

The role of renewable energy mini-grids in Kenya's electricity sector

Evidence of a cost-competitive option for rural
electrification and sustainable development

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Summary

Even with the global electrification rate rising from 83% in 2010 to 89% in 2017, about 573 million people still lack adequate access to electricity in Sub-Saharan Africa. The Sustainable Development Goal (SDG) 7 calls for action to “ensure access to affordable, reliable, sustainable, and modern energy for all” by 2030. It is estimated that investments worth USD 30 to 55 billion per year will be needed to achieve universal electricity access in Sub-Saharan Africa by 2030. Provision of electricity, particularly in rural and remote settings, is inherently challenging and resource intensive. Although large interconnected electric grids are designed to take advantage of economies of scale, distribution efficiency, and cost-optimal generation sites, they also require large upfront investments. These investments are difficult to justify when connecting rural and remote areas with unproven demand and low consumption densities to the centralised grid. Such areas are best served by decentralised systems such as mini-grids. The World Bank has adopted the working definition of mini-grids as “electric power generation and distribution systems that provide electricity to just a few customers in a remote settlement or bring power to hundreds of thousands of customers in a town or city. They can be fully isolated from the main grid or connected to it but able to intentionally isolate (“island”) themselves from the grid”.

An estimated 47 million people are connected to about 19,000 mini-grids globally. Mini-grids provide electricity access to households, public facilities, and businesses using decentralised electricity generation technologies, managed by governmental institutions, private enterprises, or community cooperatives. The deployment of mini-grids has accelerated globally in recent years, driven by the rapidly decreasing costs of renewable energy technologies, which are now the most cost-effective options for mini-grid deployment in many countries. The choice of operator varies; mini-grids can generally be classified as public utility operated, private sector operated, community operated, or hybrid (a mix of two or all of the aforementioned models). Renewable energy mini-grids are expanding in many regions in Sub-Saharan Africa, particularly in countries where rural electrification targets are explicitly complemented by policies and measures for mini-grids. The total off-grid renewable energy capacity in Africa was nearly 900 MW in 2016, a 40% increase from the previous year. Most of this growth came from solar photovoltaic (PV), in the form of mini-grids or standalone solar home systems [Section 1.1]. Multiple studies have shown that mini-grids are the least-cost option for providing electricity to an estimated 100-300 million people in Africa.

Mini-grids have a long history in Kenya, with the first installations dating back to the early 1980s. In recent years, several diesel-based mini-grids have been transformed into hybrid diesel-solar or diesel-wind systems, and several fully renewable energy mini-grids have been deployed. The total installed capacity in 2016 was approximately 25.3 MW, most of which consists of public operated mini-grids [Sections 1.2.1 & 1.2.2]. However, to date, the overarching strategy for Kenya's electricity sector focuses primarily on national grid extension; mini-grids are included but significantly under-represented in the *2018 Kenya National Electrification Strategy (KNES)*. The private sector development of mini-grids has also been restricted due to limited policy support, although this will be improved with the proposed mini-grid regulations in the new Energy Act 2019 [Section 1.2.3].

The Government of Kenya has set a target for 100% access to electricity by 2022. Progress towards this target in recent years has been encouraging, with electrification rates increasing from 36% in 2014 to an estimated 57-70% in 2017. Overall, approximately four million households still lacked access to electricity in 2017, 3.6 million of which were in rural areas. Options for electrifying these non-connected households include the extension of the national grid to rural areas and the installation of off-grid solutions, including mini-grids and solar home systems [Section 2.1]. Independent studies have determined that mini-grids may be the most cost-effective option for a large proportion of the remaining non-connected households in rural Kenya. According to one of these studies, renewable energy mini-grids deployed in 2017 in Kenya are estimated to have a total capital cost of approximately USD 1,000 (KES 103,000) per household connection, with significant potential for cost reduction in the near future. The Africa Mini-Grid Developers Association (AMDA) has reported a steady reduction in the average cost per connection across private sector built and operated mini-grids as the

market in Kenya and Tanzania has expanded: the cost was USD 1,163 in 2017, decreasing to USD 934 in 2018, with further projected reduction to USD 600–700 in 2020. In contrast, recent investments in grid extension to isolated rural areas have resulted in total costs of up to USD 2,427 (KES 250,000) per household connection [Sections 2.2 & 2.3.1]. **Although the 2018 KNES estimates that about 38,661 household connections will be best provided through mini-grids in Kenya, several other studies find this figure to be between 660,000 and 2.1 million connections, representing 17-58% of the non-electrified households in rural areas. Based on this range, mini-grids in Kenya could supply between 180 and 570 GWh of electricity in 2030** [Section 2.3.2]. Despite mini-grids' significant potential contribution to the total electricity supply, this option is not yet sufficiently integrated into current electricity sector policies or strategies or included in the demand and supply calculations of the *2017-2037 Least Cost Power Development Plan (LCPDP)*, which is the central planning document for Kenya's electricity sector. This may be an indication that the potential of mini-grids to contribute to the overall national electricity supply nexus is not yet well understood or could be significantly underestimated.

The potential for upscaling mini-grids in Kenya could be realised through the formulation of a clear policy and corresponding strategy promoting decentralised solutions, including mini-grids, and the integration of this strategy into future updates of the LCPDP. In addition, targeted public interventions could encourage increased private investment in mini-grids; **basic policy interventions, including modest subsidies considerably lower than the current grid connection subsidies in grid extension programmes, could reduce mini-grid project payback periods from over 30 years to just 5.5 years** [Section 2.4]. Rural electrification has historically depended on public finance and employed centralised distribution approaches. Addressing the inadequate electricity access affecting millions of people across Sub-Saharan Africa within the SDG 7 timeframe requires an incremental approach that strengthens existing forms of electrification and supports complementary approaches. **Mechanisms for incentivising private investment in mini-grids need to be explored** as one of these approaches. This report reviews case studies from Chile (Programa de Electrificación Rural (PER)) and Nigeria (Universal Electrification Project: Promoting solar hybrid mini-grids) and explores how their approaches could be applied in Kenya [Section 3].

