutional structures will differ across countries and regions with varying levels of maturity; acknowledging and anticipating this will be crucial in bringing together the pieces of the multi-stakeholder puzzle – engineering/technology, economics, financing and policy –for coherent implementation of clean energy investment initiatives. For, it is the currently disjointed nature of the policy and stakeholder environment that makes implementation and uptake at scale impossible.

The thinking is that mapping out the parameters of multi-stakeholder engagement will set up the necessary institutional mechanisms at community level, defined by local stakeholders, thus creating the foundation for community-centred energy infrastructure and financing. This, in turn, will help countries to not only extend other basic services (i.e. access to water and other community infrastructure) but also strengthen the other three pillars of inclusive growth as defined in the MAP crucial needs: education, healthcare and entrepreneurship.

MAP FINANCIAL INCLUSION CLEAN ENERGY *household demand methodology*

The MAP financial inclusion ***clean energy household demand methodology to identify opportunities for financing*** *uses the MAP financial inclusion diagnostic approach and inclusive growth lens, meaning that, as with all of the MAP work, representative consumer livelihoods market data is positioned at the centre.*

The methodology focuses on helping stakeholders make sense of demand for access to energy, as reflected in households' current usage, ability to afford energy, and access to infrastructure. Crucially, the methodology also guides the multiple stakeholders through the process of understanding a country's overall energy provision and enabling environment.

The energy markets involved are highly complex, spanning the engineering/technology, economic and financial realms. The reality is also that such markets call for stewardship rather than market 'design' in the command-and-control fashion. For these reasons, grid electrification and off-grid energy solutions will need to exist symbiotically, balancing the introduction of new technologies in clean energy investment towards fulfilling countries' energy needs via an integrated energy mix.

UNDERSTANDING THE PRECISE FORM THAT SUCH ENERGY MIXES COULD ASSUME PER COUNTRY IS WHERE THE TOOLKIT METHODOLOGY AND FINDINGS WILL SUPPORT GOVERNMENT AND PRIVATE SECTOR INVESTMENT DELIBERATIONS.

This toolkit sets out the clean energy investment case for those interested in closer involvement in the clean energy markets in LDCs and developing countries. It is an invitation to consider new ways of thinking about investment, financing and markets.

While the toolkit demonstrates the opportunities available in five particular Sub-Saharan African countries (four of them LDCs and the fifth a developing country), and models how to think about the market strategically, it also provides stakeholders and decision makers with sufficient evidence on the methodology to allow for interrogation of the MAP logic, insights and conclusions, and for participation in excogitating real-world energy interventions and solutions. Decision makers can apply the methodology in part or as a whole in similar environments where they are grappling with comparable complexities of clean energy investment.

The toolkit also provides insight into the realities and challenges of steering energy markets, given rapid and ongoing technological and symbiotic fintech development, and thus also the importance of constituting functional, multi-stakeholder teams and partnerships able to engage with the depth, range and intersection of issues and interests to be accommodated.

MAP financial inclusion clean energy household demand methodology to identify opportunities for financing.

1

Collect energy market data

- Scope the existing energy market and enabling environment
- Map out the existing landscape of energy provision
- Understand options for least-cost energy expansion
- Understand energy access, including for low-income consumers

2

Analyse the low-income energy market

- Estimate the electricity access deficit
- Understand the consumer profile of energy needs and usage
- Understand the affordability of energy – including clean energy
- Establish the potential for MSMEs' uptake and usage of clean, off-grid energy

3

Weigh up the opportunities and challenges for clean energy investment

- What is the investment case?
- What is the current state of market development?
- What is the value of the addressable market?
- What are the barriers and challenges to uptake?

There are three main aspects to the MAP clean energy household demand and financing methodology: collecting energy market data; analysing the low-income energy market; and weighing up the opportunities and challenges for clean energy investment.

*When applying this **MAP financial inclusion clean energy household demand methodology to identify opportunities for financing**, it is necessary to encompass the full range of options for least-cost electrification: grid electricity; off-grid mini-grids; off-grid SHS and pico-solar solutions; and off-grid limited-purpose clean energy products such as improved cookstoves.*

The following template is useful for capturing and comparing the salient findings to assist with weighing up the investment case for clean energy:

	GRID ELECTRICITY	OFF-GRID		
		MINI GRIDS	SHS OR SINGLE-PURPOSE SOLUTIONS, INCLUDING PICO-SOLAR	IMPROVED COOKSTOVES
Environmental considerations				
Demand				
Supply				
Policy and regulation				
Market size and growth				
Opportunities				
Challenges				
	National: Current and immediate future	Localised/regional: Where current and immediate future can't reach. Rural, but higher density rural	Localised/regional: Where current and immediate future can't reach. Rural, but lower density rural	Cross cutting: Based on affordability of other sources. Lower income that don't use electricity for cooking.

DECREASING INTENSITY OF CAPEX REQUIRED

It is important to note that most LDCs and developing countries lack the detailed supply and demand data that serves as the analytical basis for this methodology. However, this level of detailed data exists across the MAP footprint of 20 countries, and MAP data scoping also illustrates that some form of such data does exist in most countries through the multilateral system, thus making the methodology presented in this toolkit almost universally applicable.

Collect energy market data

Scope the existing energy market and enabling environment

- This step in the methodology focuses on understanding existing conditions in a country's energy market and enabling environment. In addition to characterising the market on the continuum of monopoly provision to market-based operations and gaining a clear view of the different stakeholders, it is important to understand licensing, technology, pricing/tariffs, and quality issues. The following questions can be helpful:
- What are the existing licensing categories and options, and what rules, rights, obligations and fee structures currently apply?
- Given the larger landscape of electricity provision in the country, what technology options exist? Is it possible to identify pockets of energy innovation in the country/region? And how might newer, distributed technology options be balanced with the main access grid for national provision?
- Who are the current and emerging energy stakeholders? What new business modalities of generation, distribution and purchase need to be accommodated?
- What logic underpins the pricing and tariff design across wholesale and retail?
- How would you characterise the quality of the service options available, and what could be inferred from this with regard to obligations and responsibilities to the country's consumers?
- What are the financing considerations?

The answers to the above will also be informed by market size; licensing boundaries and the potential for market disaggregation; consumers' income levels and access to finance; energy consumption patterns; the appropriateness of technology options linked to the realities of geographical terrain (including climate factors such as sunlight for solar, wind for turbines); country risk profile; and general investment appetite.

From a policy and regulatory point of view, it is important to understand the country's growth aspirations and national policy objectives relating to energy and clean energy provision, as well as the country's current emissions levels versus emission-reduction targets.

The supporting environment for electricity generation and distribution includes the use of subsidies, the profitability of provision within the context of current regulation and agreements, and where the mandates for generation, distribution and the like are located. It is also important to understand the wider, regional energy context and to consider existing and planned regional strategies.

FIVE-COUNTRY STUDY FINDINGS

MAP's five-country study found that, in terms of current emission levels from grid electricity provision, these countries are enviably green, being among the lowest emitters in the world (percentages of renewable energy generation compared to global averages are: Lesotho: 100%; Malawi: 91%; Mozambique: 86%; Madagascar: 55%; and Eswatini: 47%, UNCDF 2020). There are three reasons for this:

- In terms of their own electricity generation, the countries depend largely on *hydro*, which is a renewable (climate impacts in the form of drought and floods aside).
- Levels of *consumer access to and usage of electricity* are extremely low (average domestic annual consumption per person ranges between 53 kWh and 1,033 kWh).
- The countries included in the study have comparatively small population sizes (ranging between 1.1 million and 29.5 million).

However, in terms of *other energy sources that are a major contributor to black carbon emissions* – such as solid fuels, biomass (e.g. firewood, charcoal, animal dung), and diesel engines for transportation and in the case of Madagascar also for power generation – these countries have a long way to go to become greener.

As these countries continue to develop, it will therefore be important that they retain their green energy generation track record, while transitioning their economies from the current reliance on other energy sources that account for the majority of black carbon emissions globally.

- MAP also found that, despite broad government support for the expansion of clean energy access in all five countries:
- While grid and off-grid solutions need to exist symbiotically, in fact the policy and regulatory environment is not currently conducive to the development of off-grid solutions or balancing the introduction of new technologies in clean energy investment.
- There has been limited success in off-grid energy initiatives, especially in seamless interconnection – certainly not success commensurate with the scale of the problem.
- Most donor initiatives and funding to date have focused on grid electricity.
- There is a general failure to implement donor programmes coherently and/or as part of an agreed overall strategy for increasing energy access at scale.
- Existing energy policies mostly do not include a specific rural focus.

There is insufficient understanding of household energy spend and related demand for energy.

Map out the existing landscape of energy provision

- A crucial aspect of the investigation into a country's energy market is for the multiple stakeholders to develop shared understanding of the following characteristics of domestic energy supply:
- What is the average domestic annual consumption in kWh (per person)?
- What is the electricity generation capacity in megawatts (MW)?
- What are the main sources for electricity generation?
- What are the issues around electricity generation (e.g. seasonality due to dependence on particular source; existing infrastructure; infrastructure maintenance)?
- How dependent is the country on energy imports?
- What are the barriers to further infrastructure expansion?
- What is the cost of supplying the country's energy and what degree of subsidisation occurs?
- What responsibilities and mandates exist in terms of generation versus distribution?
- What advantages and opportunities can be highlighted?

FIVE-COUNTRY STUDY FINDINGS

The MAP research highlighted a number of cross-cutting issues that characterise the overall landscape of electricity provision across the five countries:

ELECTRICITY GENERATION CAPACITY IS VERY LOW. Generation capacity across the five countries ranges from about 70 MW each for Lesotho and Eswatini, to around 500 MW to 600 MW for Malawi and Madagascar. Perhaps the only outlier is Mozambique, which has a much higher electricity generation capacity (close to 3,000 MW), with more than two-thirds of this coming from one plant, the Cahora Bassa dam; however, much of Mozambique's electricity is exported to South Africa and other neighbouring countries. Total electricity generation for domestic consumption across all five countries is therefore only around 2,000 MW.

DEPENDENCE ON HYDRO CREATES SEASONAL SHORTFALLS. In all five countries, the vast majority of generation of grid electricity within the country (i.e. domestic generation) comes from hydro stations, with three of the countries relying close to or 100% on hydro, Madagascar relying on both hydro and diesel generator mini-grids, and Eswatini having the lowest dependence on hydro but still substantial at close to half of its electricity being from that source. While dependence on hydro is good in terms of clean energy goals, it is not without its own problems. For instance, all five of the countries are susceptible to droughts and floods, making hydrological conditions unpredictable. At least three of the countries noted this as a reason for periodic deficits in domestic electricity supply. In the case of Eswatini, in particular, the natural geography does not allow for many dams to be built; as a result, the existing hydro stations (which account for almost all domestic generation capacity) cannot function as base stations but are rather used to supplement the grid during peak demand.

AGEING INFRASTRUCTURE AND POOR MAINTENANCE UNDERMINE ELECTRICITY GENERATION. The challenges experienced with electricity generation are also directly linked to the age of existing infrastructure, coupled with low capacity for maintenance, particularly in Mozambique and Madagascar:

- In Mozambique, only about three-quarters of generation capacity is actually available, a problem that is directly attributable to ageing plant and system infrastructure and a lack of routine maintenance. The state provider does not generate enough revenue from electricity sales to fund operating and maintenance costs. Some sources point to an additional issue: a shortage of the technical staff needed to service the growing number of grid connections. The country diagnostic also noted long delays in the rehabilitation of existing generation.
- In Madagascar, grid electricity is mainly generated by six ageing hydro plants that provide over two-thirds of capacity, but available capacity is only around 60% owing to maintenance problems. A contributing factor to unfunded maintenance and subsequent plant failures is low levels of collection of (high) tariffs. As a result, existing efforts to improve supply are focusing on assisting with governance and capacity building of the state provider, especially towards improving infrastructure maintenance.

THERE IS HEAVY DEPENDENCE ON ENERGY IMPORTS. Despite an abundance of energy sources (including renewables such as water, sun and wind, and even, in the case of most of the countries, quite substantial reserves of coal), they are heavily dependent on imports to meet their domestic energy requirements. However, this varies substantially from country to country:

- Lesotho and Eswatini, perhaps owing to their small population sizes and the easy availability of imported electricity through South Africa's distribution network, import between 50% and 66% of their domestic electricity consumption requirement from South Africa and Mozambique.
- Mozambique, on the other hand, 'imports' electricity through South Africa – meaning that electricity that is exported from the north of the country to South Africa comes back into the south of the country from South Africa.

Madagascar is entirely bordered by the Indian Ocean, yet a third of its electricity consumption is dependent on imports – mostly that of diesel, which powers diesel generator mini-grids (in the process contributing significantly to Madagascar's carbon emission levels).

THE DISTRIBUTION INFRASTRUCTURE (NATIONAL GRID) IS INADEQUATE. In addition to generation capacity, distribution of electricity via the national grid is a major issue across three of the five countries. Geography presents challenges in Mozambique and Madagascar (the two largest of the countries, with the lowest population densities), where the national grid simply does not reach most of the country, being concentrated around urban areas. Lesotho, despite being a small country, also faces barriers to expanding the grid given its mountainous terrain. However, it is the maintenance and state of distribution infrastructure that is the bigger concern:

- In Mozambique, the limited existing infrastructure makes power supplies vulnerable to outages. In addition, 27% of the power generated is subsequently lost during the administration, transmission and distribution processes, which exacerbates the generation deficit. Low revenue also hinders capital expenditure on transmission, distribution, and grid expansion.
- Low revenue is also a factor in Madagascar, where grid infrastructure is deteriorating due to age and insufficient maintenance. In addition, the fractured nature of the grid means that electricity loads cannot be shifted outside areas of generation.

BARRIERS TO FURTHER EXPANDING THE GRID. Both Malawi and Eswatini face additional barriers to the ones discussed above:

- In Malawi, 95% of the population live within 10 km of the grid, which means the grid is the most likely least-cost electrification technology in the long term. For a range of reasons, however, the rate of electrification is simply not high enough; while there are barriers to increasing supply, the huge obstacle to extending the grid is the country's extreme poverty levels, which mean the majority of households are simply unable to consider paying for grid electricity.
- Similarly, in Eswatini, while grid electricity for the remainder of the population is the least-cost option, the business case for connecting the remaining population (high capital and maintenance cost, but a low return expected from poor rural areas) makes further investment less attractive.

HEAVILY SUBSIDISED ELECTRICITY IS NOT REFLECTIVE OF THE COST OF PRODUCTION. In all five countries, the business case for electricity provision is hindered by the set electricity tariffs, which are not fully cost reflective: the revenues collected do not cover the full costs of producing the power plus a market-related return on capital invested. Perhaps the single biggest factor impacting the cost reflectivity of tariffs is that at least four of the countries set some type of floor on electricity pricing, for usage below a minimum threshold (a pro-poor subsidy mechanism called the 'lifeline tariff'). This ranges from 25 kWh per month to as much as 100 kWh per month. Given that the majority of retail users (i.e. households, MSMEs) consume even less than this amount, electricity tariffs are essentially heavily subsidised. However, even when taking into consideration users that consume more than the minimum threshold, the effective tariff at which electricity is sold on average is lower than the cost of producing or purchasing the electricity.

Although subsidies are beneficial in terms of expanding access in low-income country contexts, they undermine the sustainability and business case for provision. Across the five countries, electricity prices will have to increase substantially if they are to be cost reflective (with disruptive implications for user segments currently benefiting from significantly discounted supply). The challenges are compounded both by the requirements of power purchase agreements from independent power producers (IPPs), for example, specifically in the case of Mozambique and Madagascar, where the agreed purchasing cost of the electricity exceeds the subsequent selling price; and by reliance on imports (electricity or fuel), which can also push up costs due to exchange rate volatility.

GENERATION AND DISTRIBUTION OF ELECTRICITY TEND TO BE UNBUNDLED – THOUGH NOT BY DESIGN. In each of the five countries, there are state-owned public utilities that are responsible for the transmission and distribution of electricity via the national grid. However, in only three of the countries (Mozambique, Madagascar and Eswatini) are these utilities also involved in electricity generation; and in only one country (Madagascar) is the state-owned utility responsible for supplying (i.e. both generating and distributing) the majority of electricity consumed in the country.

However, with the exception of Malawi (where the 2016 Electricity Act specifically mandated it), this separation of generation and distribution is not the result of deliberate unbundling but rather because electricity is also purchased from independent providers, as well as from the Southern African Power Pool (SAPP):

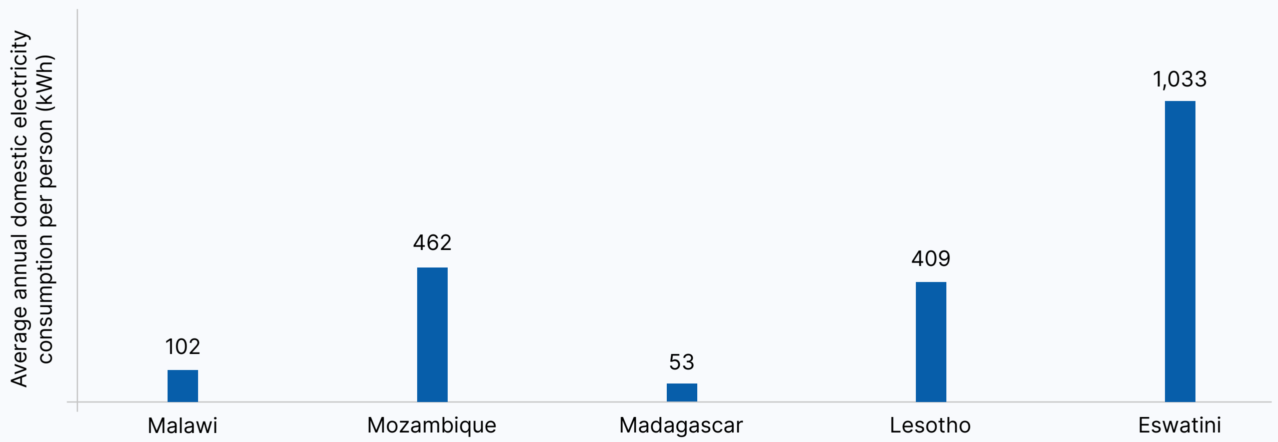
- In Mozambique, the state-owned electricity utility purchases the majority of locally consumed electricity through a public-private agreement with a state-owned hydroelectric plant. An aluminium plant near the country's capital, Maputo, however, purchases electricity directly from South Africa's state-owned utility, Eskom. Mozambique also has regulatory requirements to purchase electricity from IPPs.
- In Madagascar, the state-owned utility is responsible for the majority of electricity provision: solely responsible for the electricity generated and distributed via the national grid, with IPPs competing with the state-owned utility for the electricity distribution that occurs via mini-grids.

In both Lesotho and Eswatini, the majority of locally consumed electricity is purchased by the state-owned utility from South Africa, Mozambique, and the SAPP. Eswatini's state-owned utility generates some of its own electricity, while Lesotho's state-owned utility purchases electricity domestically from a state-owned hydroelectric plant, operated through a joint venture between Lesotho and South Africa.

WHAT ADVANTAGES AND OPPORTUNITIES CAN BE HIGHLIGHTED? Despite the apparent drawbacks in the electricity sectors of the five countries, there are also significant benefits they can draw on:

- In most countries, the expansion of clean energy access enjoys broad government support.
- Countries with good natural resource endowments for clean energy, such as Mozambique, Madagascar and Lesotho, can also benefit from, and indeed have plans to expand, their clean energy generation

FIGURE 3
Levels of average domestic annual electricity consumption (kWh) per person, by country



capacity using available natural resources: mostly hydro, but also natural gas in the case of Mozambique.
- The availability of regional distribution infrastructure, and a common SAPP from which some countries already procure their electricity, also opens the door for greater regional collaboration and a cross-border energy market.

LEVELS OF DOMESTIC CONSUMPTION OF ELECTRICITY ARE LOW. Despite varying widely across the five countries, levels of average domestic annual electricity consumption per person can still overall be categorised as low (see Figure 3).

In Madagascar, as a result of both the large access deficit (people who do not have access to electricity) and low levels of usage by those who do have access, average domestic annual consumption per person is among the lowest in Africa and the world at 53 kWh. Malawi has domestic consumption almost double that of Madagascar (102 kWh), while Mozambique and Lesotho exceed Malawi's consumption by a factor of four or more (462 kWh and 409 kWh, respectively). Eswatini has the highest average domestic annual consumption per person, at 1,033 kWh, due to its high levels of access and small population.

Understand options for least-cost energy expansion

When countries develop strategies to extend energy access, the most logical place to start is to look at existing grid energy production and distribution. However, extending the grid or potentially increasing production of electricity for grid distribution, may not always be the cheapest option. Countries therefore have to consider the *cheapest* options to increase access to electricity to meet their electrification targets.

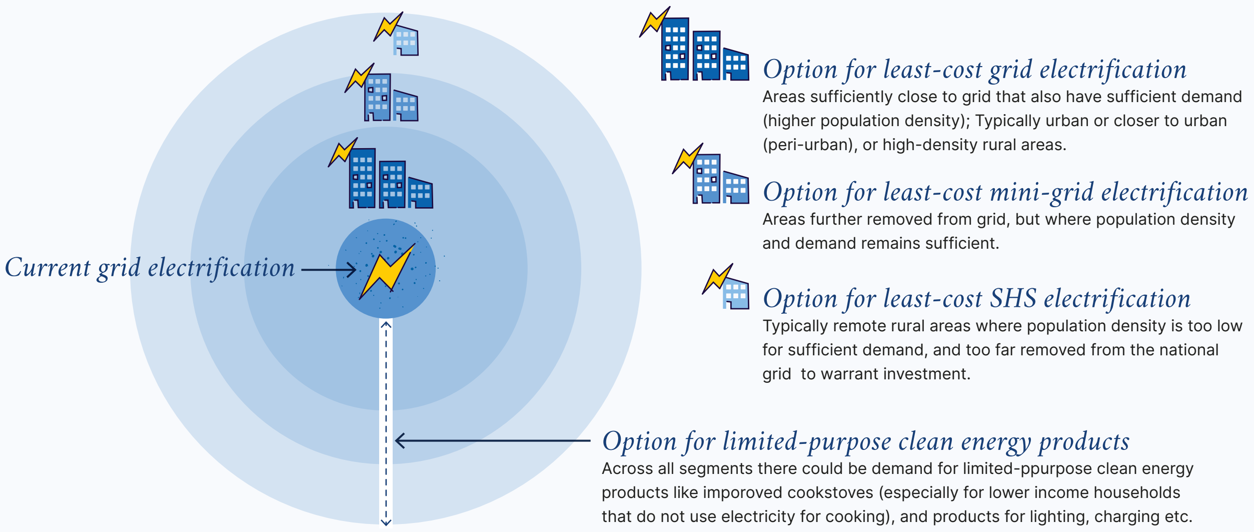
UNDERSTANDING LEAST-COST ENERGY SOLUTIONS ENTAILS UNDERSTANDING BOTH THE *DIFFERENT OPTIONS FOR ENERGY PRODUCTION* IN A COUNTRY AND THE *DIFFERENT SOURCES OF ENERGY* THAT HOUSEHOLDS AND BUSINESSES RELY ON; WITH THIS UNDERSTANDING, IT BECOMES POSSIBLE TO START ASCERTAINING THE DEFICIT IN TERMS OF ACCESS TO ELECTRICITY AND PLAN HOLISTICALLY TO EXPAND ENERGY ACCESS VIA AN INTEGRATED ENERGY MIX.

Different options for energy production

When planning ahead for least-cost electrification expansion, extending the grid in areas that are both in reasonable proximity to the grid and densely populated usually makes sense. This is because the distance from a particular community to the existing electricity grid would impact the cost of extending the distribution infrastructure, while the estimated demand in the community might also impact the cost-effectiveness of such an investment. In areas that are densely populated, it typically would make sense to extend the electricity grid, as long as the estimated demand in the areas that would be newly reached were sufficient.

FIGURE 4

Least-cost electrification: different options for energy production



Source: UNCDF own illustration

Similarly, in countries where one finds densely populated areas that are further from the current grid and not yet connected, provided the cost of extending the distribution infrastructure compares favourably with the estimated demand in that area it can make sense to extend the electricity grid.