In addition to being the most cost-effective option for achieving rural electrification in some areas, mini-grids could also have positive economic and social impacts, including synergies with national development objectives and the SDGs [Section 4]:

- **For every 1 MW of mini-grid capacity developed, approximately 800 full-time-equivalent job-years are created for Kenyan workers.** While the total job creation potential for grid extension, the alternative option, would be a similar order of magnitude, it is likely that the proportion of jobs for Kenyan workers and in rural areas will be higher in the case of mini-grid deployment, particularly in terms of jobs created in local construction, community services, ongoing onsite business administration, and other sectors from induced effects. This is especially the case considering regulations require that all solar PV installers – the majority of whom are local experts – be registered with EPRA and the fact that Kenya now has a local solar PV assembly plant in Naivasha [Section 4.1].
- **Using the latest technologies, mini-grid development may contribute to increasing the number of households with electricity access and improving the reliability of electricity supply** in rural areas, where national grid-based electricity supply is frequently disrupted by unplanned outages caused by technical issues and extreme weather events [Section 4.2].
- **Renewable energy mini-grid development can improve domestic energy security by reducing dependence on fossil fuel imports.** If 180-570 GWh of coal-based generation was displaced by mini-grids, coal imports could be reduced by 55-175 thousand tonnes per year, equivalent to cost savings of USD 5.5-17.3 million (KES 550-1,742 million). This would also reduce the demand for foreign currency and improve the import-export balance [Section 4.2].
- **Mini-grids can play an important role in advancing healthcare provision in rural areas.** Lower costs for mini-grids can allow for more connections to medical facilities at the same level of investment.

Furthermore, more reliable electricity provision through mini-grids can lead to improved healthcare services in areas not connected to the main grid in terms of capacity, service hours, and the range of services offered [Section 4.3].

- **Solar mini-grids contribute to enhanced water security in some locations when used for water pumping and where the solar canopy can be utilised for rainwater capture and storage.** Increased deployment of mini-grids also reduces the need for large thermal plants, which require substantial amounts of cooling water in the generation process [Section 4.4].
- **Renewable energy mini-grids offer significant potential for climate change mitigation**, if they displace on-grid fossil fuel power plants. Through offsetting the supply of 180-570 GWh of coal-based electricity, **mini-grids could contribute to reducing emissions by 0.14-0.48 MtCO₂e per year**. This mitigation potential makes mini-grid development an interesting prospect for consideration in climate change mitigation planning processes, and it may be possible to attract further support for the implementation of measures through climate-related finance [Section 4.5].
- **Mini-grids in unelectrified rural areas help improve resilience to the impacts of climate change.** They can offer a degree of autonomy from the national grid and, in the case of climate-related natural disasters, ensure that the communities they serve continue to have access to electricity and are thus better able to cope with the local effects [Section 4.6].

Given mini-grids' cost-effectiveness and proven synergies with sustainable development and national objectives, potential action points, summarised below, have been identified to enable renewable energy mini-grids to progress to the next level and realise the associated benefits [Section 5]. Due to the potential climate change mitigation benefits, international climate finance proposals may also be an option for financing specific actions.

1. Conduct a thorough, up-to-date comparative assessment of the costs of mini-grids and grid extension for rural electrification, considering integration of a shadow carbon price.
2. Formulate a clear strategy for mini-grid development, aligned with grid extension plans.
3. Integrate the strategy for mini-grid development into the next iteration of the KNES.
4. Integrate the strategy for mini-grid development into the next iteration of the LCPDP.
5. Conduct a thorough assessment of rural energy markets to reduce perceived investment risk.
6. Streamline administrative processes for prospective project developers.
7. Identify the most effective financial instruments to maximise investments in rural electrification.
8. Conduct a comparative analysis of various business and management models.

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Abbreviations

AFD	Agence Française de Développement (French Development Agency)
AMDA	Africa Mini-Grid Developers Association
CAPEX	Capital Expenditure
CIF	Climate Investment Funds
CO₂e	Carbon Dioxide Equivalent
DfID	(United Kingdom) Department for International Development
ECN	Energy Research Centre of the Netherlands
EIM-ES	Economic Impact Model for Electricity Supply
EPC	Engineering, Procurement, & Construction
EPRA	Energy and Petroleum Regulatory Authority
ERC	Energy Regulatory Commission
EU	European Union
EU-AITF	European Union-Africa Infrastructure Trust Fund
EUR	Euro
FIT	Feed-in Tariff
GBP	British Pound Sterling
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)
GMG Facility	Green Mini-Grid Facility
GPOBA	Global Partnership for Output Based Aid
GW	Gigawatt
IAP	Indoor and Ambient Air Pollution
IRR	Internal Rate of Return
KEEP	Kenya Electricity Expansion Project
KEMP	Kenya Electricity Modernization Project
KenGen	Kenya Electricity Generating Company
KES	Kenyan Shilling
KfW	Kreditanstalt für Wiederaufbau (German Development Bank)
km²	Square kilometre
KNES	Kenya National Electrification Strategy
K-OSAP	Kenya Off-Grid Solar Access Project
KPLC	Kenya Power and Lighting Company
kWh	Kilowatt-hour

LCOE	Levelized Cost of Electricity
LCPDP	Least Cost Power Development Plan
LMCP	Last Mile Connectivity Project
MOEP	Ministry of Energy and Petroleum
Mt	Megatonne
MTP	Medium-Term Plan
MW	Megawatt
NAP	National Adaptation Plan
NCCAP	National Climate Change Action Plan
NDC	Nationally Determined Contribution (to the Paris Agreement)
NDF	Nordic Development Fund
PER	Programa de Electrificación Rural (Rural Electrification Programme)
PGTMP	Power Generation and Transmission Master Plan
RBA	Results-Based Approaches
RBF	Results-Based Financing
REA	Rural Electrification Authority
RECP	(Africa-European Union) Renewable Energy Cooperation Programme
REMP	Rural Electrification Master Plan
REREC	Rural Electrification and Renewable Energy Corporation
SDG	Sustainable Development Goal
SIDS	Small Island Developing States
SREP	Scaling Up Renewable Energy Programme in Low Income Countries
TWh	Terawatt-hour
UK	United Kingdom
USD	United States Dollar
VAT	Value Added Tax
WEO	World Energy Outlook
WHO	World Health Organisation
Wp	Watt-peak

1 Introduction

Kenya is at an important crossroads in its electricity sector planning, facing decisions on how to work towards achieving the target of universal access to electricity by 2022, while simultaneously developing reliable and cost-effective electricity supply infrastructure in the face of increasing energy demand. Different options will have different implications for other national development objectives, such as job creation and energy security, as well as climate change mitigation objectives.