However, there are also cases where grid electrification might not be the least-cost option for extending electricity access over the medium or even sometimes longer term. Often, such cases are found in rural areas that are far removed from the current grid infrastructure. In such cases, there are typically two options for electrification: mini-grids or solar home systems (SHS). In addition, there are clean energy products designed for single use, such as improved cookstoves and solar lamps (see Figure 4).

MINI-GRIDS

Mini-grids consist of decentralised power generation, distribution and sometimes also storage that are not linked to the central electricity transmission grid of a country (but sometimes can opt to be connected), and that are typically small in comparison to grid electricity production and distribution, supplying anything from a few kW (5 to 10) to a few MW in larger cases (typically lower than 10 MW), to a limited number of customers (whether households or businesses/institutions).

In terms of cost, mini-grids require substantial upfront investment (including the generator or power plant, system inverters, power lines, electricity meters, and sometimes battery storage), as well as provision for management and maintenance costs over time. For this reason, this option is typically more cost effective in rural areas where the population density is relatively high, such as villages or towns with a certain number of households located in sufficient proximity to one another to constitute a viable demand. For instance, in Lesotho, the World Bank conducted a study that concluded that, compared to extending the grid, mini-grids offer a better solution for electrifying off-grid households, community facilities and small businesses located more than 15 km from existing grid infrastructure (World Bank 2020).

There are different types of mini-grids, depending on the source of the power (and thus ‘mini-grid’ is not necessarily shorthand for ‘clean energy’); the type of power generation used could be diesel, solar, wind, hydro, or hybrid, the latter typically being diesel and one of the others. There are also different models of ownership and operation – including the public utility model, private sector model, community ownership model, and hybrid model (i.e. the public-private model). Different types and different models all have benefits and drawbacks.[1]

THE COST OF ELECTRICITY PRODUCED VIA MINI-GRIDS IS CURRENTLY STILL SIGNIFICANTLY HIGHER THAN THAT OF GRID-PRODUCED ELECTRICITY.

The World Bank, in a study that covers over 26,000 current and planned mini-grids (mostly in developing countries in Asia and Africa), finds that the cost of unsubsidised solar-hybrid mini-grid electricity (least-cost option) was USD 0.55/kWh in 2019 compared to a grid-distributed electricity average cost for 39 public utilities in Africa of USD 0.27/kWh. The same study, however, estimates that by 2030 the cost of mini-grid electricity will decrease to USD 0.22/kWh.[2]

These kinds of considerations with regard to mini-grids can impact the affordability of the electricity generated (and therefore the demand), as affordability is already an issue even in urban areas, and rural areas tend to be the very places where consumers have even lower incomes.

Assessments on the economic viability of mini-grids tend to be hampered by a lack of local data on things like population density, income distributions, current energy usage for particular uses (e.g. lighting, charging devices, cooking), as well as a lack of information on natural factors such as seasonal resource fluctuations (and even the type of terrain). Reliability of supply can also be an issue for clean energy mini-grids if not coupled with battery power or where not hybridised with diesel.

In addition to cost, factors to be considered when considering whether mini-grids are the least-cost option for electrification include the following, which have implications for sustainability and reliability in particular: lack of local skills for operation and maintenance (or a lack of maintenance itself); in the absence of minimum quality standards in the country, the use of poor-quality technology; uncertainty with regard to funding (especially over the lifetime of the grid); high cost to collect payments (e.g. via agents); and reliance on resources as inputs that can sometimes be scarce (especially clean energy inputs like wind, solar or hydro, but also applicable to reliance on diesel). Uncertainty around future energy policy and regulations, especially as they relate to mini-grids, can also hamper investment decision making.

SOLAR HOME SYSTEMS (SHS)

SHS are basically solar panels and supporting equipment (e.g. cables, switches, a mount for the panels, charge controllers/inverters, and at least one battery) that can be used by individual households or institutions to power a small number of low-power electrical devices (lights, radio, TV etc.). They are therefore much smaller in capacity than mini-grids, and are used (mostly) to provide power to a single user (a residence, business or facility); in other words, they stand apart from the grid. Their capacity ranges from as little as 10 Wp (watt-peak) that can generate 30 Wh per day (products below this range are sometimes called pico-solar products), to as much as 4 kWp generating 16 kWh per day (a 300 Wp unit should be able to generate 1 kWh – the amount for the standard consumption package, or SCP).[3]

Despite exponentially lower upfront costs than a mini-grid (based purely on the smaller size), the SHS cost per kWh has historically tended to be much higher than grid or mini-grid provided electricity. While costs have been reducing drastically over time, they can also vary drastically across different countries, as well as across different-sized SHS. The effectiveness with which the system generates power (based on solar radiation and the mounting and maintenance of a system) can vary substantially too, affecting the cost per kWh. As recently as 2019, estimates of roughly USD 0.9 to USD 1.5/kWh were noted.[4] This positions the cost of SHS at double (at least) that of mini-grids, and more than four times that of grid electricity.

GIVEN THAT ACTUAL USAGE OF ELECTRICITY VARIES WIDELY ACROSS HOUSEHOLDS AND IS TYPICALLY FAIRLY LOW IN LOW-INCOME HOUSEHOLDS, IT MIGHT STILL MAKE SENSE FOR A HOUSEHOLD TO PURCHASE A SMALL SHS THAT MEETS ITS NEEDS.

Nevertheless, the biggest barrier to uptake of SHS remains lack of affordability; most low-income households in the five study countries simply cannot afford the *upfront costs*, no matter how economically priced a package is, unless they can secure finance that breaks the cost into manageable monthly payments that fit into their cash flow. For instance, even the smallest-sized SHS can cost between USD 50 and USD 100, which makes it utterly unaffordable for most low-income households. What is more, these would be systems of only a few Wp; at the SCP (1 kWh per day), an SHS at least 10 to 15 times bigger is likely required.

Other than the upfront cost, what other issues hinder the adoption of SHS? While plug-and-play systems are available, the installation (and correct planning) of an SHS can have a big impact on its operation and total lifetime costs, not only in terms of the efficiency of the installed system but also because installation not done correctly can add to costs down the line. If installation is done correctly, however, maintenance (mostly cleaning and replacement of batteries) can be done by the user. Given the historic lack of standardisation of technical specifications for SHS though (for parts, to allow for optimal compatibility), installation and maintenance have often been problematic, especially in contexts where local skills are not available. Finally, the fact that solar panels can be subject to theft if not properly protected can act as a disincentive to SHS adoption.

SINGLE-USE/LIMITED-PURPOSE CLEAN ENERGY PRODUCTS

In addition to the options of grid, mini-grid and SHS electricity are single-use/limited-purpose clean energy products for specific purposes. Examples include solar lamps (which can also be classified as ‘pico-solar products’) that use a very small, built-in solar panel to charge a single light (and sometimes allow for device charging as well), rechargeable batteries, clean energy cookstoves, photovoltaic pumping (PVP) systems (for instance, used in agriculture), and solar water heaters. While these can all play a role in meeting the specific energy needs of a household or institution, with the exception of solar lamps and rechargeable batteries they generally also involve an upfront outlay that, unless they are heavily subsidised, would tend to put them out of reach for low-income households.

COMPARATIVE OVERVIEW: DIFFERENT SOURCES OF ELECTRICITY PRODUCTION

Using rough ranges and estimates, Table 1 provides a comparative overview of the generation capacity, typical energy usage range, average/typical cost per kWh, and customer pool for each of the different energy production options discussed. It is clear from this summary that costs tend to increase for the consumer the smaller the electricity producing unit.

TABLE 1

Typical capacity, usage, cost and customer pool, per option for energy production

	TYPICAL GENERATION CAPACITY	TYPICAL USAGE RANGE PER USER PER DAY	AVERAGE/TYPICAL COST PER KWH	CAN SERVE
Grid supplied electricity	100s to 1000s MWs	Unlimited(12 Whto 30 kWh)	USD 0.27/kWh	Any application
Full mini-grid electricity	125 kW to 10 MW+	200 Wh to 30 kWh	USD 0.55/kWh	500+ households
Mini-grid electricity	25 kW to 125 kW	200 Wh to 8 kWh	USD 0.55/kWh	100 to 500 households
Micro-grid electricity	5 kW to 25 kW	200 Wh to 8 kWh	USD 0.55/kWh	20 to 100 households
SHS large	250 Wp to 4 kWp	1 kWh to 16 kWh	USD 0.9 to 1.5/kWh	1 or more households
SHS medium	50 Wp to 250 Wp	200 Wh to 1 kWh	USD 0.9 to 1.5/kWh	1 household (limited appliances)
SHS small	10 Wp to 50 Wp	40 Wh to 200 Wh	USD 0.9 to 1.5/kWh	1 household (limited function)
Pico-solar products	3 Wp to 10 Wp	12 Wh to 40 Wh	>USD 1.5/kWh	Limited function

Source: UNCDF, using various, including data as referenced in above section

IMPROVED COOKSTOVES

While limited-purpose, clean energy products are mostly too expensive for low-income households, as the discussion above indicates, one important exception is cookstoves. A lot of donor and government activity is attempting to steer the energy market in this area, especially in terms of innovation and a reduction in cost, to the point that, especially if they are financed, cookstoves are becoming an increasingly feasible option for low-income households.

Interventions in the cookstove space have a long history but generally focus on four categories of benefits: improved efficiency (cook more quickly using less fuel), reduced impact on the environment (through lower emissions levels), improved health outcomes for users (through lower emissions levels), and improved safety. These benefits are generally pursued by focusing on the equipment and the fuel used for cooking; for instance, the improved cookstoves would still be reliant on biomass but require less of it than a traditional cookstove or open fire would.[5] There are also limited cases of people using solar and retained heat cookers.[6]

The majority of the poor do not use electricity for cooking, even if they have access to electricity. Instead, they rely mostly on biomass (e.g. firewood, charcoal), whether used in a cookstove or on an open fire; and where household income is slightly higher, people also use the solid fuel coal and modern fuels (i.e. LPG, ethanol, paraffin).

However, biomass resources have come under intense pressure through the overreliance on fuelwood (firewood and charcoal), combined with the clearing of land for agricultural production, contributing to environmental degradation, rural poverty and rural energy shortage. The significant dependence on biomass is undesirable as it is not only inefficient but also has a negative climate and health impact. It is estimated, for example, that firewood and charcoal are responsible for the emission of between 1 and 2.4 gross tonnage (Gt) of carbon dioxide equivalent (CO2eq) greenhouse gases annually; this amounts to 2% to 7% of global anthropogenic emissions.[7]

These emissions are largely due to inefficient biomass combustion, unsustainable harvesting of forest resources (particularly firewood), and environmentally damaging charcoal manufacturing. The emission from solid fuels (i.e. coal and biomass) used for cooking in Sub-Saharan Africa alone is estimated to account for 6% of global black carbon emissions and 1.2% of carbon dioxide emissions.

Large proportions of a household's income or time are spent on fuels for cooking, either to purchase fuel or to gather it from nature (work that is mostly done by women and girls). More efficient cookstoves can therefore lead to reduced cost or time – regardless of the fuel used – in the process saving household income or freeing up productive time for women and girls. More efficient cookstoves also have a reduced impact on the environment, by reducing forest depletion (which can impact significantly on the local environment and economy) as well as reducing greenhouse gas emissions. Lastly, improved cookstoves not only significantly reduce particle emissions that can negatively impact the health of households but, by reducing the risk of fires or burns, such cookstoves can also be safer.

However, when it comes to encouraging consumers to make a switch such as to more efficient cookstoves, many lessons have already been learned.

For instance, adoption of new cooking fuels and technologies is based firstly on awareness and then initial adoption, but improvements are only seen if the switch is to sustained use. In reality, people tend to use different energy sources for different cooking needs, and any particular new fuel source or technology (cookstove) might only be convenient to use for a specific or particular need.

Furthermore, the cost of switching may be expensive for households, even if the new cooking appliance itself is subsidised or free. While the first barrier is usually the upfront cost of the cookstove or appliance itself, the fuel used can also imply significant additional expenditure for households. Maintenance can sometimes require further expenditure, be bothersome, or require expertise not available at the local level.[8]

A comprehensive study[9] of the main research on improved cookstove affordability found that, in addition to the upfront cost of improved cookstoves, the monthly cost of fuel is mostly unaffordable to poor households. In order to encourage sustained use of the improved equipment, therefore, microfinance institutions (MFIs) should incorporate in their portfolio of financing options the ongoing cost of using the cookstove as a potential bridging financing option.

THE STUDY ALSO FOUND THAT, SURPRISINGLY, ALMOST NO IMPROVED COOKSTOVES THAT SOLD FOR USD 5 OR LESS ACTUALLY ADHERED TO PARTICLE EMISSION STANDARDS, MEANING THAT SUCH STOVES DO NOT ACTUALLY IMPROVE HOUSEHOLD HEALTH OUTCOMES OR REDUCE ENVIRONMENTAL IMPACT.

Lastly, the study confirmed the MAP research finding that 'affordability' of improved cookstoves must be considered realistically within the context of findings that poor households rarely spend less, as a percentage of their income, for energy than the affordability threshold; in fact, poor households' energy expenditure is often much higher than the threshold, mostly because they 'stack' different types of energy usage; in other words, they alternate different forms of energy – clean and traditional unclean – depending on a range of considerations, including budgetary at the time.

Different sources of energy

We have seen that understanding the different *options for energy production* in a country is central to understanding least-cost options for electrification to meet targets. Equally crucial in this regard is understanding the different *sources of energy* – that is to say, how/where households and businesses actually source the energy they need to perform their various daily functions.

Simple metrics such as the proportion of households that have access to electricity via the national grid are important, both per country and as a means of comparing countries. Least-cost energy inclusion considerations also need to include an accurate picture of the quality and quantity of energy provided. For this reason, the MAP research employs a detailed framework based largely on the work of the Energy Sector Management Assistance Program (ESMAP) and Sustainable Energy for All (SEforAll) – an initiative co-chaired by the secretary-general of the UN and the president of the World Bank. The ESMAP/SEforALL *multi-tier framework* is useful for looking at different types of energy users in conjunction with different types of energy sources.

SUSTAINABLE ENERGY FOR ALL

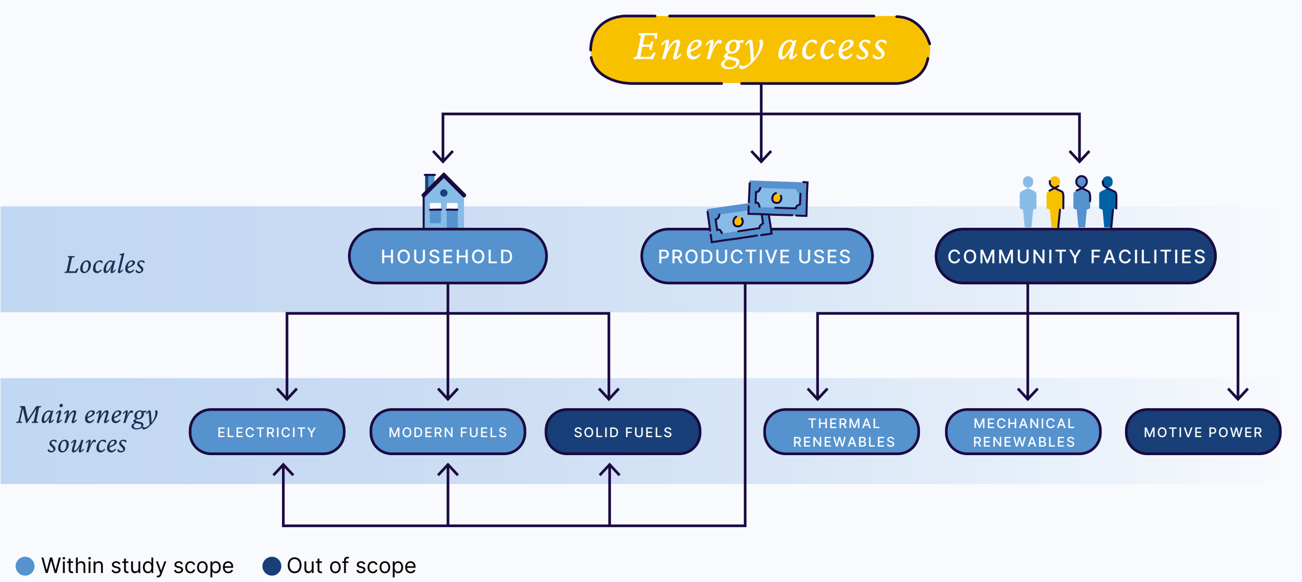
SEforAll is an international organisation that works in partnership with the UN and leaders in government, the private sector, financial institutions, civil society and philanthropies to drive faster action towards the achievement of SDG 7 – access to affordable, reliable, sustainable and modern energy for all by 2030 – in line with the Paris Agreement on climate. [10]

The ESMAP/SEforAll multi-tier framework (see Figure 5) begins by making a distinction between the three main environments in which people access energy: households, productive uses (i.e. business, industry), and community facilities. These categories are referred to as the 'locales of energy access'. (In terms of the locale of energy access that is classified as 'productive uses', the MAP clean energy research only focuses on MSMEs – rather than large firms or industry. And the MAP research does not focus in any substantive way on the third locale, community facilities.)

The framework then focuses on main source of energy. Households make use of three main sources of energy: electricity, modern fuels, and solid fuels. As defined in the framework, modern fuels include LPG, natural gas, paraffin and ethanol, while 'solid fuels' comprises coal and biomass (e.g. wood, charcoal and dung). In low-income contexts such as the five study countries, modern fuels and solid fuels are the main fuels used for cooking and heating.[11]

Energy sources for industry and business (productive uses) include: electricity, modern fuels, solid fuels, thermal power from direct renewable sources (e.g. water, wind or solar), mechanical power (also from renewable sources) and motive power (from animals or humans).

FIGURE 5
Framework for evaluation of energy access: locales and main energy sources



Source: UNCDF analysis based on ESMAP/SEforAll multi-tier framework (Bhatia & Angelou 2015)

THE MULTI-TIER FRAMEWORK APPROACH ALLOWS FOR MEASURING ACCESS TO HOUSEHOLD ELECTRICITY ON A CONTINUUM OF IMPROVEMENT (AS OPPOSED TO A BINARY METRIC SUCH AS ACCESS VS NO ACCESS) ACROSS SIX TIERS (TIERS 0 TO 5), BY REFLECTING ALL ATTRIBUTES OF ELECTRICITY SUPPLY THAT AFFECT THE USER'S EXPERIENCE; AT THE SAME TIME, THE FRAMEWORK IS TECHNOLOGY AND FUEL NEUTRAL.

Different energy services (e.g. lighting, TV, air circulation, refrigeration, space heating) require different levels and quality of energy. In terms of the framework, households in Tier 0 are said to have no access to electricity, while households in Tier 5 have access to safe and good-quality electricity (i.e. supply not subject to voltage fluctuations and power surges) that is reliable (i.e. not subject to frequent outages), affordable (the cost of a standard consumption package is 5% or less of household income) and available (almost 100% of the time). The relevant ESMAP/SEforAll multi-tier standards for household access to grid-supplied electricity are presented in Table 2.

While, as Table 2 shows, the framework distinguishes between the main aspects of energy access (viz. capacity, availability, reliability, quality and affordability), ESMAP/SEforALL also provide a multi-tier framework to measure household access to *electricity services* (see Table 3); this second framework is represented in terms of the typical appliances a residential consumer can use at each tier of electricity access, and the typical supply technologies for each tier (including off-grid supply).

For example, a household with Tier 1 access to electricity services would typically have a pico-solar lantern or low-end SHS that can deliver task lighting and perhaps phone-charging services. The typical supply technologies would include a pico-solar lantern with a small solar panel and USB port to charge a mobile phone. Off-grid technologies such as SHS can be used to provide electricity services from Tiers 1 to 4, while mini-grids are typically used to provide services at Tiers 3 and 4.

TABLE 2

ESMAP/SEforAll multi-tier framework to measure household access to electricity supply

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Power capacity ratings (daily watt-hour: Wh)		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
Availability (duration)		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
Reliability					Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
Quality					Voltage problems do not affect the use of desired appliances	
Affordability				Cost of a standard consumption package of 365 kWh/year < 5% of household income		

Source: Bhatia & Angelou (2015)

TABLE 3
ESMAP/SEforAll multi-tier framework for household access to electricity, plus typical supply technologies

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Supported appliances		Task lighting and phone charging	General lighting and phone charging and TV and fan (if needed)	Tier 2 + medium-power appliances (e.g. refrigerator, water pump)	Tier 3 + high-power appliances (e.g. washing machine, iron, hairdryer, low-energy cookstove)	Tier 4 + very high-power appliances (e.g. air conditioner, vacuum cleaner, cookstove)
Typical supply technologies		Solar lantern	Small SHS, rechargeable battery	Medium SHS, fossil fuel-based generator, mini-grid	Large SHS, fossil fuel-based generator, mini-grid, central grid	Large fossil fuel-based generator, central grid

SHS

Mini-grid

Source: Bhatia & Angelou (2015)

Understand energy access, including for low-income consumers

A major component of collecting energy market data is understanding the extent to which the country is marrying its supply of energy to household and business demand, as well as the extent to which energy providers have access to consumers and consumers have access to energy. This understanding includes consumers' ability to pay – i.e. energy affordability – and allows us to gain a clear picture of the electricity access deficit in the country. On the basis of this, it is possible to discern both the financing needs of low-income consumers and the investment needed for increasing energy access in alignment with national inclusive growth aspirations.

To understand energy access, it is necessary to understand:

- **OVERALL LEVELS OF ENERGY ACCESS IN THE COUNTRY.** The simplest way to understand energy access is to look at the overall level of access, such as what proportion of the population has access to electricity via the national grid (see Figure 6).
- **WHAT TIER THE COUNTRY FALLS INTO IN TERMS OF ELECTRICITY PROVISION.** Gauging overall energy access also involves considering how a country stacks up to others on the ESMAP/SEforALL metrics of availability, reliability and quality of electricity provision, which determines what tier a country falls into.
- **DYNAMICS AND DRIVERS OF ACCESS AND USAGE, BY DEMOGRAPHIC GROUPS.** Beyond simple energy access, it is necessary to grasp the dynamics of access and usage for different demographic groups, and to understand the drivers of energy usage. For such understanding, the ESMAP/SEforAll multi-tier framework also proves helpful for segmenting populations *within* a country.
- **THE URBAN–RURAL DIVIDE.** Given the reality of the 'citadel economies' of all five of the study countries, it is also crucially important to understand rural versus urban access to electricity; therefore, where available, a GIS locational analysis of exact proximity to the grid would also be useful.
- **THE COUNTRY'S FINANCIAL INCLUSION REALITIES.** In-country financial inclusion realities will be important because these influence people's behaviour and can present opportunities for, or place limitations on, financing energy access.

HIGH LEVELS OF EXCLUSION FROM ELECTRICITY GRID. Typical measures of energy access include the proportion of a country's households with access to energy via the national grid. As of 2017, 57 million people across the five study countries did not have access to electricity. The three countries (Malawi, Mozambique and Madagascar) that fall into what MAP classifies as Cluster 1 countries[12] had a total level of access to electricity in 2017 of between 13% and 27% of the population. Lesotho (a Cluster 2 country), had only slightly higher access of 34%. Out of the five countries, only Eswatini (Cluster 3) had significantly higher access, at 74% in 2017.

ENERGY ACCESS LEVELS VERY LOW, WITH SIGNIFICANT ADDITIONAL (CLEAN) ENERGY GENERATION NEEDED. The low levels of access to the national grid in the five study countries point to a distinguishing feature of the energy challenge in these countries: the problem is not that their electricity consumption is not *clean*; rather, it is that it is too *low*. In fact, their reliance for own electricity generation on hydro combined with their low levels of electricity access means the countries are among the lowest emitters (from electricity generation) in the world, and their current output is enviably green.

The related issue is that, with such low levels of access to electricity, these countries will need significant *additional* energy generation over the next decade to make meaningful progress in increasing energy access.

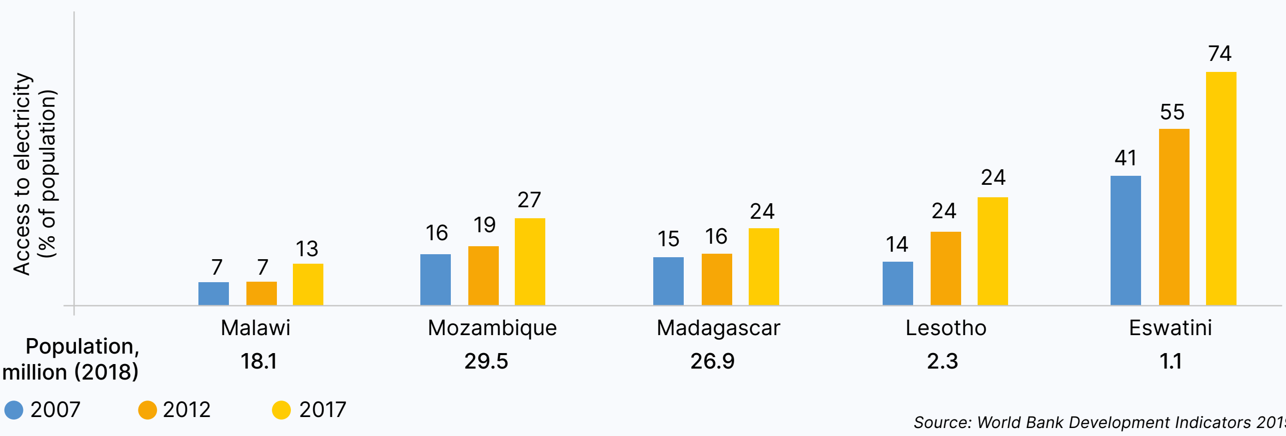
All five countries have indeed made significant progress over the past 10 years to increase electrification, with Madagascar, for example, achieving about a 60% increase in the proportion of the population with access to electricity, and Lesotho achieving about a 150% increase on the same. Importantly, too, the indications are this rate of growth will continue.

However, MAP's five-country study found that this rate of increase falls far short of what is necessary to reach the 2030 goal of universal access – and hence, logically, traditional and existing electrification efforts and strategies will need to be both supplemented and complemented, where possible, with clean, off-grid energy solutions, towards achievement of an integrated energy mix.

While simple measures such as proportion of a country's population with access to the national grid are helpful, they do not provide any kind of accurate insight into the quantity and quality of energy access. The standards of the ESMAP/SEforAll multi-tier framework are useful in this regard, allowing us to assess countries in terms of the overall *availability* and *reliability* of electricity supply through their national grids. This allows for the classification of the country's overall state of electricity provision to those who have access.

FIGURE 6

Access to electricity, as percentage of population



Source: World Bank Development Indicators 2019

FIGURE 7

Overall state of grid electricity provision (availability and reliability), by country

	MALAWI	MOZAMBIQUE	MADAGASCAR	LESOTHO	ESWATINI
Availability of grid supply (hours per day)	<4	<8	<8	>23	>23
Reliability of grid supply (disruptions per week)	<14	>14	>14	<3	<3

Source: Assessment by Nova Economics (2019) of availability and reliability of electricity, by country

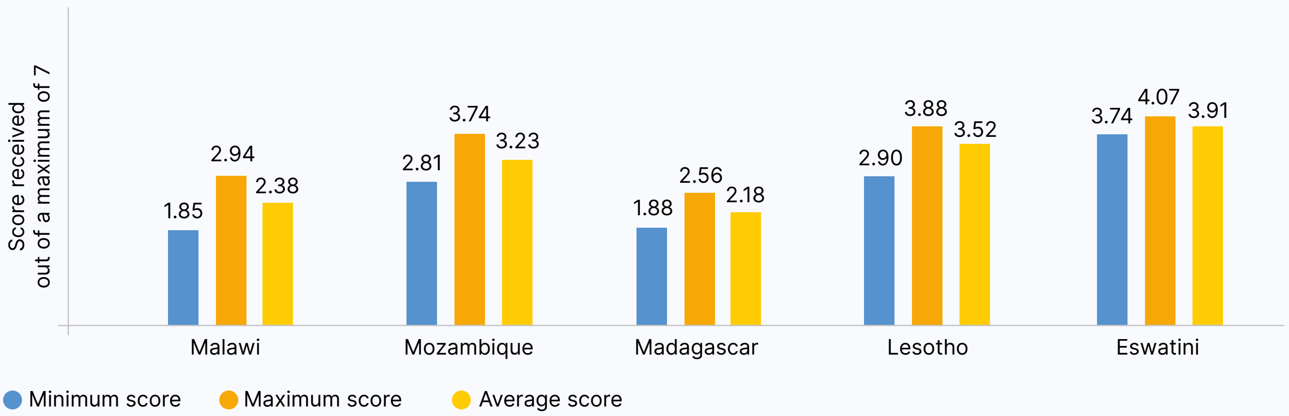
ELECTRICITY SUPPLY AVAILABILITY AND RELIABILITY LARGELY COMMENSURATE WITH LEVELS OF ACCESS. The MAP finding is that, across the five countries, availability and reliability of electricity provision largely follow levels of access to electricity: Lesotho and Malawi have more reliable electricity provision, and the other three countries less so. Malawi does seem to be a slight outlier, however, with the number of disruptions per week being less than that of Mozambique and Madagascar, even though the levels of availability and overall access to electricity are lower in Malawi (see Figure 7).

The quality of electricity provision also differs across countries. The World Economic Forum[13] measures quality of provision on a scale from one to seven. Between 2007 and 2017, the scores received by each country for quality of electricity provision were more or less in step with the overall levels of access, availability and reliability.

Mozambique, in general, received the highest score of the three Cluster 1 countries, and almost comparable to Lesotho (a Cluster 2 country). Only Eswatini received a score of higher than four out of seven, a rating which it held for only two years, however (see Figure 8). These scores are also used to rank countries, and only one country in the pool of five has ranked consistently in the top 100 countries over the past 10 years (Eswatini – ranked in the 90s). Lesotho and Mozambique have received rankings ranging mostly in the low 100s, while Malawi and Madagascar received rankings mostly from 120 upwards (to the mid-130s).

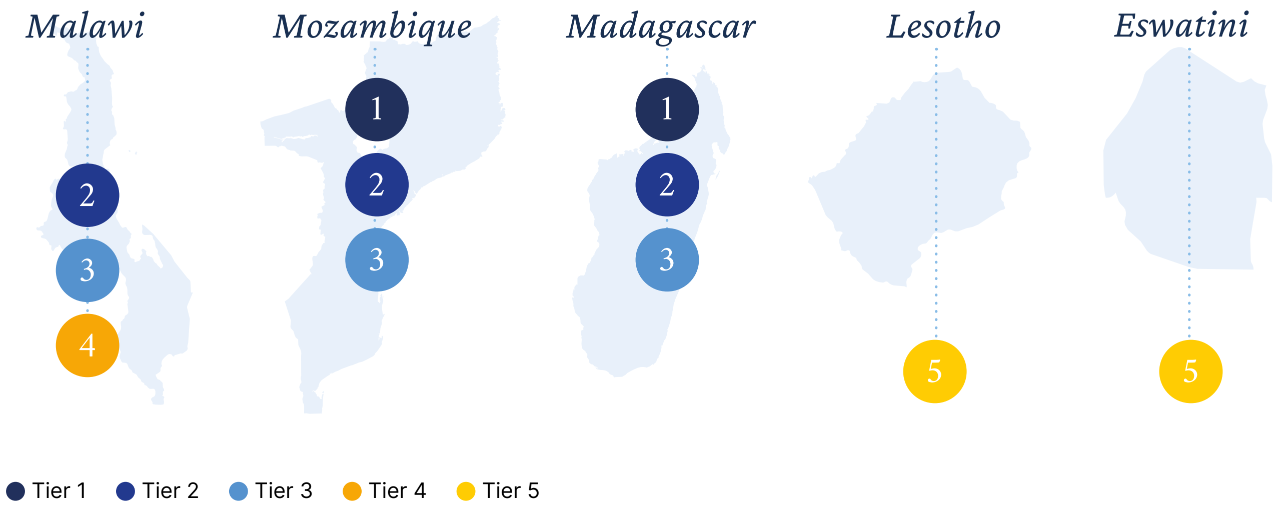
FIGURE 8

The five study countries, by quality of electricity provision



Source: World Economic Forum (2019)

FIGURE 9
The five study countries, by tier (based on overall electricity provision)



Source: Nova Economics (2019)

Based on the information relating to the availability and reliability of electricity supply, countries can be classified across the six ESMAP/SEforAll tiers in terms of overall provision.

COMPROMISED AVAILABILITY UNDERMINES PROVISION. Additional information from the MAP five-country study indicates that the quality of grid electricity provision is low in Malawi, Mozambique and Madagascar. There are often multiple disruptions per day, resulting in long periods of grid downtime and no supply. This means that even the few households with electricity access need to make use of alternative sources to meet their energy needs. To use Malawi as an example, the most recent ESCOM (Electricity Supply Commission of Malawi) electricity supply schedule (December 2019) shows planned outages of four and six hours a day, every day of the week. On the basis of availability and reliability, Malawi's overall electricity provision rating is thus limited to between Tiers 2 and 4 (see Figure 9).

BEYOND MEASURING OVERALL ACCESS, MEASURING ACTUAL USAGE IS IMPORTANT. The above assessment of overall electricity provision still does not reflect the actual levels of usage that individuals and households get by on. By using the *actual expenditure on electricity* (coupled with the cost of electricity) or, where that is not available, proxy data in the form of asset ownership of individuals and households, one can more accurately gauge actual usage.

SEGMENTING CONSUMERS WITH ACCESS INTO FIVE TIERS, BY USAGE. Livelihoods survey data allows us to estimate levels of electricity usage by the entire adult population, and categorise this usage according to the six tiers as described by the ESMAP/SEforAll framework. For instance, the FinScope datasets include country data on access to electricity, and usage of other energy sources specifically for lighting and cooking, while also containing information on ownership of specific electrical appliances, and expenditure on energy (sometimes disaggregated by source of energy). This data can be used to segment the population into five groups (corresponding to the five tiers that have some energy access), based on their energy usage and expenditure and their ownership of electrical appliances.

This is not usually a straightforward exercise, as the data availability tends to vary, and a few calculations and assumptions are therefore necessary to achieve the segmentation. The most straightforward point of departure is when the data contains information about monthly expenditure on electricity specifically. Knowing a country's electricity tariff structure then allows for the calculation of the implied monthly electricity usage in daily watt-hours (Wh), as per the multi-tier energy framework.

TABLE 4

Inferred consumer segments, based on energy usage behaviour and supported appliances

	1	2	3	4	5
Power capacity ratings (daily watt-hour – Wh)	MIN 12 WH	MIN 200 WH	MIN 1.0 KWH	MIN 3.4 KWH	MIN 8.2 KWH
Supported appliances	Task lighting and phone charging	General lighting, phone charging and TV/fan (if needed)	Tier 2 and medium-power appliances	Tier 3 and high-power appliances, including for cooking	Tier 4 and very high-power appliances, including for cooking

Once this has been calculated for all survey participants, the nationally representative weighting of the data can be applied to segment the entire population into groups based on their reported expenditure (and thus implied usage) per month.

However, in some cases this information might not be available, in which case it is still possible to infer the energy usage tier that specific survey respondents would fall into, based on their responses to other questions. For instance, a respondent would be in Tier 0 if they indicated they do not have access to electricity. For Tiers 1 to 5, the responses of those who do have access to electricity in terms of using energy for cooking or lighting can be used as a first step, and thereafter their responses to questions about ownership of specific electrical appliances (see Table 4). For instance:

- Those who only use electricity for lighting, and do not use it for cooking, and who also do not own any heavier-usage appliances (e.g. TV, refrigerator) would be presumed to fall into Tier 1.
- Those who use electricity for lighting and who have a TV, but no other electrical appliances, would be presumed to fall into Tier 2.
- Tier 3 would include those who use electricity for lighting and have a TV and refrigerator (medium-power appliances).
- Tier 4 would include those who also use electricity for cooking (high-power appliance).
- Tier 5 are the highest-end users, who, in addition to the previous usage criteria, have electric water heaters or comparable high-usage (very high-power) appliances.

Once this segmentation has been constructed for a dataset, the population characteristics for each tier can also be described: i.e. their average income, types of energy used, financial services usage and the like.

This analysis shows that while countries are classified according to specific tiers overall (see Figure 9), within a country all of the tiers are applicable *to varying extents* in terms of the amount of electricity consumers use.[14] That said, in the five study countries, only a small proportion of consumers fall into the top tiers; across all of the countries (even Lesotho and Eswatini), the majority of electricity users fall into Tiers 1 to 3,[15] further highlighting the extent to which the needs of the low-income are not yet being served.

ELECTRICITY ACCESS FIGURES ARE NOT THE FULL STORY – AND ACTUAL USAGE IS IMPORTANT. While the picture that has emerged thus far is that the majority of households in almost all of the five countries do not have access to electricity, a further crucial finding is that the majority of those who do have access to electricity use very little electricity, and can only power a rudimentary set of appliances as a result. For instance, around 18% of adults across the five countries would only be able to power lights for tasks and charge their mobile phones. Another 33% would be able to power general lighting, phone charging and maybe a small appliance like a TV or a fan. This means that around half of adults who do have access to electricity are using less than 1 kWh of electricity a day (Tiers 1 and 2 usage).

AN ADDITIONAL 33% WOULD BE ABLE TO DO THE SAME, BUT ALSO HAVE A MEDIUM-POWER APPLIANCE LIKE A REFRIGERATOR. IN OTHER WORDS, IN THE FIVE STUDY COUNTRIES THE MAJORITY OF ADULTS (AROUND 84%) FALL INTO TIERS 1 TO 3, WHILE THE REMAINDER FALL INTO TIER 4 (11%) AND TIER 5 (5%).

ACCESS TO ELECTRICITY CLEARLY IS NOT ENOUGH TO ENSURE USAGE. It is critical to understand the demographic characteristics that correlate with access and, in the process, the possible underlying factors that constrain actual usage, with a long-term view to driving more inclusive growth from the household level. Without doing this, the business models will remain opaque, thus limiting investments on a scale significant enough to promote inclusive growth and a just energy transition.

Consumer profiles of access to energy

The MAP research finds that, in the five study countries, where you live, what you earn, the kind of work you do and your level of education largely determine your access to electricity, while the impact of your gender and age on energy access is less clear. Geographic location has an obvious impact on energy access, given the infrastructure requirements for distribution. However, the MAP data allows for additional granularity to unpack differences in access for different groups of consumers based on their demographic and livelihoods characteristics. These additional indicators are, however, substantially intertwined, in the sense that having a particular characteristic also makes it more likely to have a second (or a third) characteristic; for instance, as there are fewer opportunities and there is less overall development in rural areas (compared to urban), employment in rural areas tends to largely revolve around agriculture or informal businesses. This in turn affects the income of rural adults – who tend in general to be substantially poorer than those in urban areas.

Access to education, which tends to be lower in rural areas due to the infrastructure deficit, also influences employment and income opportunities and, as a result, is one of the strongest predictors of access to particular energy sources like grid electricity.

Income source is another useful indicator, as those with the same income source tend to have similar characteristics and also tend to live in similar types of locations. Access to electricity by income group negatively correlates almost directly with both the size of the income group (proportion of population income group) and the proportion of adults in each income group that are rural.

FIVE-COUNTRY STUDY FINDINGS

The MAP country diagnostics highlight the following energy access trends across different sets of demographic characteristics:

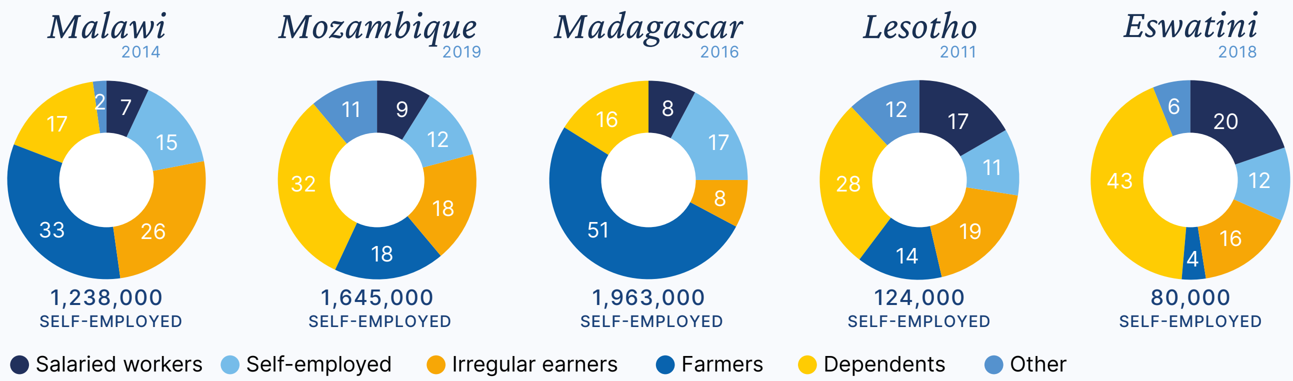
- **INCOME – ACCESS TO GRID ELECTRICITY INCREASES SIGNIFICANTLY WITH INCOME LEVELS.** The research finds that the poorest population groups (which are also the largest) have the least access to grid electricity, while those who earn more (the smallest population groups) have higher levels of access. This finding stands even if other proxies for income/poverty are considered. For instance, for those who have experienced one of three poverty-related events or risks (e.g. skipping a meal because of insufficient money to buy food; going without medical treatment or medicine; being unable to send children to school) in the previous year, access to grid electricity tends to be lower than is the case for those who have not experienced such events.

- **INCOME SOURCE – THE LARGEST AND MOST RURAL INCOME GROUPS HAVE THE LOWEST ACCESS, THE SMALLER AND MORE URBAN GROUPS HAVE HIGHER ACCESS.** Farmers and informal workers tend to be the largest and most rural income groups, and also have the lowest levels of access to grid electricity. Salaried workers and the self-employed, on the other hand, tend to be much smaller groups (especially salaried workers), be much more urban based and have higher levels of access to grid electricity. Income groups with the highest access to electricity in general also tend to have the highest income (the formally employed, and the self-employed), and those with the lowest access tend to have the lowest income (farmers and irregular earners).
- **EDUCATION – THE LOWER THE LEVEL OF EDUCATION, THE LOWER THE LEVEL OF ACCESS TO ELECTRICITY.** Education is another demographic indicator that correlates strongly with access to energy. For instance, of those who have no, or only primary, education very few tend to have access to grid electricity, even though this group usually represents a large portion of the population. Those with a secondary education tend to have higher levels of access to electricity (even though this group can also be substantial in some countries), but those with an education in addition to secondary (i.e. a vocational or tertiary education) tend to have the highest levels of access to electricity; the latter group, however, usually constitutes a very small portion of the population.
- **GENDER AND AGE – THESE TWO INDICATORS DO NOT MAP CLEARLY TO ACCESS TO ELECTRICITY.** The correlation between gender and/or age and access to grid electricity is not very clear across the five countries. Women seem to enjoy marginally higher access to electricity in most of the countries. In Lesotho, the research shows higher rates of access for middle-aged adults, with youth and the elderly having slightly lower rates, while in other countries access to electricity increases with age. In addition, particular age groups and men and women do demonstrate slightly different preferences when it comes to alternative energy sources (although the findings are not sufficiently compelling to include here for the purposes of determining the clean energy investment case).

Despite the above groupings in terms of common demographic characteristics, it is important to note that in the five study countries, even population groups that are higher income, more urban, or have more consistent income sources contain large numbers of households and individuals who still have relatively low levels of access to electricity. It would make sense in the short term and without delay to target such groups as a way of expanding access provided any supply-side constraints could be addressed.

Nonetheless, with half the population (or more) in the five countries deriving their income from agricultural activities, as a long-term objective it is crucial to explore clean energy and off-grid solutions, both as a climate change-mitigation response and a means of charting pathways out of poverty by increasing energy access. The fact that in the five countries high levels of poverty and the extensive use of biomass energy for cooking are a common characteristic of by far the largest proportion of the population underscores once again how poverty, energy exclusion and environmental degradation intersect. Making progress towards achieving SDG 7 requires addressing the issues of economic and financial exclusion, energy exclusion, and climate change concurrently.

FIGURE 10
How households earn their livelihoods, per country (% of households)



Source: Most recent FinScope survey for each country

Small business profiles of access to energy

In addition to households as 'locales of energy access', the ESMAP/SEforAll multi-tier framework emphasises productive uses (i.e. industry and business) as a main environment in which people access energy. Within the low-income space, this necessitates understanding MSME access to electricity, and that is the MAP focus with regard to determining the investment case for clean energy for productive uses.

As with households, it is useful to disaggregate different groups of MSMEs (to identify those that could benefit from increased energy access), although there is typically far less data availability when looking at MSMEs. While some countries do have a livelihoods dataset equivalent for MSMEs, often analysis is limited to information that is available from consumer livelihoods datasets; in the five study countries, however, the vast majority of MSMEs are one-person survivalist operations, and so there is often not a clear division anyway between business and household energy needs.

Across the five countries, the MAP research found that the majority of households are either dependants – relying on contributions from family members, aid or grants – or are engaged in small-scale or subsistence farming. Formal employment, although increasing with GDP per capita, is scarce. Other than these sources, a substantial portion of each adult population rely on self-employment (MSMEs) to derive their income, ranging from a maximum of 17% in Madagascar to a minimum of 11% in Lesotho (see Figure 10). Across the five countries, the self-employed sector (for the most part informal) provides a direct source of livelihood for five million adults, not including those who are employed by the self-employed, which is also substantial.

When considering the energy needs of the MSME segment, it is helpful to bear in mind that some of the self-employed will be *agricultural* MSMEs; in other words, although the segments 'self-employed' and 'farmers' are distinct, on the continuum of how households derive their livelihoods there will be some complementarity between the two different segments. This could have implications in a number of areas for consideration: not only in terms of the geographic location of energy solutions and MSMEs' specific energy requirements (e.g. for activities like water pumping and irrigation, milling, crop drying) but also for access to finance, as well as for investors' expectations of the kinds of economies of scale that could be achieved in serving MSMEs when part of the 'farmers' segment can be added.

Owing to the small size and informal nature of most MSMEs, most operate from their homes (61% in Lesotho, 46% in Mozambique), from the roadside, or from a stall, table or container. Only a small portion operate from a business premises (3% in Mozambique, 21% in Lesotho). This has implications for MSME energy requirements because it means their household and business energy requirements are often undifferentiated or at least intertwined.

MSMEs that operate from the street would be a discrete sub-set of MSMEs because their energy needs might be quite different from those of businesses operating out of homes.

FIVE-COUNTRY STUDY FINDINGS

MSMEs' access to energy varies by country:

- Lesotho's MSMEs' access to grid electricity is on a par with that of its population (34%). Furthermore, and somewhat surprisingly, the country's urban-based MSMEs have much lower levels of access; considering that urban-based consumers are more accessible to supply than far-flung ones, this finding immediately suggests a potential focus area to target without delay.
- Malawian MSMEs report a higher level of access to grid electricity than that enjoyed by the general population (18%, vs 13% for the general population). Another distinguishing characteristic of the country's MSMEs is that male-owned MSMEs have higher levels of energy access, as do MSMEs owned by more educated individuals. Lastly, energy access improves for increasing size of enterprises, as well as for increasing age of businesses.
- Mozambique has lower levels of access to grid electricity for MSMEs than for the general population (7%, vs 27% for the general population).
- Eswatini too has lower levels of access to grid electricity for MSMEs (56%, vs 74% for the general population). This is even lower than the country's rural population grid electricity access levels (67%).

In the five countries, the fact that there are low levels of energy access for businesses is either driven by the nature of small businesses (mostly informal, mostly operating from homes with low levels of access to the grid, or operating door-to-door or on the street, and therefore not needing electricity), or could be related to supply-side factors. Access to energy also varies by business sector, size, and age (i.e. the larger and/or more mature the business, the greater the level of energy access), and even the gender and education levels of the business owner (as we see in the case of Malawi).

Geographic location emerges as a key determinant in many cases when it comes to energy access; for example, some sectors are by definition location-specific (e.g. agriculture, tourism). Type of business is another determinant, in the sense that businesses focused on trade will tend to have lower energy access levels than those offering professional services; and gender and education also play a role, as women entrepreneurs tend more towards ownership of micro enterprises, and women also tend to participate more in trade. Those segments of the population with higher levels of education tend to participate more in professional services.

The MAP research also found a business's level of formality to be relevant to energy access; being a registered business, or a business that employs someone, also correlates to the likelihood that the business will have access to electricity; furthermore, being registered increases the amount of electricity likely to be used.