Traditionally, the government's strategy for increasing access to electricity has focused primarily on national grid extension. Other available options, such as decentralised off-grid solutions in rural areas, are pursued with lower priority, but are increasing in prominence in Kenya and other countries worldwide. With rapidly improving technologies, off-grid solutions are well placed to provide affordable electricity services at different scales, especially in rural areas, and to complement existing national grid infrastructure in order to meet growing energy demand.

This report synthesises available analyses on the role and potential of mini-grids in Kenya and explores how this technology can help the country attain its goal of universal electrification by 2022 and also contribute to achievement of other related development objectives. The synthesis aims to provide policy makers with the required evidence and justification for elevating the position of off-grid solutions in electricity sector development and planning and the political agenda.

The first section of this report provides a summary of the status and trends of mini-grids and the related regulatory environments in Kenya and other countries worldwide. In the second section, the prospects for mini-grids in Kenya, as analysed in other independent studies, are assessed, including analysis of the most recent cost and investment data and the economic feasibility of mini-grids in rural electrification compared to that of grid extension. In the third section, the role of the private sector in promoting electrification through mini-grids is discussed. The needed incentives are highlighted based on case studies from Chile and Nigeria. Section 4 investigates the impacts that renewable energy mini-grids may have on broader sustainable development outcomes, which can be heavily affected by different electricity supply pathways. A fifth and final section provides recommendations for policy makers and practitioners active in the field of electricity sector planning in Kenya.

The report has been developed as part of the *Ambition to Action*¹ project, which seeks to support Kenya in the implementation of its Nationally Determined Contribution (NDC) to the Paris Agreement regarding climate change adaptation and mitigation measures in the electricity sector. The main objectives and activities under this project include the development of evidence-based planning for electricity supply pathways that are compatible with national sustainable development objectives and the alignment of climate planning processes with the overall electricity sector strategy. Part of the project involves the analysis of the potential role of key renewable energy technologies in Kenya's electricity supply mix, with a focus on renewable energy mini-grids and geothermal power generation. This mini-grid focus report has been developed in collaboration with the Ministry of Energy and local and international experts. It aims to support further planning activities in the electricity sector through synthesis and analysis of the most up-to-date information on the prospects and potential impact of renewable energy mini-grids in Kenya.

¹ See the Ambition to Action website at <http://ambitiontoaction.net/> for further details.

2 Current status and trends of mini-grids

2.1 Mini-grids worldwide

An estimated 47 million people are connected to about 19,163 mini-grids globally (ESMAP, 2019). Sub-Saharan Africa has about 1,465 mini-grids serving 14.9 million people, as shown in Table 1. The deployment of mini-grids is currently accelerating rapidly in developed and developing economies worldwide. More than 7,500 mini-grids are planned to be constructed over the next few years - 4,000 of which are based in Africa (World Bank, 2019). The choice of operator varies; mini-grids can generally be classified as public utility operated, private sector operated, community operated, or hybrid (a mix of two or all of the aforementioned models). While there is a diverse range of definitions of what constitutes a *mini-grid* (in some contexts in Kenya, they are also referred to as *isolated grids* or *micro-grids*), such systems are normally understood as those in which relatively small-scale power generation infrastructure is used to provide electricity to multiple nearby users for various purposes. The World Bank has adopted the working definition of mini-grids as “*electric power generation and distribution systems that provide electricity to just a few customers in a remote settlement or bring power to hundreds of thousands of customers in a town or city. They can be fully isolated from the main grid or connected to it but able to intentionally isolate (“island”) themselves from the grid*” (ESMAP, 2019). Mini-grids may be deployed as contained, self-sufficient systems in the absence of access to regional or national power grids, or they may be deployed alongside the national grid to provide backup or improve electricity affordability or reliability. In some cases, mini-grids may be configured – either from inception or at a later date – to function in combination with regional and national grids, with the ability to share power generation capacities and distribution infrastructure. The specific systems vary in terms of generation capacity, technology and technical specifications, selected business and management models, service level, and number of connections, among other characteristics. The relatively small scale nature and fragmentation of mini-grid markets in comparison to on-grid ones globally means that the availability of consistent and comparable statistical information on the current status quo of mini-grids remains very limited (IRENA, 2015). Nevertheless, trends show that investments in mini-grids worldwide are accelerating year on year, while every year, more countries are introducing specific policy instruments to maximise the potential of mini-grids.

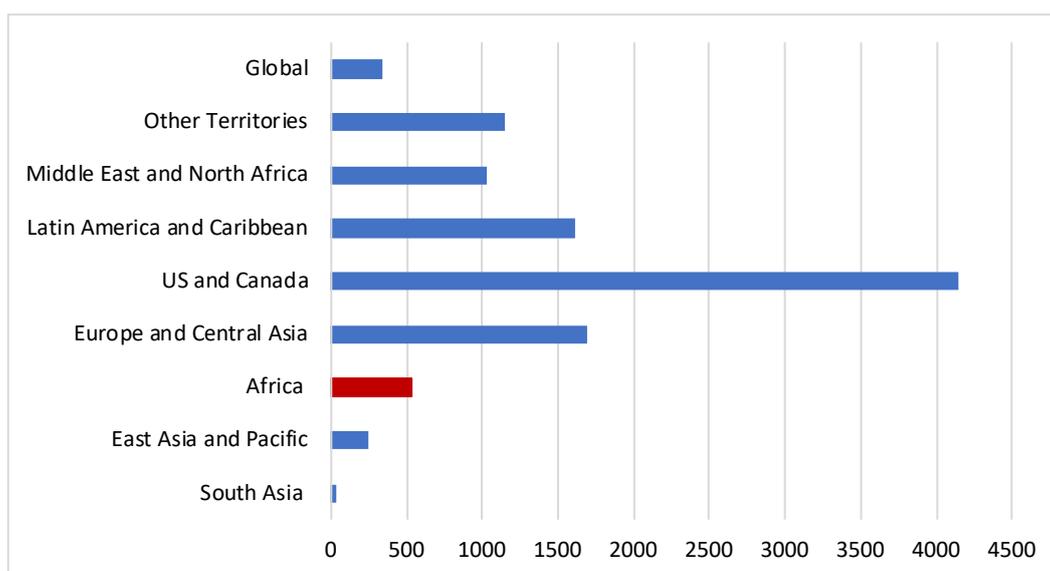
Table 1: Installed mini-grids per region (based on World Bank, 2019)