RELIANCE ON SOLAR OR GENERATOR POWER SEEMS TO BE A SUBSTITUTE SOURCE OF ELECTRICITY FOR BUSINESSES THAT REQUIRE ACCESS TO ENERGY BUT DO NOT HAVE ACCESS TO THE GRID; FOR INSTANCE, RURALLY BASED BUSINESSES AND TRADE AND AGRICULTURAL BUSINESSES ARE MORE LIKELY TO USE SOLAR, WHILE BEING LESS LIKELY TO HAVE ACCESS TO GRID ELECTRICITY.

THE RESEARCH FOUND THAT PRODUCTIVE APPLICATIONS OF ENERGY BY MSMES TEND TO BE HIGHLY PARTICULAR TO THE *SECTOR* IN WHICH THE MSME OPERATES.

For instance, retailers might typically require lighting, the use of small appliances (e.g. TV or radio) and refrigeration (e.g. for cold drinks), while agricultural MSMEs could require refrigeration, cold storage, water pumping and irrigation, milling, husking, and pulping of rice, grain and other agricultural produce, and transport. More specialised MSMEs (which are in the minority) could require additional energy services, including small-scale food processing (drying, pressing of oil, juice making), small-scale sawmills and carpentry, metal workshops, welding services, and repair shops. And MSMEs in the professions and/or services sector might require commercial services such as print shops, internet cafés, hairdressing, cloth making and the like. This type of granular data is not typically available in livelihoods surveys or even in specialised MSME surveys, however. It would be very useful to have data on the specific *uses* of energy by specific types of MSMEs – for instance to run a sawmill, or other specific equipment – because both the technology options for specific energy consumer profiles and the likely spend by the MSME are germane to accurately determining addressable market and financing needs.

Low-income consumers' profiles of access to financial services

Understanding the extent to which low-income people in a country are able to access finance for purchasing clean, off-grid energy solutions is important to growing countries' energy markets. However, this calls for a sophisticated, evidence-based comprehension of people's daily realities, including their real-economy activities, and how they use financial services (formal and informal) to help them meet their needs.

Clean energy solutions range in price from less than USD 5 to over USD 1,000 and are sold through energy service companies and/or financial institutions. Given the relatively large upfront costs of the products relative to income, few households can afford to buy the solutions on a cash basis and rather rely on access to credit or instalment payment mechanisms. Thus, one of the most important dimensions of understanding access to energy is understanding the extent to which people can access finance to purchase energy and related products.

At the micro-level, as people self-fund increased access to energy, they effectively contribute to government's achievement of its energy-related macro-level objectives. By expanding access to appropriate formal financial services, financial inclusion plays a much-needed intermediating role in the economy. Thus, by looking at countries' financial inclusion realities, energy stakeholders can explore the potential or limitations that countries face in terms of leveraging people's money as an enabler of access to energy. However, it is important to remember that financial inclusion in itself is not access to energy; it can simply facilitate (if applied correctly) household access to energy. For instance, access to payment services does not guarantee access to energy; rather, it is a service/functionality that can be used to access energy under the right conditions.

THE FINANCING OPTIONS FOR ENERGY CAN ALSO BE EXPLORED FROM A *CHANNEL* PERSPECTIVE, BASED ON THE REALITIES OF CONSUMERS VERSUS THE EXISTING FINANCIAL SERVICES PROVIDER LANDSCAPE AND FOCUS.

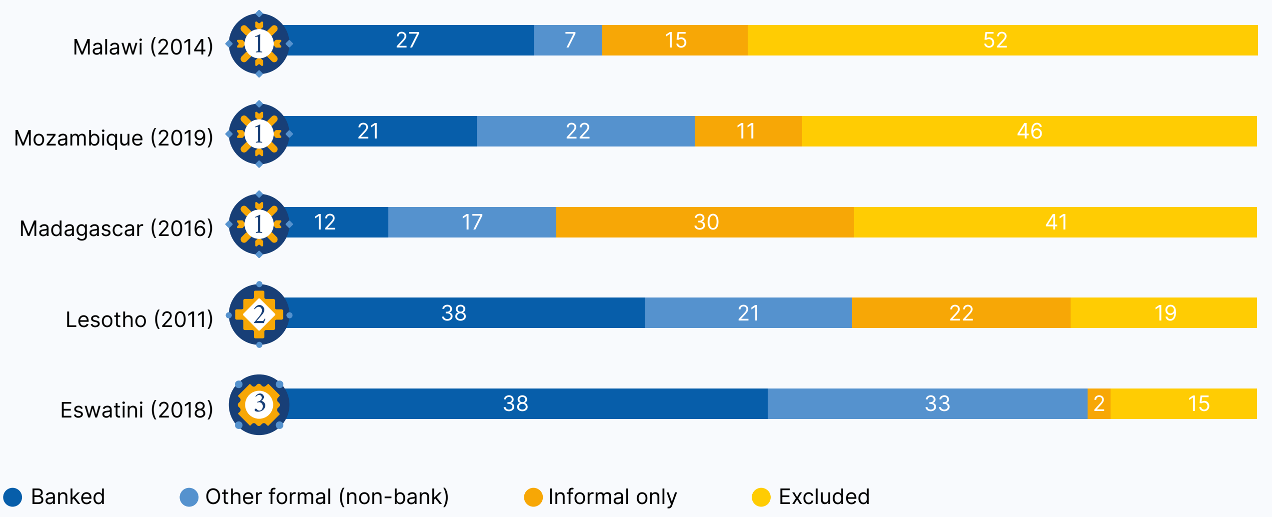
For instance, mobile payments can make purchasing electricity more convenient. But for equipment costs, which can be larger, channels such as banks or non-bank financial institutions are perhaps more suitable formal options for clean energy credit financing. The range of financing mechanisms includes:

- **CASH SALES:** consumers purchase with cash or on short-term credit through retailers.
- **LOANS:** financial institutions provide credit for consumers to buy clean energy products.
- **FEE-FOR-SERVICE:** instead of investing in electricity systems, consumers purchase electricity services from providers operating an off-grid solution such as a mini-grid.
- **PAY-AS-YOU-GO (PAYGO):** these instalment-based payments allow consumers to purchase clean energy systems on credit and then purchase electricity for them via mobile money as they use them.

Across countries, access to financial services increases from Cluster 1 to Cluster 3. However, the composition of financial services used differs substantially between countries, and reliance on formal financial services does not simply increase concomitantly with increases in GDP per capita, especially in the Cluster 1 countries. In other words, although more people might be using financial services as countries develop, they do not necessarily use *formal* financial services more – at least not in the Cluster 1 countries (see Figure 11). Rather, there is a substantial overlap between people who use different types of formal financial services, and also between those who use both formal financial services and informal (e.g. moneylenders, savings groups). That is to say, people rely on a variety of financial services to meet their needs, often largely based on their income variability and affordability at that juncture.

In addition, from Cluster 1 to Cluster 3 countries there is generally an increase in access to both 'other formal' financial services (e.g. from MFIs) and informal financial services usage, with Cluster 2 and 3 countries having the highest access to both other formal and informal financial services (see Figure 12).

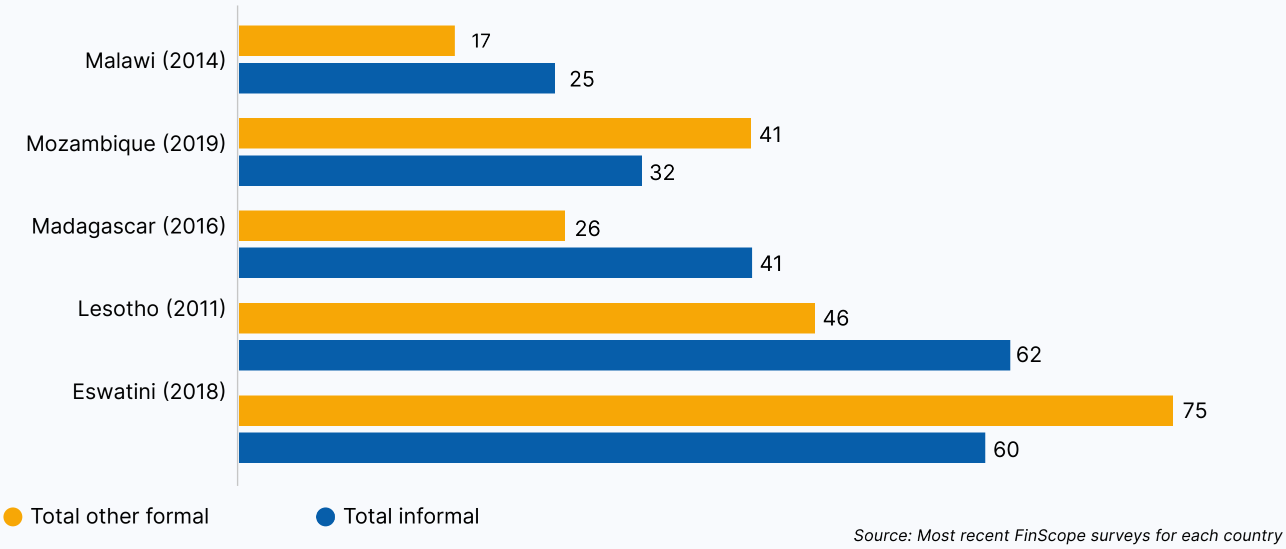
FIGURE 11
Financial access strand by country and cluster (% of adults)



Note: Malawi's figures total 101% due to rounding of decimals.
Source: Most recent FinScope survey for each country

FIGURE 12

Total access to other formal and informal financial products, by country (% of adults)



Source: Most recent FinScope surveys for each country

Given the high reliance on informal financial services, it is not surprising that in Cluster 1 and 2 countries, a large portion of the population are financially excluded; that is, they simply do not have financial access at all – other than assistance and loans from family and friends and saving at home (both not shown on Figure 12).

Across the five countries, formal financial services provision is dominated by a highly concentrated banking sector, where a small number of banks usually have the majority of market share. However, banks tend to have limited infrastructure and reach, and although access to banking is broader in the more lucrative salaried employee market, generally access to bank credit remains highly restricted.

THUS, KEY FOR THE ENERGY FINANCING AGENDA IS BRINGING TOGETHER DIFFERENT MARKET ACTORS THAT, TOGETHER, WILL BE ABLE TO OFFER AN ARRAY OF FINANCING OPTIONS: TO MEET THE VARIED NEEDS OF CONSUMERS IN A GEOGRAPHIC AREA AS WELL AS TO MEET THE NEED FOR BROADER FINANCING INVESTMENTS FOR CLEAN ENERGY IN LOW-INCOME SEGMENTS.

If one considers again the example of telecoms operators in the 1990s, financing partners ranged from large banks for funding the network capital expenditure rollout, to retail players providing phone financing, and agents selling airtime. Each of these market development/financing focus areas needed different financing options and partners, ranging from multinational banks to mass market channel providers (e.g. both retailers and local market sellers), in order to grow a national market on a scale that could meet the needs of a wide range of consumers in different segments. In other words, what was needed was a policy, business and financing framework that was flexible enough to accommodate participation by multiple partners and was aimed at enabling access to consumers across all segments of the income spectrum; the objective was to be able to match consumer profiles and the businesses that could serve these consumers.

What financial services do low-income consumers need the most in order to access energy?

In the five study countries, current access to financial services, particularly to formal financial services, is mostly driven by uptake of payments and remittance products, with very low levels of formal access to savings, credit and insurance products. For instance, in Malawi, 72% of the population has no access to any source of credit, while in Mozambique, this is 93%.

Nevertheless, when it comes to energy provision, it is often formal credit that is of the most interest in terms of potentially increasing energy inclusion. (That said, payments services can also play a role in unlocking access to energy.)

It would make sense to consider different payment and financing options for the *upfront cost* to consumers (the equipment, connection cost to infrastructure, solar panels etc.) and the cost of *ongoing usage* (whether on a daily/weekly/monthly basis), as these two payments can differ substantially in size and nature. For upfront costs, loans or a financial instrument may be required, while ongoing usage could potentially be financed from household cash flow if priced affordably. Thus, looking at different financing options for households within the context of financial inclusion becomes important.

UNDERSTANDING THE CREDIT GAP. In the five countries studied, the two main components of the credit gap – the gap between the current supply of credit to consumers (households or businesses) and the estimated demand for credit from the same – are a high proportion of low-income population groups and a weak credit culture. Additional contributing factors to the credit gap are weak credit infrastructure (coupled with the absence of a proper functioning and comprehensive national ID system), which only covers a minority of the population, and high interest rates, particularly for the non-bank sector. Neither banks nor MFIs currently offer the kind of credit that low-income consumers would need in order to increase their access to energy; this is despite the fact that new technology options and the improved availability of payment histories and profiles provide a sound basis for informed decisions on credit provisioning, allowing for better risk management. While banks do not come close to serving the low-income, particularly when it comes to credit provision, MFIs too are not solving the problem, even where they have an explicit mandate to serve rural or poor people.

Beyond the fact that credit availability is limited for low-income population groups, there are also limited examples of financial service providers having loan products explicitly aimed at financing energy or clean energy products.

COMING TO GRIPS WITH PAYMENTS MECHANISMS. It is also helpful to consider payments mechanisms that can play a role in facilitating access to energy. The use of cash, rather than other forms of payment, is still pervasive across all five of the countries. (The exception is remittance payments, which are more likely to happen through formal payment channels.) Currently, people who use electricity are likely to use cash as a payment option because cash is specifically favoured for bill payments and also because just in general people across the five countries still prefer cash. However, payment solutions that in any way lower households' costs for energy access would make a significant difference to low-income households and would likely be of interest.

PAYGO or prepaid mobile options are likely to be viable options, based on consumer preferences, and this also mirrors the telecoms industry business model. The use of mobile payments can also make purchasing electricity more convenient (including enabling consumers to avoid the opportunity cost of travelling to a specific location to make a payment).

In other words, mobile money offers solutions. But it is dependent on both the level of mobile phone ownership and network coverage (as a minimum – although other factors become significant once these are pervasive).

Although both mobile phone penetration and network coverage are substantial (even in the Cluster 1 countries), the environment for mobile money is still uneven. For instance, in countries such as Malawi, Mozambique and Madagascar, substantial portions of the population do not yet own or use a mobile phone (70%, 48% and 65%, respectively). Where mobile phones are used, many people still use 2G phones, although 3G has increased in recent years. And in terms of coverage, although it is good in urban areas, it is patchy or sometimes non-existent in remote rural areas. However, both network coverage and mobile phone penetration are much higher in Lesotho and Eswatini than in the other countries, covering closer to the entire population (coverage above 90%, and penetration 80% and 86%).

In addition, the ability to continuously use and access mobile phones in low-resource settings is often dependent on the availability and/or cost of electricity to charge the device. So the population segments that could most benefit from mobile payment solutions are also precisely the ones that struggle with access to energy to do so. Even where energy is available, consumers often have to pay to charge their devices with shops and/or neighbours.

FIVE-COUNTRY STUDY FINDINGS

Although mobile money solutions are available in all five markets, uptake is much lower than actual mobile phone penetration or ownership. For instance, in Madagascar, FinScope (2016) suggests that approximately 69% of adults have heard of mobile money, but only 13% are current users of mobile money solutions.

There are, nonetheless, some encouraging signs. The rapid adoption of mobile money across some of the study countries indicates a need for cheap, safe payment solutions with good distributional reach:

- Although Lesotho's economy remains highly cash based, in the two years after the introduction of mobile money solutions, nearly 450,000 of the country's adults had subscribed to one of the two services available.
- In Malawi, mobile money account ownership increased from 2% of the population in 2014 to 10% in 2015.
- In Mozambique, FinScope (2019) finds that 55% of those who have a mobile phone also have a mobile money account.
- Although use of mobile money was still limited in Madagascar in 2017 (at 13%), it is developing rapidly and there are four different providers. While mobile phone ownership levels are generally low (35%), access is much higher: 75%.
- Eswatini has very high levels of mobile phone penetration (86%) and network coverage, and use of mobile money services is also very widespread. According to the Central Bank of Eswatini (2018), approximately 92% of the country's adults have active mobile money accounts.

Who are the various current players in the market and what is their potential to serve consumers?

MFIS – PROVISION OF CREDIT. MFIs are available in all of the five study countries, although the level of market development differs. MFIs tend to have better reach than banks into the low-income market segments, and play a key role in promoting financial inclusion, especially in rural areas. Yet they do have their limits in terms of reach; and their business case – microfinance portfolios, especially ones that contain loans to lower-income or unemployed people – is risky and unappealing to for-profit financial institutions.

MFIs typically benefit from grants and investments from international finance institutions and governments in an attempt to make their lending business more sustainable or to increase the incentive for them to provide loans to specific groups. However, MFIs increasingly have sustainability considerations, ranging from a minimum of capital protection to full commercial profitability. Larger MFIs, in particular, more and more view their loan business through a commercial lens, meaning that, for such MFIs, provision of credit is primarily limited to salaried employees, while the provision of credit to low-income people and non-salaried entrepreneurs falls to those credit institutions subsidised by donors or government grants to lower the risk.

MOBILE MONEY PROVIDERS – PROVISION OF PAYMENT SERVICES. While mobile money is playing an increasing role in countries like Eswatini and Lesotho, and offers new ways to extend the reach of financial services, the emphasis is on *payments services*, with limited application beyond payments.

INFORMAL PROVIDERS, AND FAMILY AND FRIENDS – PROVISION OF CREDIT. The financial services sector is segregated heavily by income and location: extremely poor, rural people tend to be fully financially excluded or rely mostly on family and friends, or informal options. Many informal moneylenders exist, as well as informal savings groups that serve a large proportion of the population; that is to say, in the five study countries, credit is most often obtained from informal sources, or from family and friends. Yet even these sources are used to a limited degree.

MSME' profiles of access to financial services

In the five study countries, for the majority of MSMEs the same financial inclusion approach can be applied as when targeting the support and improvement of livelihoods for households. This is because most of the MSME owners rely on a range of their personal financial mechanisms to meet their business needs; in addition to drawing on personal savings, MSME owners obtain loans in their personal capacity, using their personal collateral to fund sunk costs and operating expenses. In other words, in these countries, there is a fundamental interconnectedness of business and personal financial services; younger, informal and smaller MSMEs, in particular, rely on these to fund business operations or investment.

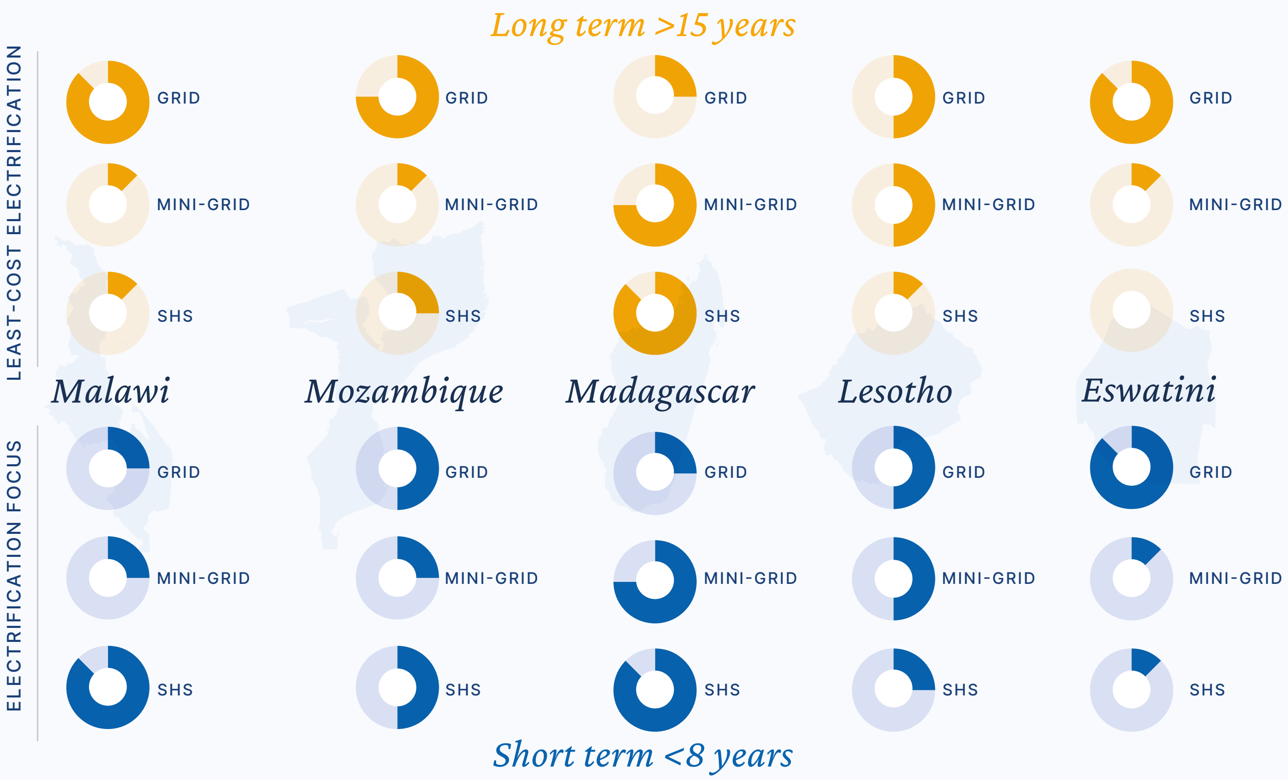
What is more, the financial services market has typically struggled to serve MSMEs, even those that are clearly high potential and high impact. Existing financing models – small business credit markets and banks alike – are for the most part incompatible with the smaller-scale credit needs of MSMEs. It is also expensive for MSMEs and funders to find each other. Diversifying financial products to service MSMEs, particularly 'missing middle' SMEs (high-impact/high-potential enterprises that are too big to benefit from MFI loans but too small to be eligible for bank credit), is an important element of the structural transformation of developing economies, and important too in widening energy access for MSMEs. (For more on missing middle SMEs, see the UNCDF MAP SME Investor Toolkit.)

ANALYSE THE LOW-INCOME *energy market*

While the first 'pillar' that supports ascertaining the clean energy investment case is collecting energy market data, the second is analysing the low-income energy market in particular.

The options to be included in this exercise need to include grid electrification, mini-grid electrification, and SHS, as well as alternatives for improved and/or clean energy cooking. An important part of the analysis at this point, as becomes clear in the discussion below, is to ascertain the likely limits of least-cost electrification in a country and to identify the resulting market that will *not* be served by grid electricity over the short or medium term but could be served by off-grid alternatives – in other words, the section of the population who fall into the *estimated future electricity access deficit*. Specific categories of clean, off-grid energy solutions can then be assessed in terms of current potential demand as well as affordability, all of which informs the investment case for clean, off-grid solutions.

FIGURE 13
Long-term, least-cost electrification options vs short-term focus, by country



Source: Nova Economics (2019), based on World Bank and country master plans

Ascertaining a country's long-term, least-cost vs short-term electrification options

In each of the five study countries, the options for least-cost electrification have been assessed by donors and/or government. Given country-specific constraints and resulting trade-offs, these least-cost options assume a minimum time horizon of 15 years and thus the least-cost electrification options can also be classified as *long term*. At the same time, countries are balancing the current rate of electrification in each country in relation to the pressing need to make progress on meeting the 2030 deadline for the SDGs; countries therefore also identify short-term electrification objectives to cover the period up to a maximum of the next eight years, which for each country might be different from the long-term, least-cost electrification options (see Figure 13).

FIVE-COUNTRY STUDY FINDINGS

Extending the electricity grid appears to be the long-term, least-cost electrification option in all of the countries except Madagascar over the longer term (more than 15 years):

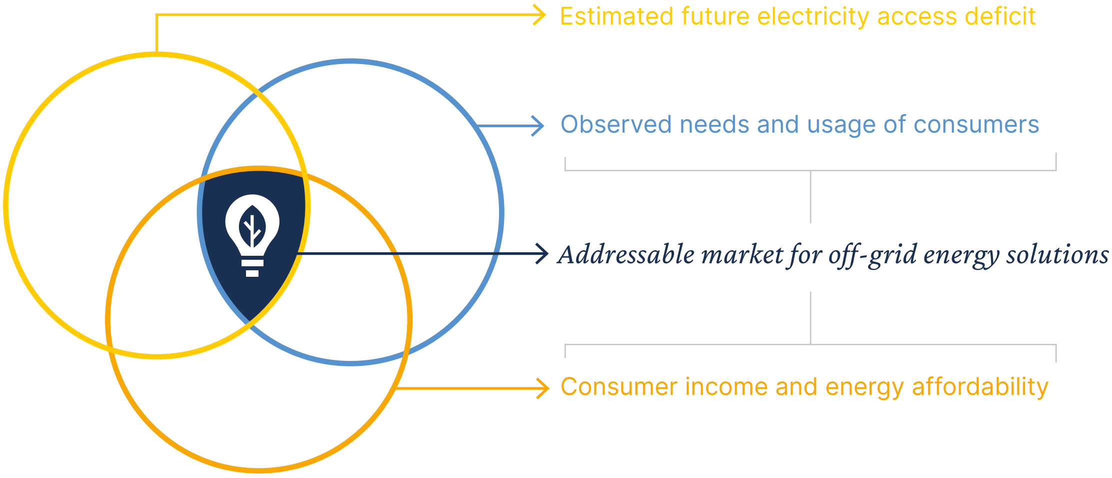
- In Madagascar, the long-term, least-cost electrification option seems to be mini-grids and SHS.

In all five countries, in the short term, SHS, and by extension pico-solar products, can play a larger role. And in all four countries where grid electrification is the long-term, least-cost option, both mini-grids and SHS still have a role to play in both the short and long term:

- Lesotho offers opportunities particularly for the use of mini-grids, which make sense for over a third of the population: those located in more remote and mountainous terrain.
- In Eswatini, too, mini-grids are being considered for geographically isolated rural communities.
- In Mozambique, where higher levels of grid electrification will take many years to achieve, 25% of the population could benefit from mini-grids and SHS.
- In Malawi, even though only 5% of the population live more than 10 km from the grid, many will wait longer than 10 years to be connected due to the slow rate of electrification given the low GDP per capita of the country; thus, both mini-grids and SHS (and particularly pico-solar options) should be considered.

Mini-grids' application to date indicates that while they are suitable for households in some instances, as set out above, they are also suitable for niche markets, including that of MSMEs. In other words, mini-grids could provide energy solutions in the two different 'locales of energy access' of households and MSMEs.

FIGURE 14
Factors influencing the addressable market for off-grid energy solutions



UNDERSTANDING THE THREE FACTORS THAT WILL INFLUENCE THE MARKET FOR OFF-GRID ALTERNATIVES. Given the options for long-term, least-cost electrification and the resulting market that can be served by off-grid alternatives (i.e. will not be served by grid electricity over the short or medium term), there are three factors influencing the future addressable market for off-grid (see Figure 14):

- **THE ESTIMATED FUTURE ELECTRICITY ACCESS DEFICIT:** no matter the least-cost option, if future supply is not projected to meet future demand there will be an electricity access deficit, and off-grid alternatives can therefore be considered for this market.
- **THE OBSERVED NEEDS AND USAGE OF CONSUMERS:** the MAP analysis shows that most people in the five study countries who have access to electricity do not use it for cooking, and rather rely on alternative sources of energy for cooking; this is largely influenced by the third factor: affordability.
- **AFFORDABILITY TO CONSUMERS:** we cannot assume that the entire electricity access deficit can be served by off-grid alternatives, because, similar to the case of grid electricity, people will only use energy products they can afford.

IT IS THEREFORE NECESSARY TO UNDERSTAND EACH OF THESE THREE FACTORS BEFORE PRONOUNCING ON THE ADDRESSABLE MARKET FOR OFF-GRID ENERGY SOLUTIONS.

Estimate the electricity access deficit

*The **levels of electricity access required for countries to meet SDG 7** can be estimated by assuming that governments will be able to continue with electrification at the same rate as what they have historically achieved and then, based on this forecasting, calculating what the access deficit would be in 2030.*

This should be done on a sub-national level, by considering rural and urban levels of electrification and therefore deficits, and aggregating these figures to a national level. To do this, firstly, it is necessary to establish the period over which the projection will be done by stipulating a future date (in this example, 2030). If we look at Table 5, the additional steps required in this calculation are as follows:

A: For the projection calculation it is also necessary to know the absolute population size (disaggregated by urban and rural) during past periods. In this example, three years were used: 2007, 2012 and 2017. Then countries' current population growth rates[16] are used to estimate their future absolute population size (projected absolute population size in 2030, in this example).

B: For these years, the electricity access levels for a country's urban and rural areas respectively can be used for the historic years included. The electricity access level for the projected future date can be calculated (if required), once the steps below are completed (taking the projected absolute population size with access to electricity in line C, divided by the calculated absolute projected population size in line A).

C: The absolute population size with access to electricity would be known for the three historic years, or can be calculated by applying the percentage in line B to the absolute number in line A. The method followed in our methodology to calculate the absolute number of people who are projected to have access to electricity in 2030 is explained below.

D: The absolute increase in the number of people who gained access to electricity over each historic period (2007 to 2012, and 2012 to 2017) can be calculated by subtracting the absolute population size with access to electricity in consecutive periods (in line C) from each other.

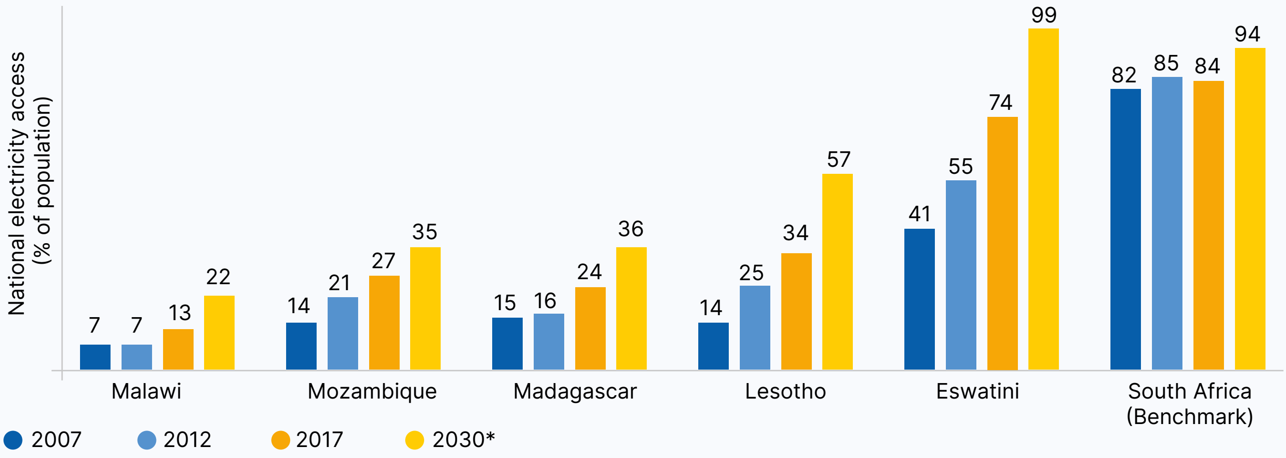
Once these absolute increases have been calculated, the highest annual average achieved between each of the two periods can be used to apply to the future projection: the average number of people who will gain access to electricity every year over the projection period (2017 to 2030). Using the highest average allows some leeway for the multitude of factors that could impact the pace of electrification (see Table 5).

TABLE 5
Methodology for calculating projected electricity access levels

	2007	2012	2017	2030 (PROJECTED)
A: Absolute population size (urban and rural)				
B: Level of access to electricity (urban and rural)				
C: Absolute population size with access to electricity			1	4
D: Absolute increase in population size with access to electricity over period		2	3	

1+highest of (2 or 3) = 4

FIGURE 15
Electricity access levels by country



** Projected access levels assume no significant grid defection or loss of grid connections (due to natural disasters, for example).*
Source: Nova Economics (2019) analysis based on electricity access rates from the UN Statistics Division

Once the *absolute population size with access to electricity at the future date* has been projected, the *level of access* to electricity at the future date can be calculated (see Figure 15), and hence the *electricity access deficits* can also be calculated against a specific access-to-electricity goal (100% under the SDGs). These calculations take into account population growth but assumes no significant reductions in the number of people connected to the grid due to factors such as natural disasters, for example.

The *projected nominal electricity access deficit* – in other words, the absolute number of people who it is calculated will be without electricity access in the year of projection (2030) – is known from this calculation (being number 4 in Table 5) but can also be recalculated by subtracting the projected number of people with electricity access from the estimated 2030 population.

We can then calculate the *annual average nominal change in electrification* that would be required in order to meet SDG 7 by 2030, by dividing the absolute number of people in a country's projected electricity access deficit by the number of years in the projection period (see Table 6).

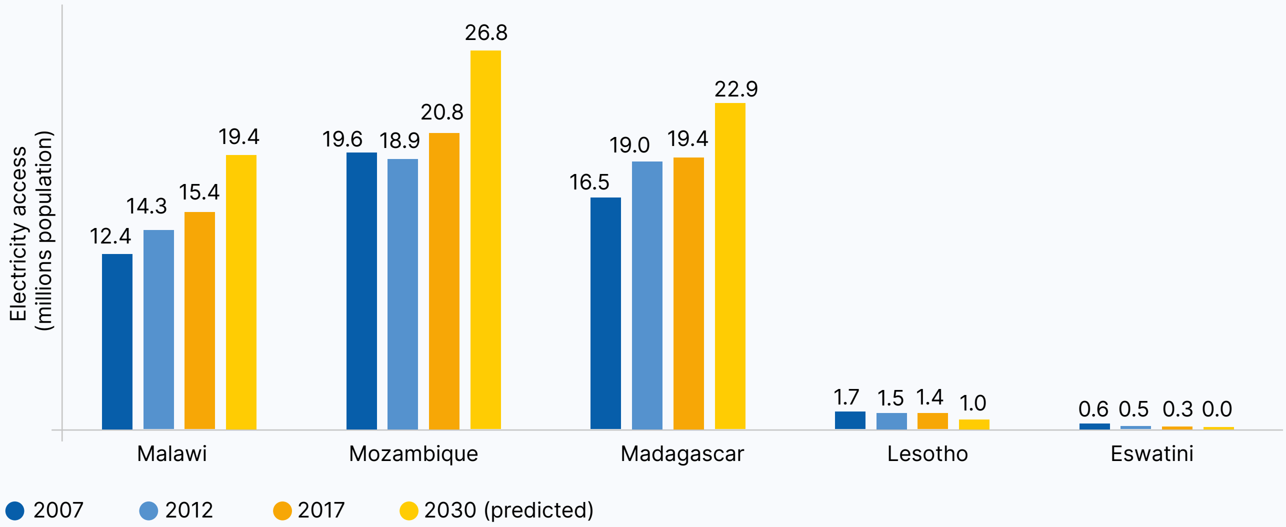
TABLE 6
Nominal change in electrification required to meet SDG 7 (annual average), by country

	MALAWI	MOZAMBIQUE	MADAGASCAR	LESOTHO	ESWATINI
Nominal change in electrification required (number of additional people per year)					
Urban	262,354	809,383	887,910	35,308	9,705
Rural	1,467,677	1,775,612	1,376,464	91,033	28,808
*Multiple of historic changes in the nominal rate of electrification **					
Urban	1.6	1.7	1.6	1.6	1.1
Rural	3.2	46.5	22.3	3.2	0.9

** Required nominal change in electrification (historic change in the nominal rate of electrificationper year plus nominal change in electrification required, divided by historic change in the nominal rate of electrification per year)*
Source: Nova Economics (2019) analysis

FIGURE 16

Electricity access deficit, in millions of the population



Source: Nova Economics (2019) analysis based on data sourced from the World Bank Development Indicators database

As a measure of the *additional effort required* to increase the nominal rate in electrification by the 2030 deadline, the nominal change in electrification that will be required can be calculated as a multiple of historic changes in the nominal rate of electrification (i.e. the historic change in the nominal rate of electrification per year plus the nominal change in electrification required, divided by the historic change in the nominal rate of electrification per year).

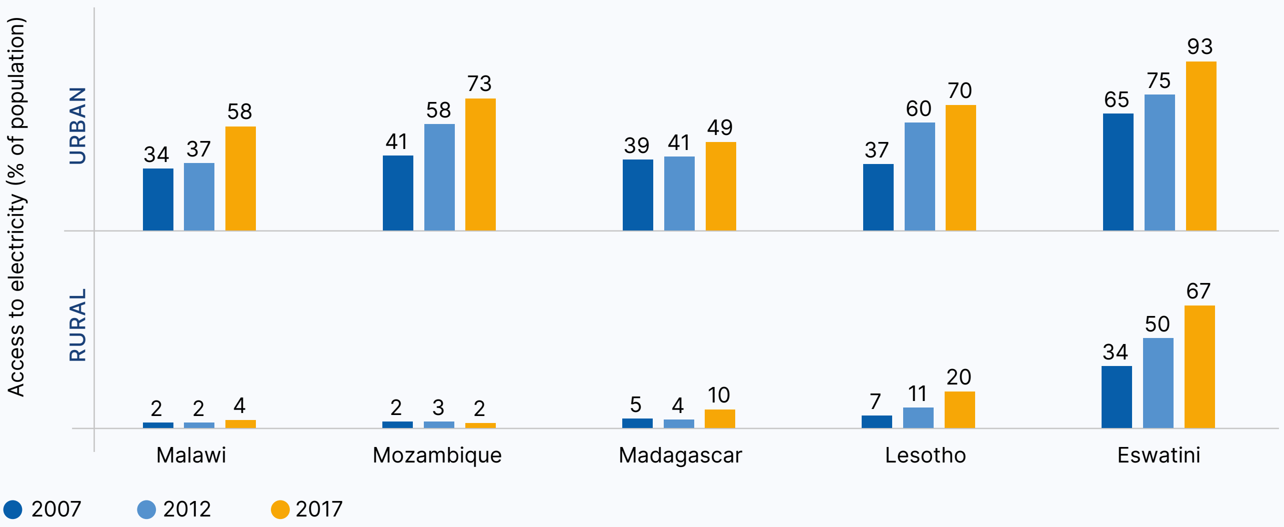
Based on these calculations and projections, it is clear that there are vast differences in the rate of acceleration of electrification required between countries (as evident in Table 6):

- Eswatini, for example, only needs to increase the rate of electrification slightly (by a factor of 1.1) to achieve SDG 7 for the *urban* population; and at the current pace of electrification, rural areas will reach universal access before 2030.
- Mozambique, by contrast, to achieve SDG 7 for its *rural* population, must accelerate rural electrification from an annual average of roughly 38,000 people (achieved between 2007 and 2012) to nearly 1.8 million every year (between 2017 and 2030): a 46.5-fold increase.

DESPITE INCREASED RATE OF ELECTRIFICATION, ELECTRICITY ACCESS DEFICIT IN ALL FIVE COUNTRIES IS INCREASING. Although all of the five countries increased their *rate* of electrification over the 10-year period of 2007 to 2017, in the three Cluster 1 countries the *number* of people who do not have access to electricity – i.e. the nominal electricity access deficit, in millions of the population – has actually increased (by over 7 million), due to population growth (see Figure 16). And, based on the predicted 2030 access rates, this trend is only set to accelerate up to 2030. By then, the nominal electricity access deficit will have grown by an additional 13.5 million people, meaning almost 70 million people in these three countries will not have access to electricity (an increase of 40% since 2007). Thus, despite projected electricity deficit levels falling from 74% to 69% over the same period, this is still far off the 2030 goals. This is the crisis in these countries: that energy access is increasing – but just not fast enough.

In all five of the countries, regardless of the overall levels of access to grid electricity, access levels in rural areas are substantially lower than in urban areas (see Figure 17).

FIGURE 17
Access to electricity, as percentage of urban and rural populations



Source: World Bank Development Indicators 2019

Although this was also the case as far back as 2007, access to electricity in urban areas increased dramatically over the 10-year period to 2017, with most countries achieving an increase in access of between 45% (Eswatini) and 89% (Lesotho). As a result, urban access levels of around 60% and higher are now seen in four of the countries. The exception is Madagascar, where access levels are still low: in 2017, the rural access level was 10%, while the urban access level was at 49%, with the growth in the level of access in urban areas over the 10-year period to 2017 being only 26%.

2030 ENERGY ACCESS GOALS ACHIEVEMENT WILL BE PARTIAL, AND DIFFER BY COUNTRY AND BY URBAN/RURAL. Based on current trends, it is not inconceivable that four of the five countries could be able to achieve close to universal energy access in *urban* areas by 2030.

Despite the improvements in urban areas, it is perhaps more encouraging that increases in electricity access levels in rural areas have matched or exceeded those in urban areas in all but one country. Other than Mozambique (where rural electricity access rates stagnated between 2007 and 2017), countries managed to expand their rural access levels either on a par with urban areas (in the case of Malawi) or faster than the rate of expansion in urban areas. However, given the very low levels of electricity access to start with in rural areas, a vast urban–rural divide still exists.

IN ALL FIVE OF THE COUNTRIES EXCEPT PERHAPS ESWATINI, *UNIVERSAL* ACCESS BY 2030 IS NOT ACHIEVABLE BASED ON CURRENT TRENDS.

The FinScope data at country level provides a more detailed geographical analysis of access at the provincial, district and sub-district levels (categories vary by country). This allows for exposition of electricity access in granular detail, which is valuable for informing any effort to expand the reach of distribution infrastructure. It is possible to clearly discern districts where electricity access is either non-existent or much lower than the norm for the provincial and national levels.

Understand the consumer profile of energy needs and usage

Despite the large deficits in access to electricity noted in terms of country, geographic location and demographic groups, people find ways to meet their energy needs. These ways obviously differ according to households' particular energy needs, preferences and constraints; what the energy is used for at a household level (e.g. cooking, lighting, space heating and cooling, powering various appliances, and charging mobile devices), and the availability and affordability of alternative sources of energy.

IMPORTANT TO UNDERSTAND HOUSEHOLDS' CHOICE OF ENERGY SOURCES. From nationally representative demand-side surveys, the MAP study gained insights into low-income households' energy needs and the mechanisms they have available and use to satisfy those needs; this informs the business case for various types of energy provision, including expanding access to grid-supplied electricity.

Table 7 provides an overview of which energy services can be accessed by households/MSMEs at each tier of the ESMAP/SEforAll multi-tier framework, and which of the services could be met using modern fuels and/or solid fuels (in addition to electricity). While modern fuels (e.g. LPG, ethanol, paraffin) and solid fuels (coal, biomass) can often be used instead of electricity for cooking, heating and lighting, access to electricity is required for most other energy services (including services more applicable to productive uses, such as 'mechanical loads' and 'product heating'). However, as a result of the much lower electricity access levels in rural areas compared to urban, the reliance on less efficient, less safe and/or traditional unclean energy sources for things like lighting and cooking is much higher in rural areas.

TABLE 7
Access to energy services, by source of energy and ESMAP/SEforAll tier

	ELECTRICITY						MODERN FUELS	SOLID FUELS
ENERGY SERVICES	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5		
Lighting		✓	✓	✓	✓	✓	✓	✓
Entertainment and communication		✓	✓	✓	✓	✓		
Space heating and cooling			✓	✓	✓	✓	✓	✓
Refrigeration				✓	✓	✓		
Mechanical loads				✓	✓	✓	✓	
Product heating					✓	✓	✓	✓
Cooking				✓	✓	✓	✓	✓

Source: Nova Economics analysis (2019) based on Bhatia & Angelou (2015)

AFFORDABILITY A BIG FACTOR FOR DIFFERENT ACTIVITIES IN THE HOME. Even where people have access to electricity, its lack of affordability can cause people to opt for alternatives for higher-intensity energy activities such as cooking or heating. Not only do low-income people purchase less electricity than those who are not poor, but they are also more likely to use electricity alternatives such as modern fuels or biomass; in most cases, especially in rural areas, for cooking and heating people can obtain firewood for free, or use charcoal (a costlier option). For lighting, candles and paraffin lamps are more affordable alternatives to electricity.

LESS COSTLY ALTERNATIVES TO ELECTRICITY OFTEN FAVOURED FOR HIGHER-ENERGY USES. Provided they have access to electricity, even the poor are more likely to use electricity than other energy sources for low-energy purposes such as lighting or charging a phone. For higher-energy activities such as cooking or space heating, though, the poor (and even higher-income households) are more likely to use more affordable alternatives.

Lighting

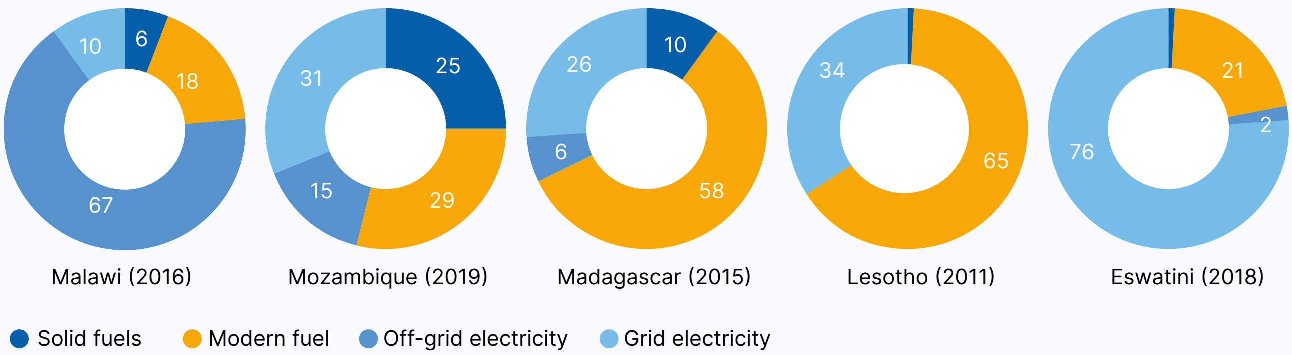
ACROSS THE FIVE COUNTRIES, MOST PEOPLE NEED TO RELY ON ELECTRICITY ALTERNATIVES FOR LIGHTING. In most of the five countries, the proportion of the population who use electricity for lighting is close to the proportion of the population who have access to electricity. But, considering the low levels of access to electricity in most of the countries, when it comes to lighting at least two-thirds of the population in most cases must rely on alternatives to electricity.

AS ELECTRICITY ACCESS INCREASES, RELIANCE ON SOLID FUELS AND OFF-GRID ELECTRICITY FOR LIGHTING DECREASES. This is another clear trend in energy use for lighting across the five countries. The Cluster 1 countries, in particular, are still highly reliant on solid fuels and off-grid electricity for lighting. In Malawi, many people use battery-powered torches as their primary light source, while home generators and solar power are also used in the three countries. Worth noting is that solar power is the most likely choice for lighting in these countries: used by as many as 10% in Mozambique, and 6% in Madagascar.

However, Cluster 2 (Lesotho) and Cluster 3 (Eswatini) countries have low levels of reliance on solid fuels and off-grid electricity for lighting. Instead, countries with higher GDP (which also includes the Cluster 1 country Madagascar) seem to switch from an initial reliance on solid fuels or off-grid solutions, to increasingly using products that rely on or incorporate modern fuels for lighting: paraffin, candles, oil lamps, torches and lanterns. This trend continues for Cluster 2 countries, up to a point where electricity access become sufficiently high for the majority of people to rely on grid electricity for their lighting needs (as is the case in Eswatini).

ACROSS ALL FIVE COUNTRIES, MODERN FUELS AND ELECTRICITY LIKELY TO REPLACE SOLID FUELS FOR LIGHTING. Compared to cooking, which requires relatively high levels of energy (thus, higher quality and cost of energy service), lighting requires much less energy. This means for lighting it is more affordable (than for cooking) for a household to adopt modern fuels or use grid electricity. Additional factors

FIGURE 18
Primary use of particular energy sources for lighting, by country (% of adults)



Source: Most recent FinScope surveys for each country (date noted on graph).

that could act as an incentive include that lighting from modern fuels and grid electricity is far safer, more reliable, higher quality (including brighter), and less messy than lighting provided by solid fuels, and saves households the time and effort required for collecting (in the case of biomass).

In addition to the differences across countries in terms of energy sources for lighting, there are differences within countries, linked to geographic location, demographics and livelihoods.

MOST PEOPLE IN URBAN AREAS USE GRID ELECTRICITY FOR LIGHTING. The largest driver of difference is again geography; access to electricity in urban areas is higher. By far the majority of people in urban areas, across all of the five countries, rely on grid electricity for lighting and, consequently, they rely less on all three other sources (solid fuels, modern fuels, off-grid electricity).