Region	Number of mini-grids	Number of connections (millions)	Number of people (millions)	Number of developers identified	Mean capital cost (USD/kilowatt)	Total capacity (megawatts)	Total investment (USD millions)
South Asia	9339	2.9	16.2	537	1850	298	632
East Asia and Pacific	6905	2.9	12.1	4158	4379	1721	8236
Africa	1465	3.0	14.9	479	6668	783	3966
Europe and Central Asia	594	0.1	0.3	56	5015	1007	5050
U.S. and Canada	519	0.2	0.6	246	3973	2152	8551
Latin America and Caribbean	283	0.7	2.7	188	3800	456	1632

Middle East and North Africa	31	0.1	0.1	17	3,387	32	110
Other Territories	27	> 0.1	> 0.1	9	3,986	31	125
Global	19,163	10.1	46.9	5,690	4,410	6,481	28,302

Mini-grid systems and technology – including both diesel systems and renewable energy-based systems – first reached a state of maturity and rapid deployment in North America, which accounts for approximately two thirds of installed global mini-grid capacity, with 4 gigawatts (GW) already installed or planned (Schnitzer et al., 2014; IRENA, 2015). Much of the deployment in North America has been driven by desired improvements in the reliability of power supply and its resilience to external shocks, particularly important for industrial and commercial users (IRENA, 2017b). In other regions, the deployment of mini-grids has accelerated as a means of providing electricity access to areas difficult to reach through centralised regional and national grids; in the Asia-Pacific region, Small Island Developing States (SIDS), and Indian sub-continent, mini-grids have achieved significant penetration and a considerable degree of technological maturity. South Asia has the largest number of mini-grids, estimated at 9,339, but also the smallest average size, at 32 kilowatts (kW), compared to Africa's average size of 534 kW. The United States (U.S.) and Canada have the largest mini-grids, with an estimated average size of 4,146 kW (ESMAP, 2019).

Figure 1: Average mini-grid size (kW) per region (based on ESMAP, 2019)



The accelerated deployment of mini-grids in recent years has included – and perhaps partially been driven by – an increasing use of renewable energy generation technologies, which are now the most cost-effective options for mini-grid deployment in many countries. In India alone, the Indian Ministry of New Renewable Energy aims to install an additional 500 megawatts (MW) of renewable energy mini-grid capacity by 2021 (Dalberg, 2017). Although the availability of statistical information remains very limited, significant acceleration in the installation of these technologies can be seen in recent years, with total off-grid renewable energy capacity – including both mini-grids and standalone solutions – doubling between 2014 and 2016 to over 4 GW (IRENA, 2017a). As of 2019, the installed capacity of renewable energy mini-grids is estimated to be 6.5 GW (ESMAP, 2019).

Renewable energy mini-grids are emerging and expanding in many countries in Sub-Saharan Africa (REN21, 2017). Such systems are increasingly cost-effective solutions in many parts of Africa, given the high cost of grid extension due to the remoteness of the non-electrified areas. In particular, Tanzania, Nigeria, and Mali

have made significant initial progress in the deployment of mini-grids. Tanzania has an estimated installed capacity of 158 MW, which is the second highest in Africa, after Madagascar (175 MW), and higher than India (138 MW) (ESMAP, 2019). Rural electrification targets are in place in each of these countries, as they are in Kenya. In Tanzania, the National Rural Electrification Expansion Project includes renewable energy and hybrid mini-grid extension as a pathway for the expansion of electricity access (World Bank, 2017c). In Mali, the Rural Electrification Hybrid System Project also includes the enhancement and extension of existing mini-grids in the country (World Bank, 2017b). The total off-grid renewable energy capacity in Africa – including both mini-grids and standalone solutions – was estimated at nearly 900 MW in 2016, an increase of nearly 40% from the previous year (IRENA, 2017a). Most of this growth came from solar photovoltaics (PV).

In addition to offering a sustainable, cost-effective option for the accelerated electrification of rural households in Sub-Saharan Africa, the wider deployment of mini-grids can bring about other benefits, such as job creation, local industry development, health improvements, etc. To date, there is very little information available worldwide or from specific countries regarding the quantified impact and potential benefits of mini-grids compared to other electricity supply options. This, along with the generally limited availability of statistical information on mini-grids, remains a considerable barrier for research and policy planning.

2.2 Mini-grids in Kenya

2.2.1 Mini-grid development in Kenya

The Government of Kenya has set a target to achieve universal electricity access by 2022, a milestone reflected in Kenya's Vision 2030. A major challenge lies in the geographical distribution of Kenya's population. Approximately two thirds of the population live in the southern belt, where most of Kenya's fertile cropland is located, and can be reached by national grid extension. However, the remaining third is spread across the arid and semi-arid Northern and North-Eastern areas of the country, which are sparsely populated and therefore expensive to connect to the national grid. One possible way forward is the expansion of decentralised electricity generation and distribution networks, including off-grid solutions.

Mini-grids, as one type of off-grid solution, have a long history in Kenya. The first mini-grids date back to the early 1980s, when the Rural Electrification Programme, a government plan to subsidise the cost of electricity in rural areas, made rural electrification a public priority. Traditionally, mini-grids in Kenya were diesel-powered and run by the national utility, the Kenya Power and Lighting Company (KPLC). Since 2011, several diesel-powered mini-grids have been transformed into hybrid systems that have an additional solar or wind power component, while several new mini-grids, powered exclusively by renewable energy technologies, have been deployed. Further hybridisation of existing mini-grids is planned for the near future (AHK Kenya, 2016).

Public sector mini-grids

Most existing larger-scale mini-grids in Kenya are part of the public sector operated electricity supply infrastructure. The national power supply consists of an interconnected grid system and 21 public sector mini-grids, of which 19 are owned by the Rural Electrification and Renewable Energy Corporation (REREC) and managed by KPLC, while the other two are owned and managed by the Kenya Electricity Generating Company (KenGen). Electricity prices for mini-grid consumers are identical with those connected to the national grid, and the mini-grids' higher operating costs are partially cross-subsidised by other national grid customers through the so-called "Rural Electrification Programme levy". To date, all public mini-grids are diesel-powered; twelve of them have been retrofitted with a renewable energy component. The two mini-grids operated by KenGen, in Lamu and Garissa, have recently been connected to the national grid (Ministry of Energy and Petroleum, 2016).

Table 2: Existing public mini-grids in Kenya (based on AHK Kenya, 2016 & DANIDA, 2018)

County (Locality)	Commissioning date	Number of connections (June 2016)	Installed capacity (kW) (October 2018)
Garissa (Daadab)	2016	4,800	784 (diesel)
Homa Bay (Mfangano)	2009	3,000	650 (diesel) 10 (solar, 2013)
Isiolo (Merti)	2007	1,485	250 (diesel) 10 (solar, 2011)
Lamu (Faza)	2017	2,010	1,370 (diesel)
Lamu (Kiunga)	2017	350	260 (diesel)
Mandera (Elwak)	2009	1,700	740 (diesel) 50 (solar, 2012)
Mandera (Mandera)	1979	8,000	3,130 (diesel) 330 (solar, 2013)
Mandera (Rhamu)	2013	400	520 (diesel) 50 (solar)
Mandera (Takaba)	2013	500	320 (diesel) 50 (solar)
Marsabit (Laisamis)	2016	160	264 (diesel) 80 (solar)
Marsabit (Marsabit)	1977	8,200	2,900 (diesel) 500 (wind, 2011)
Marsabit (North Horr)	2016	160	184 (diesel)
Tana River (HOLA)	2007	1,300	800 (diesel) 60 (solar, 2012)
Samburu (Baragoi)	2009	473	240 (diesel)
Turkana (Lodwar)	1976	9,598	3,425 (diesel) 60 (solar, 2012)
Turkana (Lokichoggio)	2010	350	1,050 (diesel)
Turkana (Lokitaung)	2018	34	184 (diesel)
Turkana (Lokori)	2016	150	184 (diesel)
Wajir (Eldas)	2013	342	184 (diesel) 30 (solar)
Wajir (Habaswein)	2007	1,180	1,160 (diesel) 50 (wind, 2012) 30 (solar, 2012)
Wajir (Wajir)	1982	12,055	4,200 (diesel)

There are a couple of public mini-grid expansion initiatives in the works in Kenya. REREC has carried out feasibility studies and is understood to be currently implementing 25 mini-grids. All of them are planned as hybrid systems that combine diesel and renewable (wind or solar) components. Furthermore, the Government of Kenya, with support from the World Bank, has initiated the Kenya Off-Grid Solar Access Project (K-OSAP), which plans to improve access to electricity in 14 underserved counties.² The project is housed under the larger North and North-Eastern Development Initiative, which is a USD 1 billion initiative of the Kenyan government and World Bank to increase investment in the North and North-Eastern regions of Kenya. The programme aims to reach 1,272,525 beneficiaries through 151 mini grids and 250,000 solar home systems. In addition, 1,097 community facilities, including 784 health facilities, 207 secondary and tertiary education institutions, and 106 public offices, will be provided with improved electricity services. USD 40 million is dedicated to the mini-grid component of the project (World Bank, 2018b).

² The 14 counties identified as "underserved" are the following: Garissa, Isiolo, Kilifi, Kwale, Lamu, Mandera, Marsabit, Narok, Samburu, Taita Taveta, Tana River, Turkana, Wajir, and West Pokot (Kenya Power and REA, 2017).

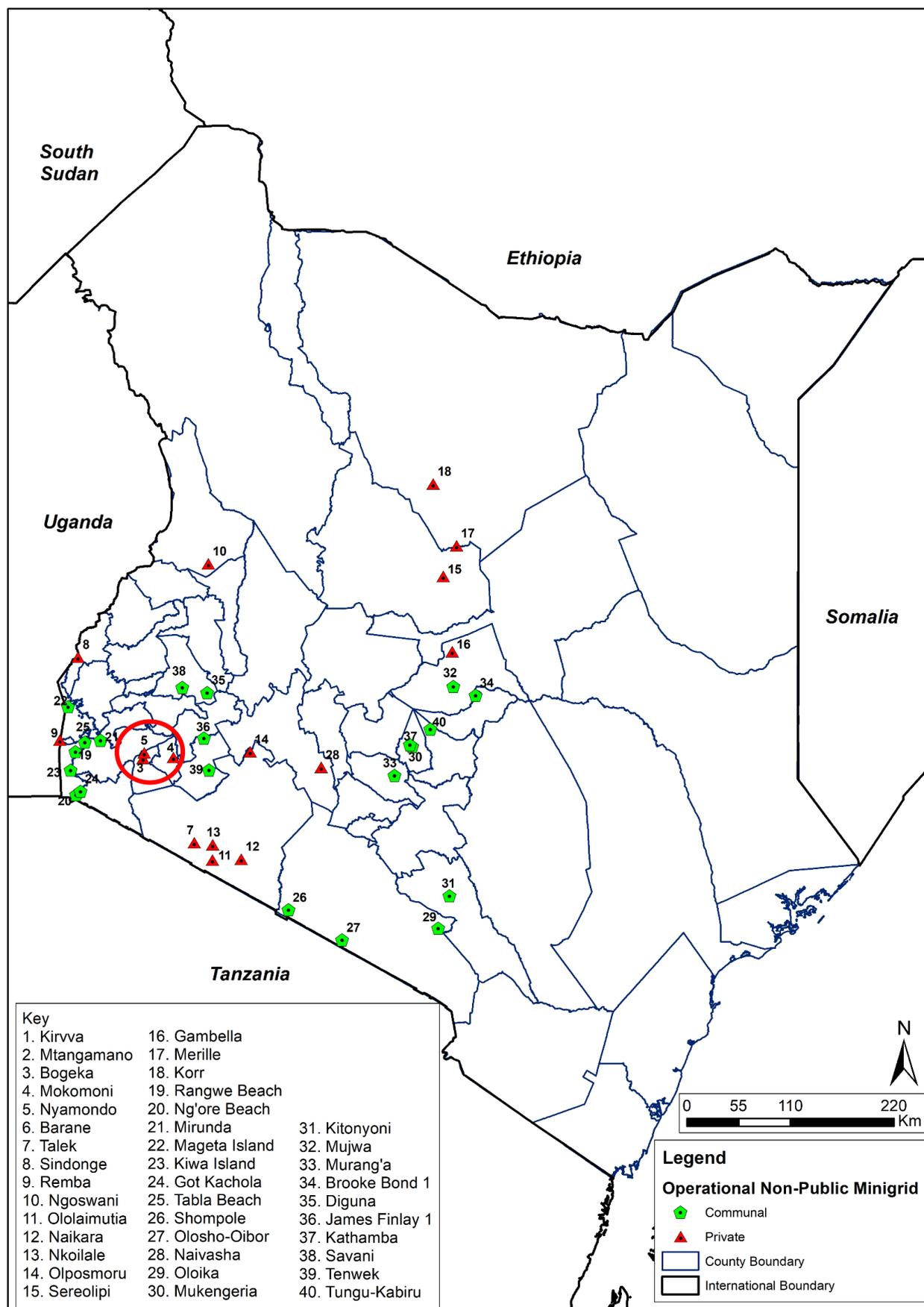
Private sector and community-based mini-grids