URBAN HOUSEHOLDS LACKING ELECTRICITY ACCESS SEEM TO FAVOUR MODERN FUELS FOR LIGHTING. In cases where urban households do not have access to electricity, they seem to substitute with modern fuels rather than with off-grid solutions or solid fuels, perhaps partly owing to the fact that urban households have higher levels of income, which makes modern fuels more affordable than they would be for other households. (Practically, too, gathering free solid fuel in the form of biomass would be less of an option for most urban dwellers.)

SEVERAL OTHER DEMOGRAPHIC FACTORS ARE LIKELY TO CORRELATE WITH INCREASED ACCESS TO ELECTRICITY AND WITH THE LIKELIHOOD OF HOUSEHOLDS OPTING TO USE MODERN FUELS RATHER THAN OFF-GRID AND SOLID FUELS FOR LIGHTING: HIGHER INCOMES, MORE STABLE INCOME SOURCES, AND HIGHER LEVELS OF EDUCATION.

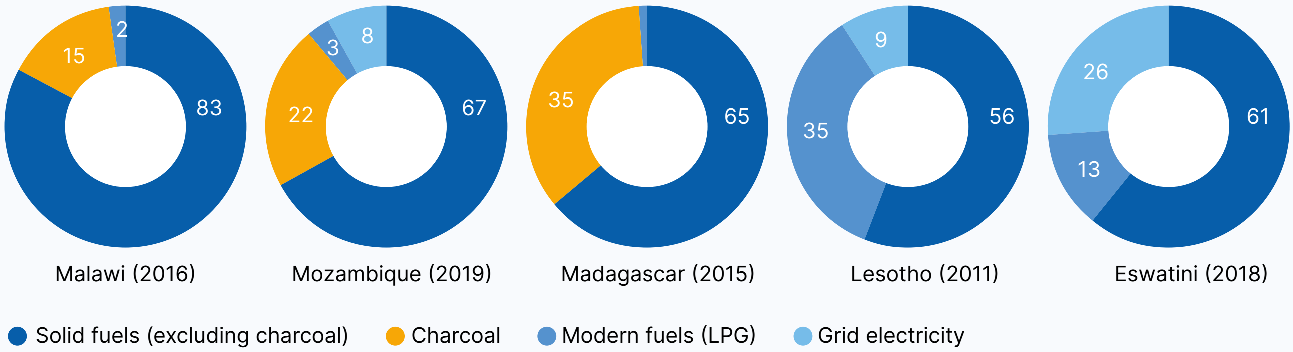
Cooking

Whereas electricity is much more likely to be used as an energy source for lighting where people do have electricity access, very few people in the five countries who have access to electricity use it for cooking. Compared to lighting, cooking requires more energy; according to the World Energy Council, poor households consume nine times more energy for cooking than for lighting.[17] It is probably not surprising, therefore, that low-income people's choices regarding energy sources for cooking are very different from those for lighting.

FOR COOKING, MOST PEOPLE RELY ON SOLID FUELS LIKE COAL AND FIREWOOD. Even in Eswatini, where 74% of the population have access to electricity, only 26% report using electricity for cooking. And in countries like Malawi and Madagascar, almost no one uses electricity for cooking. Instead, most people continue to rely on solid fuels such as coal and biomass – and particularly firewood – for cooking in all five countries: around 90% or more of people in the Cluster 1 countries, and more than half of people in the Cluster 2 and 3 countries.

BIOMASS POPULARITY EXPLAINED BY AVAILABILITY, ACCESSIBILITY AND AFFORDABILITY. The demand and preference for biomass for cooking, whether in a cookstove or over an open fire, can be attributed to its availability, accessibility and the fact that it is usually inexpensive, if not free, in rural areas (save for the opportunity cost of time spent gathering firewood or animal dung from nature – which, however, is relatively low, given people's limited earning potential).

FIGURE 19
Primary use of particular energy sources for cooking, by country (% of adults)



Note: Solid fuels category for Eswatini might include charcoal, as it is not asked for specifically.
Source: Most recent FinScope survey for each country (date noted on graph)

RELIANCE ON CHARCOAL AND COAL HAS SOME DISADVANTAGES COMPARED TO FIREWOOD. While the finding is that most people use solid fuels for cooking, not all solid fuels are inexpensive or free; some forms of solid fuel, such as coal and charcoal, can mostly only be obtained by spending money. Furthermore, people in urban settings have a harder time collecting free biomass from nature. Finally, the burden of gathering biomass falls largely on women and girls, affecting their availability to engage in income-generating activity for the household.

RELIANCE ON ELECTRICITY OR MODERN FUELS FOR COOKING SEEMS TO CORRELATE WITH HIGHER GDP PER CAPITA. There seems to be some increase in the use of either grid electricity or modern fuels (mostly LPG) for countries with higher GDP per capita (see Figure 19); this trend is especially observable for the Cluster 2 and 3 countries (Lesotho and Eswatini). The same also holds for urban adults, higher-income groups, groups with more stable income sources, and individuals with higher levels of education.

WHERE PEOPLE CAN AFFORD IT, THEY CHOOSE CHARCOAL RATHER THAN FIREWOOD FOR COOKING. Even though reliance on firewood for cooking is extremely high for Cluster 1 countries, and remains high across the Cluster 2 and 3 countries, as per capita income increases people show substantial preference for charcoal over firewood – especially in the Cluster 1 countries. (Lesotho instead relies largely on LPG, as opposed to charcoal, as a substitute for firewood, while data on the use of charcoal versus firewood is not available for Eswatini.) Similarly, across the five countries, individuals with a higher income, or those who are formally employed, urban, and have higher levels of education, are more likely to use charcoal as a substitute for firewood.

BIOMASS WILL LIKELY REMAIN POPULAR FOR COOKING – MANY ACTIVELY PREFER IT. For the reasons explored above, including how ‘energy-hungry’ household cooking needs are, modern fuels and electricity are much less likely to replace biomass, especially firewood, as the primary source of energy for cooking than for lighting.

Where poor or even lower-middle-income households rely on biomass-fuelled cookstoves for cooking, clearly it would be difficult to persuade them to invest in cleaner or ‘efficient’ cookstoves –cookstoves that use less firewood, or even low-energy *electric* cookstoves – when firewood is free; after all, what significant saving does an ‘efficient’ cookstove then deliver?

Finally, research with stakeholders indicates that a large driver of the active preference for using biomass for cooking may also be the taste: fire-cooked food just tastes better.

In cases where people’s current fuel source for cooking is not free (e.g. charcoal), the business case for clean cookstoves or efficient electric cookstoves is stronger. But even in these cases, a market-led approach is unlikely to generate significant demand; as things stand, general uptake of clean/efficient electric cookstoves in Malawi, Mozambique and Madagascar is very low (in the single-digit percentages) and would be even lower among the low-income population.

Understand the affordability of energy – including clean energy

*While the five study countries have as their high-level objective the achievement of universal access to reliable, safe and good-quality electricity that meets the particular needs of their populations, the business case for electricity provision is strongly underpinned by the **cost of production**.*

The latter is crucial for producers, in relation to the selling price, and ripples through to consumers in the form of affordability in relation to incomes.

In other words, producers need to produce or buy electricity at a price that makes it worth selling, while consumers need to be able to access electricity at a cost that fits their budget. Unfortunately, these two objectives are not easily married, and across countries we find conundrums on both sides; utility companies are not procuring electricity at financially sustainable rates, while consumers struggle to afford already-subsidised electricity. The same issues need to be kept in mind in considering the rollout of mini-grids, SHS, pico-solar products, and improved cookstoves.

Electricity affordability

The ESMAP/SEforAll multi-tier framework measures the affordability of grid electricity by comparing the cost of a standard consumption package (SCP), based on 1 kWh per day (or 365 kWh per year) to a maximum energy expenditure threshold per household. The SCP would, however, only apply to consumers who consume enough electricity to be at least in Tier 3 or higher (as those in the lower tiers consume less than 1 kWh per day). It is important to understand that, at a scant 1 kWh per day, the SCP still only allows for the bare minimum energy usage. For instance, even at the SCP level of usage, very little energy is available for normal use of appliances.

To put this in perspective, Table 8 provides examples of energy usage for different energy usage brackets. At the SCP, a household can use a 2,000 watt (i.e. 2 kW) electric stove (and nothing else) for only 30 minutes a day. This does not leave any energy for lighting, heating/cooling, charging a mobile phone, running a TV or a radio, or any other appliances. Even at twice the SCP, a household can use a 2,000 watt stove for only one hour a day, still only allowing them to cook one meal. At four times the SCP, a household can cook one meal a day, and run a very small fridge to allow food not to spoil. Therefore, while the SCP provides a good measure of the bare minimum usage, and helps to identify those who use even less than

TABLE 8

Examples of energy usage, by energy usage bracket (based on the ESMAP/SEforAll SCP)

ENERGY USAGE BRACKET	EXAMPLE ENERGY USAGE
Nothing	N/A
50% of SCP	Using 2,000 watt cooking stove 15 minutes per day
SCP	Using 2,000 watt cooking stove 30 minutes per day
2 x SCP	Using 2,000 watt cooking stove 1 hour per day
4 x SCP	Using 2,000 watt cooking stove 1 hour per day, and having a 100 watt mini fridge
More than 4 x SCP	Above + other appliances

Source: UNCDF calculated

TABLE 9

Electricity tariffs and cost of SCP, by country (2019)

		MALAWI	MOZAMBIQUE	MADAGASCAR	LESOTHO	ESWATINI
Lifeline	Tariff (local currency/kWh)	47.50	1.07	251.95	0.73	1.65
	Tariff (USD/kWh)	0.06	0.02	0.07	0.04	0.1
	Cost of SCP (USD)	**23.49**	**5.94**	**24.69**	**16.38**	**36.50**
Standard residential	Tariff (local currency/kWh)	67.25	6.63	431.00	1.48	1.75
	Tariff (USD/kWh)	0.09	0.01	0.12	0.09	0.01
	Cost of SCP (USD)	**33.26**	**36.83**	**42.23**	**32.70**	**38.71**

Source: Nova Economics (2019)

this, it is important to understand that very few people in the five-country study buy sufficient energy to operate a more diverse set of electrical appliances.

Electricity tariffs for domestic, single-phase, prepaid supply from the respective electricity utilities in each of the five countries show that all utilities have poverty alleviation or social lifeline tariffs, and the SCP falls completely or partially within the criteria of these reduced tariffs:

- Eswatini's lifeline tariff is based on capacity, not usage (a 20 Amp supply).
- Lesotho and Madagascar allow for slightly less than the SCP in their lifeline tariffs (i.e. some usage up to the SCP is charged at the normal tariff).
- By contrast, the lifeline tariff for Malawi and Mozambique applies to more electricity than is required for the SCP: for instance, in Mozambique, the lifeline tariff applies to the first 100 kWh usage per month, far exceeding the 31 kWh per month usage tier of the SCP.

ALL CONSUMERS BENEFITING SUBSTANTIALLY FROM AN OVERALL SUBSIDISED TARIFF. In other words, given that the majority of electricity users in the five countries fall into Tiers 1 and 2, they would benefit from these reduced tariffs, while even those in Tier 3 and higher benefit from the subsidy on the first 1 kWh per day. In addition, the electricity tariff charged to consumers, regardless of whether it is the lifeline or standard tariff, seems to be significantly *below* the average cost of production – meaning that all consumers are benefiting substantially from an overall subsidised tariff for electricity and, by the same token, that production is only possible due to government subsidies (see Table 9).

The ESMAP/SEforAll multi-tier framework's metric for the affordability of grid-supplied electricity – i.e. the affordability *threshold* – is that the cost of an SCP should not exceed 5% of a household's income.

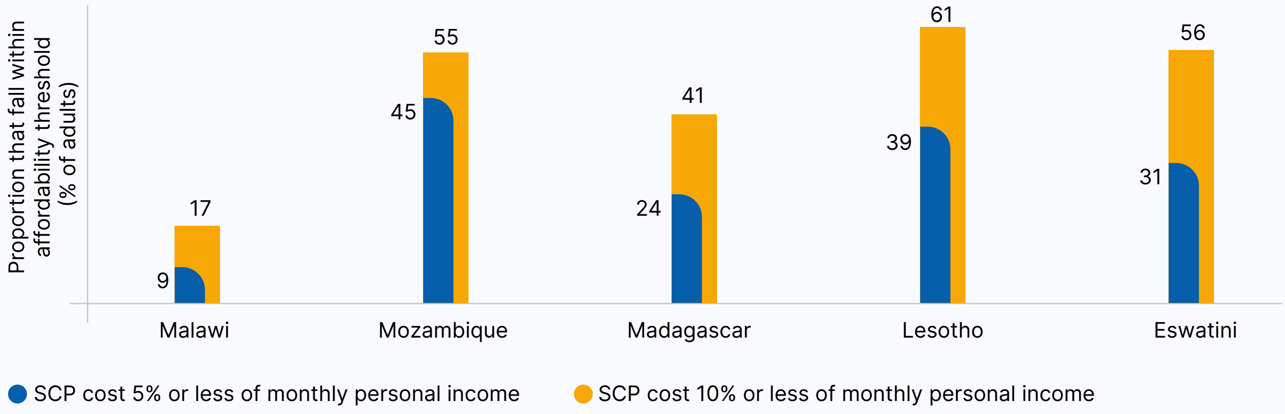
PEOPLE SPEND MORE THAN THE THRESHOLD. Across the five countries, MAP (using FinScope data) finds that individuals and households in fact spend more than the affordability threshold, especially if all their energy expenditure is included.

In Madagascar, for instance, the expenditure on electricity (for those with access) is 11% of all monthly expenditure. The expenditure on all energy sources (for everyone with access to energy) is 15% of all monthly expenditure. Furthermore, this can be higher for both electricity and all energy sources when looking at specific sub groups: as high as 20% for the elderly (61+) for all energy sources.

This is despite the fact that most people with access to electricity fall into Tiers 1 and 2, and that those currently in Tier 1 actually use less than the SCP per month, while those in Tier 2 use at most up to the SCP per month. Nevertheless, there is a trade-off between affordability, on the one hand, and the quantity of electricity consumed and mix of energy sources used, on the other.

FIGURE 20

Proportion of population falling within affordability thresholds of the SCP at lifeline tariff, by country



Note: Data for Eswatini is based on actual expenditure on electricity as percentage of total monthly expenditure.
Source: Most recent FinScope survey for each country

MOST WOULD STRUGGLE TO AFFORD ELECTRICITY AT THE 5% AFFORDABILITY THRESHOLD – OR EVEN THE 10%. Using FinScope data, MAP calculated (using monthly personal income) the proportion of adults that fall into different affordability groups: in other words, the proportion where the SCP (at the lifeline tariff) would be in a specific range of affordability, in relation to monthly income, starting with the ESMAP/SEforAll threshold of 5%, as well as a threshold of 10% (based on actual observations of expenditure in countries like Madagascar and Eswatini).

USING THIS MEASURE, IT IS CLEAR THAT THE MAJORITY OF THE POPULATION WOULD, IN FACT, STRUGGLE TO AFFORD ELECTRICITY AT THE 5% AFFORDABILITY THRESHOLD IN THAT FOR MOST PEOPLE, THE COST OF THE SCP WOULD EXCEED 5% OF THEIR MONTHLY INCOME, AND THAT A SUBSTANTIAL PROPORTION WOULD STRUGGLE EVEN AT THE 10% AFFORDABILITY THRESHOLD.

MALAWI'S CONSTRAINED GRID AFFORDABILITY WILL BLOCK EFFORTS TO INCREASE ENERGY ACCESS. Across the five countries, the discount provided between the standard tariff and the lifeline tariff ranges between 6% (Eswatini) and 84% (Mozambique). Of all five countries, Malawi provides the second lowest discount (29%) between the two tariffs, meaning its discounted lifeline tariff is the third highest of the five countries': almost 400% higher than that of the second-poorest country, Mozambique. Given that Malawi has the lowest GDP per capita of the five countries, and given current levels of access to electricity, in Malawi *lack of affordability* will soon become a serious constraint to expanding access to electricity, regardless of supply-side and regulatory interventions.

FIVE-COUNTRY STUDY FINDING

MOST PEOPLE SPEND ON ENERGY – AND THOSE WHO CAN AFFORD IT SPEND MORE ON ELECTRICITY. In countries where expenditure data was available, MAP found that:

- When it comes to expenditure on *all* energy sources, the proportion of the low-income population who spend on energy is comparable to the proportion of higher-earning individuals who do so, though the expenditure as a proportion of monthly income is less among the poor than among higher-income people.
- When it comes to expenditure on *electricity*, the poor (compared to higher-earning individuals) spend a higher *proportion* of their monthly income, although understandably less of the poor make this expenditure, and the absolute amount spent is less. The same trend can be observed for those who are not formally employed, who are rural, who are female and/or who have very low levels of education, as well as those who are younger adults.
- Clearly, most people do spend on energy sources – but the richer people are, the more they fulfil their energy requirements by choosing electricity.

Mini-grid affordability

What can we conclude from the discussion thus far? We know that:

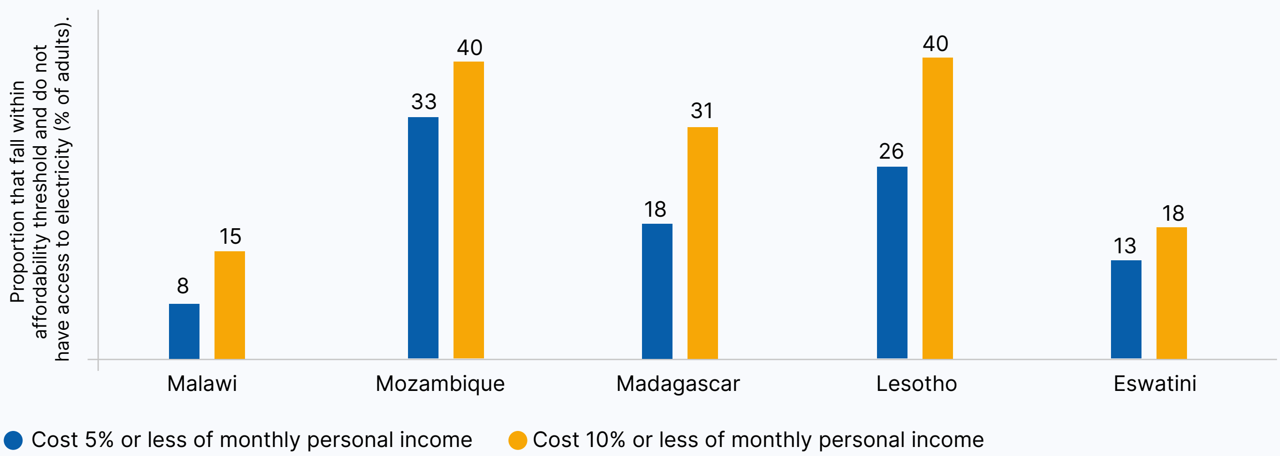
- Almost everyone that has access to electricity at the subsidised tariffs uses electricity for lighting.
- The cost of producing electricity far exceeds the cost to consumers.
- The majority of people still use alternative energy sources for lighting as they do not have access to grid electricity.
- The average cost of producing electricity through a mini-grid currently exceeds the cost of producing electricity through the grid, being roughly double.

What is not clear at this point is to what degree mini-grid production is subsidised, either by governments on an ongoing basis or by donors covering the upfront and/or operational cost.

If it is presumed, for now, that this cost is subsidised, so that the cost of mini-grid electricity is the same as that of grid electricity, it would imply the same affordability levels across each population, as noted above for the SCP. Furthermore, since most people who have access to electricity use it for lighting purposes, we could assume that most people who can gain access to electricity via mini-grids would then use this for lighting as well (at the same cost as grid electricity).

FIGURE 21

Proportion of population who can afford the SCP and do not have access to electricity, by country



However, those who would potentially buy mini-grid electricity would be a subset of this: in other words, those who can afford it, but also do not currently have access to grid electricity. This can be estimated using the livelihoods data, but a rough estimate would be to apply the overall rate of not having access to electricity to the affordability figures per country (see Figure 21).

However, this proportion of the population would need to be reduced further, taking into account the short-term options for least-cost electrification in each country.

For instance, in Eswatini, the market for mini-grid electrification based on the least-cost option is smaller than the proportion of the adult population who can afford the SCP at grid rates but do not have access to the grid. This is also the case in Mozambique. Furthermore, it is highly unlikely that the cost to consumers would be equal to that of subsidised grid electricity, at least if provided on a commercial basis, meaning that the actual proportion of the population who could afford it would be far smaller (around 20% of current levels given the average cost of mini-grid production of USD 0.55/kWh).[18]

FIVE-COUNTRY STUDY FINDING

Applying the above criteria indicates that, in terms of mini-grid affordability:

- Only about 6% of the total adult population across all five countries would both need and afford access (at 10% of their income) to unsubsidised mini-grid provided electricity.
- This demand-side estimate is far lower than the options for least-cost electrification – even over the short term – would indicate (those options are supply-side estimates).
- As noted earlier, mini-grids make sense in areas that are far removed from the grid but still have high enough population densities to both warrant the upfront equipment and infrastructure investment and allow for recouping such investment via local demand. So, this would further reduce the market for mini-grid electricity.
- In Madagascar, the long-term, least-cost electrification option is mini-grids (and SHS). But the above calculation shows that only one in three adults would be able to afford a mini-grid even if it matched the price of grid electricity. Therefore, in countries like Madagascar there is clearly a need to explore further alternatives for electrification that would also align with actual demand.

SHS and pico-solar affordability

SHS (and in particular, pico-solar products), despite being more expensive than grid or mini-grid electricity per kWh, can be more affordable to low-income consumers due to flexibility in terms of size and usage. These products can thus meet consumers closer to their actual demand, and allow for use as and when needed.

The easiest, entry-level product is solar-powered or battery-powered light (pico-solar lanterns and rechargeable-battery lanterns). These are typically broadly available in all five countries (and have been for longer than larger SHS have) and can sometimes also be used to charge phones. A rechargeable light can cost as little as USD 6, while pico-solar solutions can be rented on a daily or monthly basis, for a total annual cost of USD 12 to USD 37 (Madagascar), or purchased outright for USD 42 (Malawi).

SHS are increasingly becoming available, mostly in the form of Tier 1 products that can power two to four lights, charge a phone, and sometimes allow for a radio. These can cost as little as USD 69, and as much as USD 204. The availability of Tier 2 products (or higher) is very limited.

They are much more expensive than Tier 1 products but can be used to power four lights, charge a phone and run a TV. A stand-alone Tier 2 SHS product is available in Malawi (USD 437 to USD 612), while Madagascar has a nano-grid product, which links several SHS for more than one home. Cost varies depending on usage but is typically between USD 58 and USD 237 per user per year – depending on the amount used.

Given that affordability remains the single largest barrier to the use of particular energy sources to meet particular needs, it is essential to size the market for lower-tier SHS and pico-solar products. Even common Tier 2 SHS products are too expensive (costing around USD 200 per year) for almost all these countries (with the exception of Eswatini). There is, however, a clear incentive for households to purchase small SHS or pico-solar products because they can replace candles and paraffin typically used for lighting and also replace phone-charging services, which currently add up to about USD 6 to USD 10 per month in the respective countries.

THE MOST POPULAR AND WIDELY AVAILABLE SOLUTIONS IN THE FIVE STUDY COUNTRIES WERE TIER 1 STAND-ALONE SOLAR LANTERNS OR ENTRY-LEVEL SHS – COMMENSURATE THE LOW-INCOME EXPENDITURE AND AFFORDABILITY BARRIERS.

Solutions at the low end of Tier 1 would typically consist of a pico-solar solution, with a 5.5 watt solar panel, 400 lumen light and phone-charging kit. A Sun King branded solution like this currently costs about USD 42 in Malawi and USD 46 in Madagascar (upfront cash price). SHS solutions at the higher end of Tier 1 typically include powering two or three lights, a charging kit for mobile devices and possibly a low-power appliance (e.g. radio).

Fenix International currently sells a two-light and phone-charging solution with a 10 watt solar panel in Mozambique for between USD 107 and USD 149 per year on a 30- and 24-month payment period, respectively. Yellow Africa sells a solution with lights, device-charging functionality and radio for USD 102 per year (paid off over 24 months) in Malawi.