In addition to a limited number of public sector mini-grids, Kenya has recently witnessed the emergence of private sector mini-grid projects, generally at a smaller scale than the public systems (see Figure 2 below for a map of the private sector and community-based mini-grids in Kenya). While most of the public sector mini-grids have a standardised method of connecting customers, setting tariffs, and providing customer care support, private sector mini-grids have the flexibility to integrate smart and cost-effective technology and deploy innovative business models. The *Draft 2017 Kenya Energy (Mini-Grid) Regulations* propose that electricity prices for mini-grids with less than 100 kW capacity be determined by grid operators, while prices for larger mini-grids would be determined by the Energy and Petroleum Regulatory Authority (EPRA). These regulations are yet to be approved. In the meantime, to date, at least five private mini-grids have had tariffs approved by the EPRA (MoE, 2019). The generation capacity of private mini-grids is significantly lower than that of public sector mini-grids, often below 10 kW. Total generation capacity in installed private mini-grids reached around 500 kW in 2016, with most of these systems being solar-powered. Private mini-grid operators can integrate the local population into the development of their projects to different degrees, e.g. through community-based grids where the local community is responsible for parts of the infrastructure and/or grid operation. However, since local communities often lack technical know-how and financial resources, they usually rely on a private actor or organisation to develop and implement the project (AHK Kenya, 2016). The most prominent actors in the market are Powerhive, an American technology venture that partners with utilities and independent power producers to promote mini-grids around the globe; and PowerGen, a micro-utility company focused on the design and installation of kW-scale off-grid solar and wind power systems in East Africa. In 2015, Powerhive became the first private utility to obtain a licence from EPRA (Powerhive, 2015). The Powerhive sites are listed as 3, 4, and 5 in Figure 2.

More recently, Vulcan Impact Investing and SteamaCo have established themselves in the off-grid market in Kenya. Vulcan has developed ten solar powered mini-grids (1.5-6 kW each), which are operated in partnership with SteamaCo, a Kenya-based remote monitoring technology company that started as a mini-grid project developer and currently operates a smart metering platform. The ten mini-grids provide electricity for 325 direct and 2,000 indirect users and provide valuable live data and insights that can support the development of more sustainable, scalable mini-grid business models. Vulcan disseminated a series of papers on lessons learned and data analysis throughout the course of 2017 to help catalyse further investment in mini-grids in the near future (Vulcan and SteamaCo, 2016; Vulcan, 2017).

Finally, a hybrid model (public ownership and private operation) has been piloted by the German Development Cooperation Agency (GIZ) at Talek in Narok County. The Talek mini-grid provides electricity to about 1,500 people, with a 50 kW solar hybrid mini-grid. Upon completion by GIZ, the infrastructure ownership was transferred to the Narok County Government, but the system is maintained and operated by a private operator. This model paved the way for and inspired the abovementioned K-OSAP project under the World Bank.

Figure 2: Map of private sector and community-based mini-grids in Kenya³



International support for renewable energy and hybrid mini-grids

A multitude of development partners actively support mini-grid activities in Kenya, with a focus on policy and finance. Beyond the **K-OSAP** project, the World Bank also funds two other electricity sector projects: the **Kenya Electricity Expansion Project** (KEEP, 2010–2017, USD 330 million) and the **Kenya Electricity Modernization Project** (KEMP, 2015–2020, USD 250 million). Kenya is also receiving USD 50 million in highly concessional financing from the **Scaling Up Renewable Energy Program in Low Income Countries** (SREP), which operates under the Climate Investment Funds (CIF) initiative. There are two SREP investment focus areas, with one including a project to support mini-grid hybridisation with USD 10 million, which is expected to leverage USD 58 million (CIF, 2012).

There are also several bilateral institutions that support the hybridisation of existing mini-grids and those under construction. The **French Development Agency** (AFD) is supporting the hybridisation of 23 public mini-grids (17 existing systems and six under construction) with EUR 33 million (AFD, 2015). The **Nordic Development Fund** (NDF) is involved in retrofitting two public mini-grids (Ministry of Energy and Petroleum, 2016).

Under the ProSolar Programme, **GIZ**, in cooperation with the German Development Bank (KfW), is supporting the promotion of solar-hybrid mini-grids in remote rural areas, with a total of EUR 22.5 million. After the implementation of a pilot project in Talek county, three additional mini-grid project sites have been selected, with an expected total capacity of 690 kW (GIZ, 2016). Through the Energising Development Results-Based Financing for mini-grids initiative, EUR 2.1 million was set aside to promote private investment in solar PV mini-grids (Mutonga, 2019).