GIVEN THAT SHS IS MORE EXPENSIVE PER KWH THAN GRID AND MINI-GRID ELECTRICITY, AND THAT PICO-SOLAR PRODUCTS HAVE A MUCH SMALLER UPFRONT COST THAN SHS, THE MAP ASSESSMENT LIMITED ITSELF TO THE MARKET FOR STAND-ALONE TIER 1 SOLUTIONS.

This limits options to SHS and pico-solar products. As a first step to addressing and achieving the objectives of increased energy access to households, we have attempted to size the market, based on two typical stand-alone Tier 1 solutions currently available in the five markets:

OPTION 1: TIER 1, LOW END – PICO-SOLAR SOLUTION: The cost of these solutions varies between USD 42 and USD 69 across the five markets, providing a low-end solution with three lights and mobile device-charging solution. This is typically sold for cash, although we assumed it could be sold on an instalment basis over a maximum repayment period of 12 months.

OPTION 2: TIER 1, HIGH END – BASIC SHS: The package includes four lights, a mobile device charger, and possibly a low-power appliance (e.g. radio) with a purchase price of USD 102 to USD 150 per year over a 24-month repayment period.

The addressable market for Tier 1 products is a subset of those who can afford it; it includes only those who both need and can afford an off-grid solution. Based on the monthly instalment on the two product options above (which would be more affordable than the cash price as a proportion of monthly income), we could estimate the proportion of each population who would fall within certain affordability thresholds. We calculated the monthly instalment based on the cost of a typical Option 1 product financed over 12 months at an assumed interest rate of 10%, and the typical cost of an Option 2 product financed at the same interest rate over 24 months.

FIGURE 22
Typical stand-alone Tier 1 SHS solution

Pico-solar (low end)

BENCHMARK PRICE (USD)
42 TO 69

FUNCTIONALITY
Three lights and mobile device charging

Basic SHS (high end)

BENCHMARK PRICE (USD)
102 TO 150

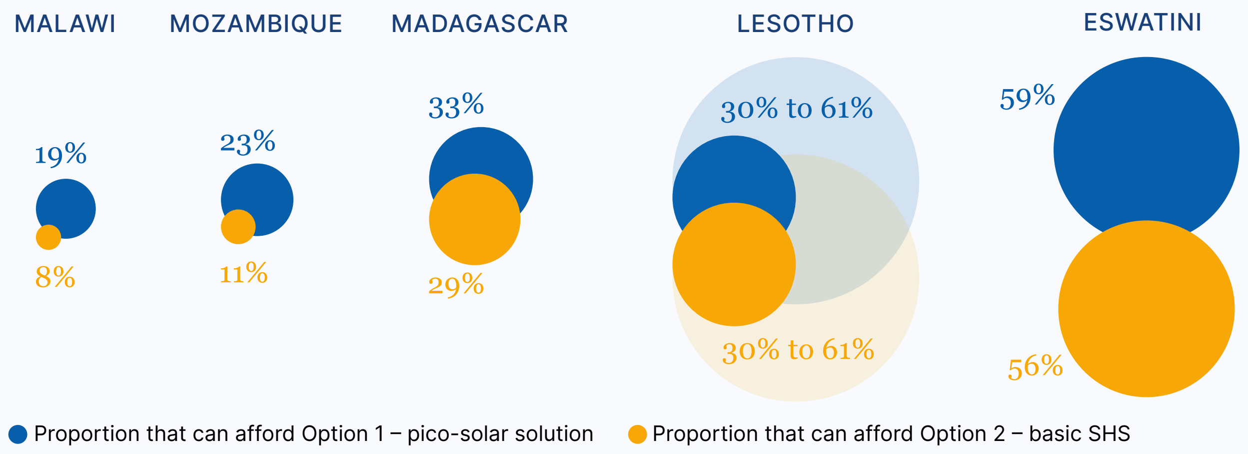
FUNCTIONALITY
Four lights, mobile device charging, low-power appliance (e.g. radio)

Source: Nova Economics (2019)

We used these calculated monthly instalments to compare against the monthly income distributions for each of the five countries (based on the MAP livelihoods data), assuming an affordability threshold for these two products of 15%. In other words, this would apply to the proportion of the population who earn enough monthly income that the noted instalments would constitute a maximum of 15% of their monthly income. This threshold is higher than the ESMAP/SEforAll multi-tier framework measure for the affordability of grid electricity (which is 5%), but is based on typical monthly total energy expenditure as a portion of income in comparable countries. This resulted in an estimate of the proportion of each country's adult population who would be able to afford the monthly instalments for each of the two options (see Figure 23).

FIGURE 23

Proportion of population who can afford SHS Option 1 or 2, by country



FIVE-COUNTRY STUDY FINDING

In terms of SHS and pico-solar affordability, applying the same rule as for mini-grids – of multiplying the proportion of the population who can afford a product/service by the proportion of the population who do not have access to electricity (as this is the proportion of the population who would use solar products for lighting) – we find that about 20% of the overall adult population across all five countries both need and can afford an Option 1 pico-solar solution. Although the cost per kWh of larger SHS products decreases, the large upfront cost places them out of reach for more households than for pico-solar products, so that the proportion that could afford SHS (Option 2) is likely smaller.

Assuming there is no overlap, this implies there is a large deficit in the market, despite the potential for mini-grid and solar products to supplement and complement grid electricity access:

- The 2017 rate of access to electricity was about 24% across all five countries.
- Another 6% can potentially use mini-grids.
- About 20% more would be able to use solar products for lighting.
- This implies that 50% of the adult population across all five countries will not be reachable by *any* of these three options for electrification – underscoring the observed behaviour, which is that most people use alternative sources of energy for lighting (and even more so for cooking).

Improved cookstoves affordability

The market for improved cookstoves is potentially far larger than that for pico-solar products. This is because most people who have access to electricity still rely on alternative sources of energy for cooking. However, given that a large proportion of such people use energy sources (e.g. biomass in the form of firewood or animal dung) that can be obtained for free, they are unlikely to switch to a product that requires an expense (either upfront or over time).

IF WE CONSIDER IMPROVED COOKSTOVES THAT USE BIOMASS, HOWEVER, THERE IS LESS OF AN ONGOING COST (OR NO ONGOING COST), AND SIMPLY THE INITIAL COST OF THE EQUIPMENT. HOWEVER, IN SUCH CASES, INCREASED UPTAKE BY LOW-INCOME CONSUMERS WOULD REQUIRE THAT THE STOVES PROVIDE MEASURABLE BENEFITS TO THE HOUSEHOLD, SUCH AS REDUCING NEGATIVE IMPACTS ON THEIR HEALTH.

A 2021 study[19] identified 307 biomass stoves currently on the market from the 'Clean Cooking Catalog' (a global database of product and performance data for the clean cooking sector). However, only 17 of these were found to be both suitable for household use and apparently compliant with at least the minimum requirement for reductions in emissions. Of these 17 stoves, only 3 were available in Africa, and although prices varied from as low as USD 3 to USD 70, most products tended to be between USD 25 and USD 45 – placing them in a range slightly cheaper than for the Option 1 pico-solar product. However, unlike the way we added up grid access with addressable market for mini-grid electricity and pico-solar products, the market for cooking products likely overlaps with this market, and cannot be added to it. Given the lower cost of cookstoves (compared to pico-solar), the market for improved cookstoves will, however, likely expand the proportion of the population who can afford and would choose clean energy products.

FIVE-COUNTRY STUDY FINDING

In terms of improved cookstoves affordability, the MAP study found that cleaner cooking technologies and fuels are available in all five of the study countries, but uptake of unsubsidised solutions is still very limited.

The World Bank notes that while market-led efforts to promote clean cooking technologies are the preferred approach to promoting universal access to sustainable cooking energy, a differentiated approach based on the market segment, ability to pay and cost of alternatives is required:[20]

- For example, for poor and lower-middle-income collectors of wood, dung and crops (i.e. free biomass for cooking), market-led initiatives are likely to fail, and more direct subsidy models can be justified.
- The risk of creating market distortions via subsidies or low uptake and usage due to the perception that subsidised or 'free' solutions have little value must be weighed against the likelihood that a market-based approach can be successful.

THE WORLD BANK SUGGESTS THAT MARKET-LED APPROACHES TO IMPROVED COOKSTOVES ARE ONLY LIKELY TO BE VIABLE IN *URBAN AREAS*, AND THEN ONLY FOR: RELATIVELY HIGH-INCOME FIREWOOD PURCHASERS; POOR AND MIDDLE-INCOME CHARCOAL USERS; AND USERS OF UNSAFE COOKING FUELS SUCH AS PARAFFIN.

Establish the potential for MSMEs' uptake and usage of clean, off-grid energy

The market for clean, off-grid energy solutions for productive uses as the 'locale of energy access' remains undeveloped and, compared to that of households, quite opaque. This is partly because existing initiatives aimed at growing the market for clean energy have focused on the deployment of Tier 1 solutions for household use, and partly because the market for productive uses – particularly in terms of the MAP MSME focus – is more fragmented and difficult to serve.

As a result, there are very few energy service companies successfully addressing the business market for clean energy solutions.

FINANCIAL – RATHER THAN ENERGY – EXCLUSION MORE OF AN OBSTACLE TO MSME GROWTH. Although, in the five study countries, a substantial proportion of MSMEs do not have access to electricity, this is not the main constraint to operating or growing a business. Rather, *access to finance* emerges as the more pressing challenge.

Projects aimed at deploying clean, off-grid power solutions for productive applications are unlikely to be successful when MSMEs – and even high-impact/high-potential SMEs – face barriers to accessing finance (see also the UNCDF MAP SME Investor Toolkit). Rather, such barriers will need to be tackled, although doing so is not straightforward; not only are there supply-side issues for financial services (a small pool of MFIs, for instance, with limited reach), but businesses also need to be able to access *relevant* finance to address potential affordability barriers to adopting off-grid solutions.

MARKET FOR OFF-GRID SOLAR FOR PRODUCTIVE USES SEVERELY CONSTRAINED BY AFFORDABILITY. At the levels of typical energy use – actual or desired – for MSMEs, off-grid solutions would have to be high-capacity, Tier 5 solutions (or at least Tier 4 solutions). These systems cost significantly more than Tiers 1 to 3 solutions, which can mostly just be used for lighting, charging mobile phones, and maybe running a low-power appliance. Since, in the five study countries, the owners of MSMEs are typically not much better off financially than the average household, the market for off-grid solar for productive uses is, like that for households, severely constrained by affordability considerations.

MICROBUSINESSES COULD BE SERVED. However, there could be a market for lower-tier products to power lights, play a radio, or charge phones, which *micro* businesses are likely to still find useful.

A LACK OF PROVIDERS AND DISTANCE FROM THE GRID ARE CONSTRAINTS. Other factors accounting for the general dearth of clean, off-grid energy solutions for MSMEs is the lack of energy providers in this space and the distance of MSMEs from existing grid infrastructure. The problem with productive applications is that they are context- and case-specific; the solution required will depend on where the business is located.

For instance, if the business owner is a farmer, the energy solution would need to accommodate the geographic location and its constraints, the crops grown, the inputs the farmer has access to and so on. Or, if the MSME lacks sophistication and, as is often the case, operates on the street, the likelihood of large-scale deployment of off-grid energy solutions is low.

ACCESS TO FINANCE COULD INCREASE ENERGY INCLUSION FOR MSMES. Nevertheless, there is evidence that MSMEs are interested in alternative energy sources, and willing to invest in these *if access to finance can be obtained*. Based on the profile of MSMEs in the five study countries, there is also possible scope for niche productive applications.

For instance, off-grid solar power could greatly support the agriculture sector and other income-generating productive uses for rural development in all five countries. Irrigation is one of the areas where off-grid solar could play a major role in promoting sustainable rural development. Mozambique, for example, has roughly 3.3 million hectares of potentially irrigable land with only about 50,000 hectares of operational irrigation infrastructure, which is concentrated in specific areas and largely for high-value crops such as sugarcane. Widespread lack of grid electricity services means that farmers are dependent on diesel-powered systems when they can afford them. Were solar-powered drip irrigation systems to seem viable, for instance, they would potentially help farmers increase both their yields and crop variety while boosting resilience in the agriculture sector (e.g. by minimising reliance on fossil fuels and reducing water usage in increasingly drought-prone countries).

It is obvious irrigation can help farmers improve their yields, although small-scale farmers need significant support in this regard. The co-founders of SunCulture note that while the price of the cheapest solar-powered irrigation kit had fallen sharply, from USD 5,000 in 2013 to USD 500 in 2018 (for the RainMaker2 excluding battery costs), affordability remains a challenge. The upfront deposit required is about USD 70, and monthly instalments are in the region of USD 30 for 18 months. SunCulture customers in Kenya that have used a Rainmaker to irrigate maize reported a doubling of their yield, which meant an additional USD 600 in revenue per acre per year, making irrigation affordable. However, it was not affordable before irrigation; in other words, the upfront cost could be unaffordable.[21]

The One Acre Fund (OAF) has extensive experience in supporting the development of small-scale farmers in Malawi, Zambia and East African countries. The OAF offers a complete package of tailored support, including asset-based loans for high-quality seed and fertiliser, delivery of the inputs to a location within walking distance, and trading and market facilitation (e.g. crop storage and education). The organisation provides credit primarily for seed and fertiliser, but also offers a range of add-ons, including solar lights. The OAF closely tracks monthly spending on paraffin, flashlight batteries, mobile phone charging, and other related expenditures to understand the amount of savings a solar lamp provides at each price point. According to the organisation, they price the lights at a level that generates energy cost savings of between USD 0.45 and USD 0.70 a day in Kenya and Rwanda. It appears the OAF has piloted the use of solar pumps but that the solutions, such as the RainMaker2 with a 310 watt roof-mounted panel, cost roughly USD 500 and would still be unaffordable, even on an instalment payment basis, for the majority of small-scale and subsistence farmers.

FIGURE 24

Potential uses of off-grid solar energy in agriculture (not exhaustive)

Source: World Bank (2019)

Generic productive applications based on off-grid solar energy for agriculture are available (see Figure 24). A 2019 study of these applications by the World Bank suggests that water pumps are most ready to scale, cooling solutions are relatively expensive, and agro-processing units are still at the pilot stage. In terms of market readiness, productive uses of solar technology vary significantly, depending on both the use and the associated energy consumption and system requirements.[22] Understanding market readiness in countries will require an analysis of the energy needs of the particular MSMEs (e.g. farmers) so that appropriate products can be designed.

A pilot project to provide retail and service MSMEs in Malawi with access to electricity from stand-alone solar systems (SOGERV) demonstrated that there is demand and willingness to pay for basic services that require electricity as an input. Electricity services with the highest potential in the pilot villages include mobile phone-charging and battery-charging services, and providing wired electricity connections for lighting and basic appliances to co-located micro-enterprises (e.g. cold drink vendors, barbershops, video shops and hardware stores).[23]

The SOGERV findings suggest that few Malawian MSMEs can afford to rent stand-alone SHS capable of powering refrigerators, basic appliances and shop lighting at a monthly price of between USD 20.50 and USD 27.40.[24] Wired connections at a cost of USD 13.70 per month, however, appeared to be affordable.[25] The monthly earning potential of energy supply companies appears to be in the region of USD 60.30 based on income from four wired connections to co-located micro-enterprises, and income of roughly USD 5.50 per month from battery- and phone-charging services.

As the costs of solar PV hardware, battery storage and metering technology decrease, there is an opportunity to hybridise and densify existing systems and build new solar-powered mini-grids that could promote both rural economic development and electricity access. That said, the viability of such systems would still need to be calculated, based on population density and potential demand (including affordability).

IN LESOTHO, SOME MSMES ARE INVOLVED IN 'ACCOMMODATION AND FOOD SERVICE ACTIVITIES', AND WHERE THEY ARE OPERATING IN RURAL AREAS, THERE IS AN OPPORTUNITY FOR A MARKET TO DEVELOP FROM THE EXISTING DEPLOYMENT OF SOLAR LANTERNS, SOLAR KITS, SHS AND MINI-GRIDS.

A World Bank study on the opportunity for solar solutions for productive uses in Sub-Saharan Africa recommended that mini-grids in the form of solar-powered or solar-diesel hybrid multifunctional platforms (MFPs), as is common in West Africa, be introduced to equip small businesses in Madagascar. It appears that this may feasibly be rolled out in the balance of the target countries.[26] Some energy service companies are already able to viably provide co-located micro-enterprises with access to electricity for lighting and basic appliances from an SHS via wired electricity connections.

The MFP is a simple, inexpensive energy source at the village level that is built around a diesel or solar-diesel hybrid electrical generator and can power various tools, such as a cereal mill, husker, alternator, battery charger, pump, and welding and carpentry equipment. Several thousand MFPs have gone into operation in West Africa in the past 20 years, creating local jobs and adding value to local production.[27]

However, even with decreasing technology costs and upfront capital costs, the business case for mini-grids such as MFPs remains tenuous because of both businesses' and consumers' limited ability to pay. The World Bank[28] has suggested that mini-grids servicing both households and businesses might be more viable, and noted that operation and maintenance remains a major challenge, particularly in less accessible rural areas.

WEIGH UP THE OPPORTUNITIES AND CHALLENGES *for clean energy investment*

What is the investment case? To arrive at the investment case for clean, off-grid energy solutions in the five study countries of Malawi, Mozambique, Madagascar, Lesotho and Eswatini, this toolkit considers both energy supply and demand.

Given the grid electricity access deficit, which the toolkit unpacks in helpful detail, the following supply options are explored: extending electrification via countries' existing electricity grids, increasing supply via clean energy mini-grids and SHS, and increasing options for clean energy cooking (using improved cookstoves). Then, within the country context and in terms of these options, the toolkit assesses specific categories of clean, off-grid energy solutions on the criteria of current potential demand (arising from the grid electricity access deficit) and affordability.

In Madagascar, the long-term, least-cost electrification option seems to be clean energy mini-grids and SHS. In all of the other countries – Malawi, Mozambique, Lesotho and Eswatini – grid electricity appears to be the long-term, least-cost electrification option.

Yet, the research is clear that grid electricity alone will not get us to the 2030 goals, which creates opportunities for the other categories of energy provision. Thus, in those four countries, both clean energy mini-grids and SHS have a role to play in both the short and long term. And in all five countries, in the short term, SHS, and by extension pico-solar products, can play a larger role.

IN GENERAL, THE CURRENTLY LOW LEVELS OF ENERGY USAGE ARE LIKELY TO INCREASE IF AFFORDABLE ALTERNATIVES TO ELECTRICITY CAN BE PROVIDED; THUS, CLEAN, OFF-GRID ENERGY SOLUTIONS HAVE A ROLE TO PLAY AS PART OF COUNTRIES' INTEGRATED ENERGY MIX.

Countries like Eswatini (Cluster 3) and Lesotho (Cluster 2) can conceivably come close to achieving SDG 7 – universal access to clean and modern sources of energy by 2030 – given they are predicted to reach 99% and 57% grid electricity access, respectively, by 2030. However, geographic location will undoubtedly be the obstacle to reaching the remainder of the population: people located in deeply rural areas, which in the case of Lesotho lie in inaccessible mountainous terrain.

The Cluster 1 countries (Malawi, Mozambique and Madagascar) are predicted to achieve grid electricity access rates of between 22% and 36% by 2030 – increases that, given current levels of access, would represent substantial achievements.

While the projected growth rates are remarkable for most of the five countries, suggesting an increase of almost 50% or higher between 2017 and 2030 for three of them – Malawi, Madagascar and Lesotho – the MAP research estimates these Cluster 1 countries would need to accelerate their rate of electrification by between 5 and 11 times in order to reach universal access by 2030. By contrast, Lesotho would need to less than double its current rate of electrification, while Eswatini is more or less on track already.

OFF-GRID MARKET OPPORTUNITIES. Countries with large populations and low grid electricity access rates have large access deficits and, consequently, large potential for the off-grid market. Mozambique and Madagascar have the largest potential off-grid markets, closely followed by Malawi. The potential markets in Lesotho and Eswatini are much smaller by comparison as populations are smaller and grid electricity access rates (particularly in Eswatini) much higher.

THE MARKET FOR SHS AND PICO-SOLAR. Given the size of the access deficit in each country, as well as the importance of SHS and pico-solar products in both the short and long term, Malawi, Mozambique and Madagascar offer the largest market opportunities for investing in SHS and pico-solar products as a means of addressing the access deficit.

USER NEEDS AND CONSTRAINTS. The least-cost options across countries also speak indirectly to the needs and realities of users:

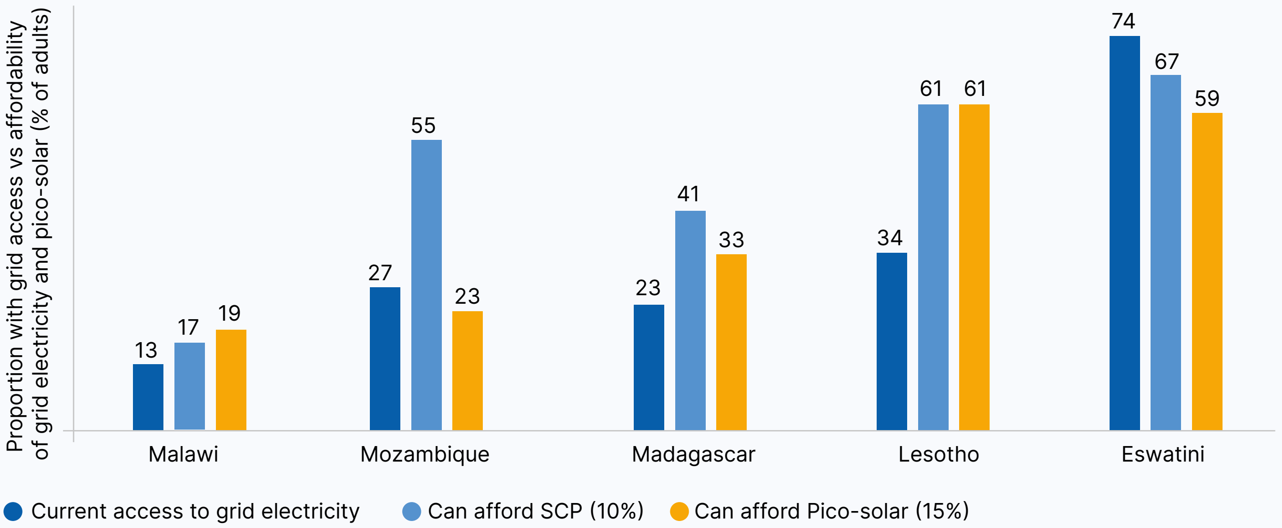
- Grid electricity could, if functioning properly, provide electricity from Tiers 1 to 5.
- But mini-grids are often more appropriate for use for Tiers 2 to 4.
- SHS, on the other hand, mostly speaks to Tiers 1 to 3 (but most often only Tiers 1 and 2).
- And pico-solar solutions only speak to Tier 1.

We also know from the low-income demand-side analysis and resulting consumer profiles of access to energy that electricity users from Tiers 1 to 3 are less likely to use electricity for higher-energy uses like cooking, and much more likely to use it for lower-energy uses like lighting, and charging a mobile phone. Furthermore, we know that most of the population who do have energy access are in fact in these lower tiers. While these consumers wait for grid electricity access, SHS and pico-solar products should be able to address their current/short-term needs, while mini-grids might be viable in select cases where remote geographic location combines with sufficient population density to justify the business case. Off-grid solar is also a far cleaner source of energy compared to lighting alternatives like paraffin, meaning that achieving such a switch would promote climate- and health-related SDGs as well.

Based on the affordability analysis of Tier 1 products across countries, the market opportunities for off-grid energy become clearer:

- In Malawi, there are more people who can afford grid electricity (17%) than currently have access (13%), but there are even more people who can afford an Option 1 off-grid product (19%).
- This is also the case in Madagascar and Lesotho, where the proportion that do not have access to grid electricity but can afford the cheapest off-grid option (Option 1) is 9% and 27%, respectively.
- In Mozambique, however, off-grid options are less affordable than grid electricity. Although there would still be a need in the short and medium term for off-grid products, affordability would need to be addressed before a viable market could be developed.
- In Eswatini, off-grid options are also less affordable than grid electricity. In this case, though, the current rate of grid expansion is sufficient to reach the 2030 goal of universal access. Nevertheless, for remote rural villages, off-grid may still be an option – although affordability will likely remain a stumbling block.

FIGURE 25
Access to grid electricity vs affordability of grid electricity and pico-solar



Source: Most recent FinScope survey for each country

The SDG 7 for 2030 is, of course, not to get everyone to Tier 5, but simply to get them on a tier – the minimum being Tier 1. In addition to the size of the opportunity, there are several other recommendations arising from the MAP study that can help catalyse the off-grid energy market in some or all of the five countries:

POTENTIAL TO INVESTIGATE REGIONAL EQUIPMENT MANUFACTURING. There are already strong regional dependencies on electricity provision in the region, with South Africa providing a large amount of the countries' electricity access. There is good potential for existing relationships to be strengthened on a regional basis towards clean energy solutions, including in the following areas: local manufacture of equipment with a view to bringing down equipment costs; financing mechanisms conceptualised and applicable across the region; and exploiting the advantages offered by the prevalence of strong national banks operating across the region.

POTENTIAL FOR AGENT DISTRIBUTION. Some energy providers have overcome distribution problems by partnering with local entrepreneurs who act as agents that facilitate last-mile distribution (both sales and after-sales servicing). However, population density is still a factor that needs careful consideration; an agent selling Tier 1 systems needs to be able to reach at least 1,000 households within a 5 to 10 km radius for the agent economics to work. If the population density is lower than this, it will be difficult to run a profitable agency.

POTENTIAL FOR PARTNERSHIPS IN DISTRIBUTION. There might be an opportunity for MFIs to partner with electricity service companies that currently provide solutions on a PAYGO basis, as the MFIs might be able to piggyback on the PAYGO providers' existing distribution networks to profitably serve a market segment hitherto excluded.

POTENTIAL TO MAKE THE MOST OF MOBILE PAYMENT SOLUTIONS. Given growing numbers of mobile phone subscribers and mobile money users, which in most cases is greater than the proportion of the population who have access to grid electricity, there are opportunities to expand energy access through allowing consumers to finance purchases of off-grid energy solutions via mobile payments (PAYGO).

What is the current state of market development?

While the market for clean, off-grid energy products is small in all five of the study countries, there are signs of new, emerging market players and developments in technology that lower the barriers to entry and the upfront investment costs for consumers.

INCREASING RANGE OF PRODUCT OPTIONS, SOME AVAILABLE ON CREDIT. Until recently, clean, off-grid energy products consisted mostly of lanterns and other small/pico-solar or rechargeable products sold on a cash basis or through donor initiatives. However, recent market entrants to the clean energy space with a range of different products addressing various kilowatt outputs have meant the availability of products that address energy requirements to varying degrees. Many of these products are available on credit (ranging from 6- to 30-month payment periods).

NOT MANY IMPROVED COOKSTOVE OPTIONS AVAILABLE THAT ACTUALLY TICK THE BOXES. The market for improved cookstoves seems to be fairly active, but data is limited for Africa as a whole, and is not disaggregated by country, which makes it difficult to understand individual, country-level markets.

The 'Clean Cooking Catalog'[29] lists 95 different stoves for Africa that cost USD 50 or less (and 123 that cost USD 100 or less), although many of these are listed under the same providers. These span all types of cookstoves, using all types of fuels, with no specifications on their efficiency, safety or environmental impact. As noted earlier, though, very few affordable cookstoves seem to have sufficient efficiency and safety ratings to have a real impact in terms of mitigating climate change and improving household health.

For Africa, in fact, there are only two cookstoves listed that cost USD 50 or less *and* meet the minimum requirements for efficiency, safety, emissions, and indoor emissions (i.e. a rating of at least one on each of the four standards).

NOT MANY SHS PROVIDERS, LOTS OF PLUG-AND-PLAY PROVIDERS. A larger number of companies or individuals are involved in energy installation or distribution (e.g. 71 in Malawi). Typically, most of the countries have a handful of providers that distribute SHS. The remainder are mostly trading in the plug-and-play household solar market and sell smaller lanterns.

PRICE-SENSITIVE, ASTUTE CONSUMERS. Energy service companies have typically been slow to enter these markets, as the perception was that the population was too poor on a GDP per capita basis and so the market would also be too small. Furthermore, consumers are very price sensitive, and affordability is a major constraint. Providers have learned that consumers are astute and will not buy solar 'solutions' if doing so costs them more than the existing alternatives (e.g. candles, battery-powered torches and/or paying someone to charge a phone). Households in Mozambique, for example, currently pay around USD 10 per month for candles, batteries and phone charging. However, affordability challenges mean that, in some markets, financing solutions are required for even the most seemingly inexpensive of products such as daily rental of pico-solar or rechargeable lights (in the case of Madagascar).

NOT MANY CLEAN ENERGY MINI-GRID PROVIDERS. There are limited examples of clean energy mini-grid providers in the study countries (e.g. in Eswatini and Lesotho), although these are to a large extent part of ongoing donor initiatives.

In terms of constraints to expansion and limits to business profitability, providers mostly cite the fact that government restrictions on tariffs mean the tariffs are not cost reflective, given that compared to grid-electricity provision mini-grid provision is riskier (as communities of rural households are the parties that buy the electricity produced).

Madagascar probably has the highest number of existing mini-grids (130), which are operated by the state-owned utility as well as by 30 private operators, and are mainly located in rural areas and powered by diesel units (although more renewable and hybrid mini-grids have been introduced), providing electricity to around 200 villages, serving approximately 7,000 consumers in total.

Mozambique probably has the second-highest number of existing mini-grids, having installed approximately 70 diesel-based mini-grids operated by local communities established under the FUNAE fund.[30]

WITH THE DECREASING COSTS OF SOLAR PV HARDWARE, BATTERY STORAGE AND METERING TECHNOLOGY, THE WORLD BANK FORESEES AN OPPORTUNITY TO HYBRIDISE AND DENSIFY EXISTING SYSTEMS AND BUILD NEW SOLAR-POWERED MINI-GRIDS THAT COULD PROMOTE BOTH RURAL ECONOMIC DEVELOPMENT AND ELECTRICITY ACCESS.[31]

In both Madagascar and Lesotho, the government is supportive of developing clean, off-grid energy solutions, both in terms of smaller solutions (such as Tiers 1 to 3 SHS and lanterns) and mini-grids (Tiers 3 to 5). In Madagascar, a national strategy for clean, off-grid energy is being developed. In Lesotho, the government is waiting to assess a pilot project before allocating further resources to developing this regulatory framework; however, while the government is cognisant of the impact of a well-developed and regulated clean, off-grid energy space, their main interest is the expansion of the current electricity grid and building additional national generation capacity.

What is the value of the addressable market?

Based on MAP's rough market size estimates, it would be possible to estimate the value of some of the market opportunities noted. This can be done by taking the number of households that both need and can afford certain energy solutions and multiplying that figure by the annual expected revenue per household for those solutions.

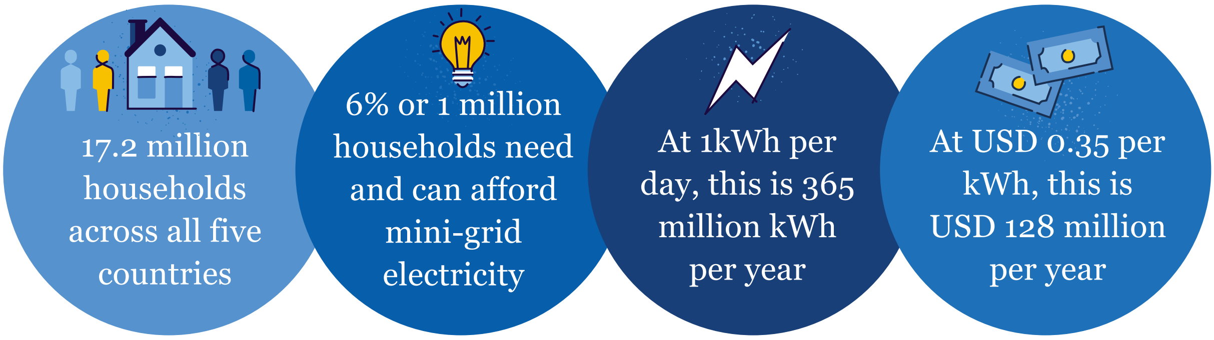
This would translate to ongoing revenue on an annual basis for grid and mini-grid provided electricity, while for SHS, pico-solar and cookstoves it would be either once off or over the period that products can be financed.

REVENUE CALCULATION FOR MINI-GRIDS. We consider the total annual revenue estimate for mini-grids across all five countries, based on the assumption that there are 17.2 million households across all five countries (Nova Economics 2019), and that 6% of households both need and can afford mini-grid provided electricity. Assuming a rate of USD 0.35 per kWh (lower than average production costs), and that all households would each use 1 kWh per day, this translates to USD 128 million revenue per year (see Figure 26).

REVENUE CALCULATION FOR PICO-SOLAR. Similarly, an estimate can be done for pico-solar products. Using the same number of households, and the estimated proportion of each country's population

FIGURE 26

Estimated annual revenue for mini-grid provided electricity across the five countries



Source: UNCDF calculated

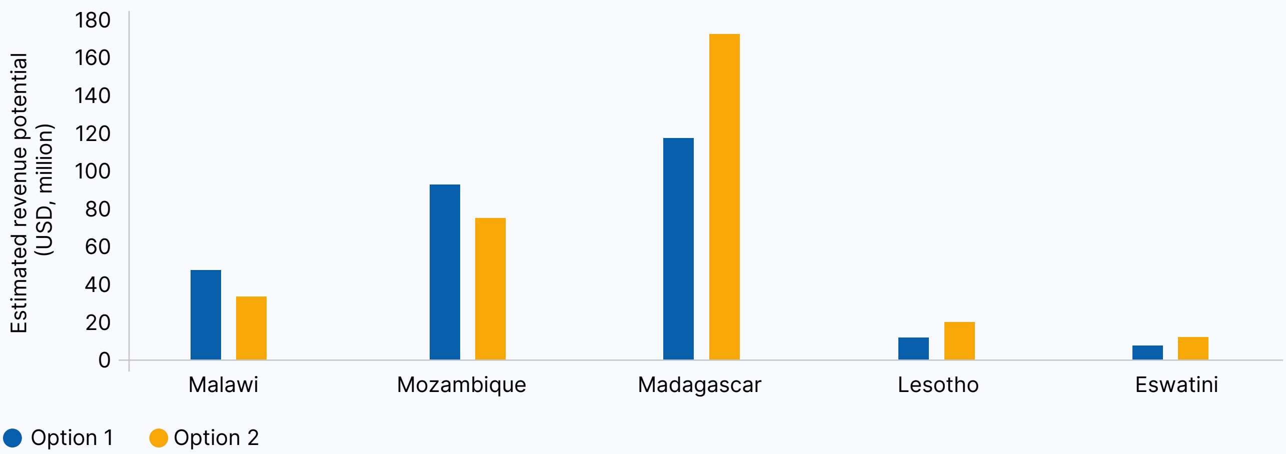
who can afford Option 1 or Option 2 presented earlier, we find that 4.6 million households can afford and would need Option 1, and 3.1 million households can afford and would need Option 2. At USD 60 and USD 100 for the two options, respectively, this translates to potential revenue of USD 274 million for Option 1 and USD 308 million for Option 2. This can be shown by country, given that we have the data at country level (see Figure 27).

As is evident in Figure 27, the biggest opportunities for pico-solar are in Madagascar, followed by Mozambique. However, in Mozambique and Malawi, the value of the opportunity for the smaller (Option 1) product is greater than the value of the larger (Option 2) product. By contrast, in Madagascar, Lesotho and Eswatini, the greater opportunity is in Option 2. This has potential implications for which opportunities investors will pursue, and also for consumers, as it might mean the low end of the market remains less served as a result.

REVENUE CALCULATION FOR IMPROVED COOKSTOVES. The market for cookstoves is less clear. The majority of households seem to need such a solution, and we can use similar affordability assumptions as for the Option 1 solar product (which would allow for a USD 60 cookstove). This would then also imply potential revenue of USD 274 million across the five countries. However, given the uncertainties around the environmental and health benefits of the improved cookstoves currently on offer, as well as the challenges around rural distribution, it is unclear to what degree this opportunity is realistic.

FIGURE 27

Estimated revenue potential (USD) of pico-solar products, by country



Source: UNCDF calculated

What are the barriers and challenges to uptake?

While barriers and challenges to the uptake of clean, off-grid energy solutions across the five countries vary, there are some commonalities.

These include lack of affordability for consumers and limited consumer access to credit and financing options; patchy or non-existent mobile network coverage in many rural areas and relatively low mobile penetration rates in general (and low levels of mobile money usage); lack of skilled personnel to facilitate distribution, and high distribution costs (particularly in remote rural areas); import duties and taxes levied on imported SHS solutions; a lack of government and investor funding for clean energy initiatives specifically; and regulatory environments that are not conducive to the development of the clean energy market.

ACHIEVING ECONOMIES OF SCALE IN SOME COUNTRIES IS PROBLEMATIC. Given the small population size of two of the countries, Eswatini and Lesotho, the potential market for off-grid solutions (i.e. the grid electricity access deficit) is also relatively small. It would be difficult to achieve economies of scale for any specific clean energy product. But because of their small size, which makes 'sandboxing' exercises relatively affordable, these countries are ideal markets for testing solutions – especially in rural areas and at a community level to understand questions of market uptake and switching from biomass to clean energy solutions. Limited private sector participation in the pico-solar PV, SHS or mini-grid space is likely due to this difficulty in achieving economies of scale in distribution, especially given the fast pace and scale of electrification in those countries. However, clean, off-grid solutions might be required in both countries, and could also be the least-cost option, given that the remaining areas that are not electrified are also the hardest and most costly to reach.

DISTRIBUTION COSTS ARE HIGH. The key to a viable operation selling stand-alone off-grid solutions in the five study countries is minimising the cost of last-mile distribution. The low population density in Southern African countries (relative to East and West African countries) means that distribution is a significant cost, as the large physical distances between customers is a challenge for both sales and after-sales service. An additional difficulty is that the remaining unelectrified population in most of the five countries are deeply rural in terms of geographic location, situated in remote and inaccessible terrain (e.g. mountainous villages in the case of Lesotho). While SHS offer solutions for such areas, in terms of both distribution and maintenance the costs of reaching these far-flung areas are high (especially considering companies installing SHS are typically located in urban areas). Furthermore, when SHS systems in rural areas malfunction, replacement parts and repairs are not easy to dispatch and apply, which again pushes up the costs.

LIMITED FINANCIAL SOLUTIONS TO OFFER ALTERNATIVES TO THE CASH AND DAILY RENTAL/ PAYGO MODELS. One of the most significant barriers to uptake of clean, off-grid energy solutions at scale is lack of affordability; and thus increasing access to finance among a country's low-income consumers is key to growing the country's energy market. Given comparatively large upfront costs of clean energy solutions relative to income in developing countries, few consumers can afford to buy the solutions on a cash basis and rather rely on either daily or monthly rentals (PAYGO), or access to credit from microfinance providers or in the form of instalment payment mechanisms paid to providers.

However, as noted, access to credit is particularly low across almost all five of the countries (and more so in rural areas), while the cost of credit is high; therefore, alternative financing mechanisms for larger products like SHS are currently limited. The cost of formal credit is lower than informal credit, but access to bank credit is very constrained: banks target high-net-worth individuals and do not provide loans for SHS. Banks also require forms of collateral that most of the unelectrified population are unlikely to have (e.g. land). MFIs can potentially play a bigger role in this space, given their rural infrastructure footprint, but currently, at least in some of the countries, they typically target a narrow band of salaried employees who are likely to already have electricity access, or they provide finance at one level below where the banks provide and one level above what is required for Tier 1 solar customers.

RELATIVELY LOW MOBILE PHONE PENETRATION AND LOW LEVELS OF MOBILE MONEY USAGE. Another barrier to the uptake of both PAYGO and alternative financing models is the relatively low penetration of mobile phones in Cluster 1 countries, the relatively low uptake of mobile money in all of the countries (despite high growth), and the lack of reliable mobile coverage generally in rural areas. The cost and availability of mobile money services is another barrier, especially given demand-side factors like income and affordability. Although mobile money can facilitate clean energy sales, the fact is that people unable to afford a mobile phone are likely unable to afford a solar product.

REGULATORY ENVIRONMENT CURRENTLY NOT CONDUCIVE TO HIGHER-TIER OFF-GRID SOLUTIONS. The current regulatory environment in most of the countries is not conducive to the development of off-grid solutions, and in particular utility-scale IPPs and mini-grids. While the returns on mini-grids are similar to those of a utility-scale or IPP project, the issue is trying to fund their development because the risk profile is significantly higher. After all, the party that buys the electricity is not the government but a community of rural households. The tariffs that mini-grids can charge are often regulated (and sometimes even subject to community approval) and typically not enough to provide the investor with an adequate return for the underlying risk. The lack of cost-reflectivity of grid electricity, lack of adequate legal guarantees for private investors, and lack of authorisation procedures for mini-grid projects also act as deterrents to private investors in clean, off-grid energy solutions. As a result, most activity in this space remains donor funded.

Governments will need to work towards establishing a regulatory framework and business model that can attract the private sector into the clean, off-grid energy space. In some of the countries, governments are developing new regulations to this effect, while others are waiting for proof of concept from donor projects on off-grid solutions.

LACK OF APPROPRIATE QUALITY STANDARDS FOR LOWER-TIER CLEAN ENERGY SOLUTIONS. Most governments do not require imported stand-alone solar PV systems to meet any quality standards, nor do they have standards to control the quality of installation, operation and maintenance of such products. As a result, the market is experiencing an increasing influx of low-quality products. There are also no systems in place for the accreditation of installers. This increases the likelihood of poor-quality imports and installations with a compromised lifespan. Malfunctioning equipment, without proper maintenance support from suppliers, can also undermine trust in clean energy solutions, especially given the affordability issues (and comparatively high cost) of such solutions for the low end of the market. Furthermore, value-added tax (VAT) rules do not differentiate between levels of quality in applications for VAT exemptions; this contributes to a large supply of low-quality solar products and equipment, damaging the product image for household SHS. The VAT exemption is inconsistently applied and fines are inconsistently enforced.

In some of the study countries, donors are working with government to put quality standards in place; but in others, even where regulation is being considered for off-grid, this mostly focuses on mini-grids, with currently no regulation planned for SHS or pico-solar solutions.

Particular challenges of serving the clean energy market for MSMEs

While the MAP clean energy methodology consumer focus is *households*, in the five study countries MSME owners are typically not much better off than the average household, and thus the findings presented in this toolkit for the most part also apply to MSMEs and clean energy.

ENERGY ACCESS NOT GENERALLY MSMES' MAIN CONSTRAINT TO DOING BUSINESS. An observation drawn from the analysis of productive applications across the five countries is that while, in many cases, the majority of MSMEs lack access to electricity, this was not identified as the most significant constraint to operating or growing a business. MSMEs identified several constraints, the major one often being limited access to credit or finance, followed by other challenges such as the lack of suitable premises, unfavourable regulations or tax regimes, and/or challenges of sales/marketing.

LACK OF ACCESS TO FINANCE IS IN MOST CASES MSMES' TOP OBSTACLE TO GROWTH. The constraints MSMEs identify vary by size of business and location, with small enterprises struggling the most in terms of lack of access to electricity, and medium-sized enterprises struggling with this the least; and with rural enterprises struggling in this regard more than urban ones. However, while MSMEs would certainly benefit from electricity access, the lack thereof is not nearly as great a concern as that of lack of access to finance (sourcing money) in most cases (see also the UNCDF MAP SME Investor Toolkit).

NEVERTHELESS, ACCESS TO ELECTRICITY MIGHT BE EASIER TO FACILITATE THAN ACCESS TO FINANCE. The low importance of access to electricity relative to other business constraints reported by MSMEs might mean that although there is a significant access deficit, uptake will likely be limited by low willingness to pay. However, while electricity access was not identified as the major constraint, it might be a widespread constraint that is relatively easy to address, compared to risk protection and access to credit.

MADAGASCAR'S MSMES FLAG BOTH LACK OF FINANCE AND LACK OF ELECTRICITY AS CONSTRAINTS. Of the five countries, Madagascar is an exception in that its lack of access to electricity is perceived by business as the second-most important barrier (after political instability) to doing business. Small and medium-sized businesses also experience on average 6.7 power outages per month with an average duration of 1.5 hours each (i.e. about 2.5 hours per week). Furthermore, high connection fees (USD 165 on average) make grid electricity unaffordable for many small businesses, while those that can afford grid electricity have to wait up to 18 months to get connected.

THREE MAIN CHALLENGES TO MEETING ENERGY NEEDS FOR PRODUCTIVE USES. In general, the challenge of serving the market for productive uses is threefold:

- There is little readily available information on the potential size of the market or the electricity access deficit.
- The market is more fragmented than is the case for households; for instance, not only different types of enterprises but different classifications of enterprises (e.g. micro-enterprises vs small enterprises) need different types of energy solutions, and it is more difficult to reach economies of scale in distribution.
- Small and micro-enterprises have irregular income and often require broader assistance to generate a steady cash flow and become credit worthy (e.g. improvements in financial literacy and farming practices) in conjunction with improved energy inputs.

INCREASING MSMES' FINANCIAL INCLUSION WOULD INCREASE ENERGY INCLUSION. Although financial inclusion remains low for MSMEs, in countries like Malawi and Madagascar they do have higher financial access than the general population; and in Malawi levels of access improved significantly compared to a previous survey in that country. However, levels of access to credit and insurance products, in particular, are very low: in Madagascar, only 15% have any type of formal credit. In most cases, therefore, improving access to appropriate financial products for MSMEs in these income-constrained countries would be a central part of a clean, off-grid energy adoption strategy.

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ENDNOTES

1 Energypedia.

2 ESMAP (2019).

3 Energypedia.

4 Antonanzas-Torres, Antonanzas & Blanco-Fernandez (2021).

5 Although energy-efficient electric stoves are also an improvement, these are not included in the term 'improved cookstoves' for the purposes of this toolkit.

6 Winrock International (2017). Module 5: Technological innovation.

7 UNEP (2019).

8 Winrock International (2017). Module 6: Consumer preferences.

9 GillWiehl, Ray & Kammen (2021).

10 SEforALL.

11 Bhatia & Angelou (2015).

12 Using an inclusive growth lens, MAP clusters countries in terms of commonalities related to financial inclusion in the context of inclusive growth. In particular, five clusters are identified, ordered from lowest to highest across all 14 inclusive growth indicators used by MAP. The clustering ranks well with the HDI as well as GDP per capita; countries in lower clusters typically have lower per capita GDP while countries in higher clusters have higher per capita GDP.

13 World Economic Forum (2017).

14 The estimates do not include adults in Lesotho, although indications from the affordability analysis for Lesotho indicates similar usage patterns.

15 For Lesotho, actual usage could not be calculated. However, only 8% of adults in Eswatini would be able to afford Tier 5 electricity usage, while only 19% (including the 8% of Tier 5) would be able to afford Tier 4 usage. The majority of adults in Lesotho will therefore only be able to afford Tiers 1 to 3 usage levels.

16 The UN population estimates can be used, sourced from the UN Economic and Social Affairs Division.

17 World Energy Council and Food and Agriculture Organisation of the United Nations (1999).

18 The MAP country diagnostics did not get data for all countries, so this is the World Bank-estimated average for mini-grids in Asia and Africa. The MAP diagnostics found that Lesotho and Madagascar have mini-grids but cost would vary based on actual usage, as this is priced per kWh used. An SCP would cost USD 164 in Lesotho, and varies in Madagascar but could be as high as USD 292. This would place it at USD 0.44/kWh in Eswatini and as high as USD 0.80/kWh in Lesotho.

19 Stanistreet et al. (2021).

20 World Bank Group (2014).

21 Nova Economics (2019): interview with SunCulture.

22 World Bank (2019): 9.

23 Frame et al. (2021): 16.

24 Based on average exchange rate for Malawi in 2018 of MKW 730 = USD 1.

25 Frame et al. (2021): 16.

26 World Bank (2013): 8.

27 World Bank (2013): 12.

28 World Bank (2013): 8.

29 Clean Cooking Catalog.

30 FUNAE (Fundo de Energia) is a government-owned and operated fund mandated to advance energy access in Mozambique.

31 World Bank (2013): 8.

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INVESTOR TOOLKIT