In addition, the **United Kingdom (UK) Department for International Development** (DfID) is partnering with AFD to implement the Green Mini-Grids programme in Kenya. A Green Mini-Grid Facility has recently been established to provide infrastructure grants, as well as technical assistance. The UK is providing a total of GBP 75 million, of which GBP 60 million is intended to support project preparation and leverage private investment in mini-grids in Kenya and Tanzania, while the remaining GBP 15 million supports a regional facility for market preparation, monitoring and evaluation, and policy development. The facility also provides assistance to the private sector in promoting the development of sustainable and scalable businesses in the mini-grid sector (DfID and AFD, 2017). After the Brexit vote in 2016, the amount of resources committed to the facility was scaled back significantly, reducing the amount allocated for Kenya to GBP 9 million, although an additional EUR 5.6 million was committed from the European Union-Africa Infrastructure Trust Fund (EU-AITF). Grant agreements with three mini-grid developers were signed in 2018. The ranges of approved EPRA tariffs and connection fees are USD 0.5-0.85/kWh and USD 65-95/connection, respectively. The facility aims to enable the installation of 2 MW of generation capacity, support 8-10 companies, and provide 19,000-25,000 connections, benefitting 75,000-105,000 people (Hendricksen, 2019).

Through a partnership with DfID and **Southampton University** in the UK, three further community-based mini-grids have been installed in Kenya: Kitonyoni (13.5 kW), Oloika (13.5 kW), and Shampole (8.4 kW). All three have attracted significant local and international attention (University of Southampton, 2014).

2.2.2 Generation technologies and the role of renewable energy

Although today, most *existing* mini-grids in Kenya are diesel powered, the rapidly decreasing costs of renewable energy technologies, as well as the abundance of renewable energy resources in Kenya, has caused solar and wind energy generation to become more cost-effective options than diesel for mini-grids (Szabó et al., 2011; Zeyringer et al., 2015; Moksnes et al., 2017). Kenya has promising potential for renewable energy-based power generation, given the country's abundant solar, hydro, wind, biomass and geothermal

³ Figure prepared by EED Advisory, based on information from Kenya Climate Innovation Centre (<https://kenyacic.org/>) and Africa Mini-Grid Developers Association (<https://africamda.org/>).

resources.⁴ With the objective to expand renewable energy generation to urban and rural areas at a low cost, the Kenyan government is currently putting more emphasis than previously on the development of grid-connected geothermal and wind power, as well as solar-powered mini-grids for rural electrification (RECP, 2016). Most existing plans for new mini-grids in Kenya are either fully renewable energy-powered or hybrid. Due to the current and increasingly favourable economics of these technologies, the analysis of the costs, prospects, and benefits of mini-grid systems in the following sections focuses on renewable energy mini-grids.

2.2.3 Mini-grid-related legislative and regulatory environment

The legal and regulatory framework in the Kenyan energy sector is currently being reformed, with the aim to align sector activities with targets under both the Kenya Vision 2030 and the Kenyan Constitution of 2010. The *2019 Energy Act* and the *2018 Kenya National Electrification Strategy (KNES)* are two recent outputs of this process. The *Draft Energy Policy* and the *2017 Draft Kenya Energy (Mini-Grids) Regulations* are still under development but are expected to be finalised soon.

Universal access to electricity

The **2018 KNES** provides a roadmap for achieving universal electrification by 2022. As shown in Figure 3, the *2018 KNES* (Ministry of Energy, 2018) recognises the importance of mini-grids in realising this development agenda through electrification of households that are beyond 15 km of the existing KPLC grid. It is the government's intention to connect households within the 15 km radius to the national grid through grid extension (extending medium-voltage distribution to housing clusters within 15 km of the existing grid), as well as grid intensification and densification (extending short – up to 2 km – medium-voltage lines to connect housing clusters that are beyond the reach of existing transformers and the medium-voltage system, and connecting households within a 600 m radius of the transformers).

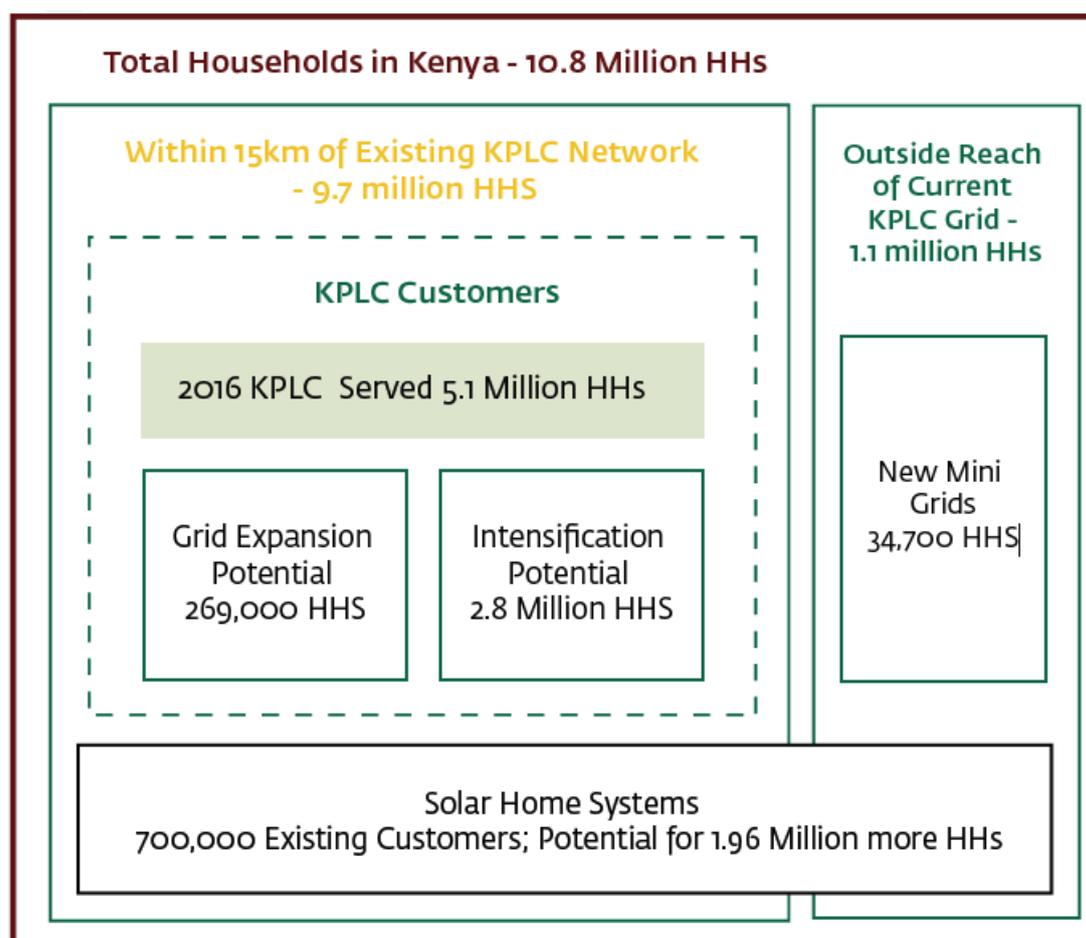
⁴ Recent estimates of the technical potential of renewable energy sources for small-scale mini grid systems in Kenya that are based on solar, wind or hydro are as follows:

Solar: The total potential for photovoltaic installations is estimated to be very high, at 23 terawatt-hours per year (TWh/year), with high insolation rates across the country (RECP, 2016); this would be equivalent to slightly less than the total national electricity demand in 2030 based on the Power Generation and Transmission Master Plan (PGTMP) projections.

Wind: There is an estimated potential output of 22 TWh/year, 4.4 TWh/year, or 1.7 TWh/year, depending on the capacity factor of the installed wind turbines. Particularly high potential lies in the North-Western part of the country and the edges of the Rift Valley, as well as coastal areas (RECP, 2016).

Hydropower: Although mini- and micro-hydropower has a long track record in Kenya, the future reliability of hydro is uncertain in some drought vulnerable areas of the country. Hence, solar and wind power are usually considered the preferred solutions for new small-scale decentralised energy systems.

Figure 3: Least-cost household distribution in on-grid and off-grid areas (Government of Kenya, 2018a)



The 2018 KNES estimates that 151 new mini-grids (revised from an earlier figure of 121) will provide electricity to an estimated 34,700 households. This number was derived from a geospatial analysis of satellite imagery to identify housing clusters that were large enough to justify mini-grid investment. The selected sites have a range of 80-420 potential households each and are spread across West Pokot, Turkana, Marsabit, Samburu, Isiolo, Mandera, Wajir, Garissa, Tana River, Lamu, Kajiado, Narok, and Homa Bay counties. The construction of these mini-grids will be carried out under the K-OSAP project (Government of Kenya, 2018a). The 2018 KNES estimates a cost of USD 856 per mini-grid connection. Solar home systems, with an estimated cost of USD 210 per household, are considered the least-cost option for electrifying approximately 97% of off-grid households in the 2018 KNES.

Energy sector reforms

Rural electrification

The 2019 Energy Act, which was adopted in March 2019, introduced various reforms to the Kenyan energy sector. Among these is the alignment of the energy sector with the Kenya Constitution of 2010 regarding the functions of the national and county governments. County governments are mandated to develop **County Energy Plans** in consideration of the national energy policy and all energy supply options available. These plans, which are consolidated to form the **Integrated National Energy Plan**, are expected to guide the selection of appropriate technologies and energy infrastructure investment to meet demand. The Act also establishes **REREC** as a successor of the Rural Electrification Authority (REA). This not only combines the fields of rural electrification and renewable energy under one authority, but also creates a body tasked with developing renewable energy infrastructure at a more localised level, reaffirming the government's commitment in its NDC to expand exploitation of renewable energy sources. According to its list of functions,

REREC is expected to work in consultation and collaboration with county governments to develop and update rural electrification master plans and renewable energy master plans. Any electrification efforts should therefore be carried out in consultation with REREC and the respective county government.

According to the Act, it is the government's obligation to "*facilitate the provision of affordable energy services to all persons in Kenya*". The Act further recognises that it may, at times, not be commercially practical to engage licenced parties to provide the necessary infrastructure for energy access and therefore gives a provision for the national and/or county governments to provide the necessary funds. The K-OSAP project provides an example of government intervention in remote areas – the intervention is designed to provide a subsidy to private sector players for the construction of mini-grids, which will then be handed over to KPLC for operation. The Act also establishes the **Rural Electrification Programme Fund**, whose objective is to accelerate the expansion of electricity infrastructure in Kenya. The Act designates REREC as the fund manager, with its primary source of financing being levies on electricity sales (up to 5%), in addition to any funds appropriated by Parliament, loans, and grants, among other funds that may be approved by the Cabinet Secretary (Government of Kenya, 2019).

Mini-grid regulations and licencing

Electricity provision in Kenya is regulated by the **EPRA**, the successor of the Energy Regulatory Commission (ERC). Among EPRA's mandates is the regulation and licencing of any entity involved in the generation, importation, exportation, transmission, distribution, and/or retail supply of electricity. The only exceptions are i) licencing of nuclear facilities and ii) licencing of persons generating up to 1 MW of electricity for their own use. This is a more stringent requirement compared to the previous law, the *2006 Energy Act*, in which licence exemptions applied to systems of less than 3 MW capacity. Now, provisions have been made for a permit for persons producing less than 3 MW intended for supply to other persons or generating more than 1 MW (but less than 3 MW) for their own use. Part of the licencing process is EPRA's approval of rates and tariffs, to ensure they are just and reasonable. To this end, the rates are intended to enable licensees to: i) maintain financial integrity; ii) attract capital; iii) operate efficiently; and iv) compensate investors for the risks assumed. The Act thus allows private sector mini-grid developers to argue for cost-reflective tariffs.

Among the grey areas of the regulatory framework is the regulation and licencing of providers of solar home systems (e.g. Mobisol or M-Kopa, which sell solar systems to end users). The **2012 Energy (Solar Photovoltaic Systems) Regulations**, anchored in the *2006 Energy Act*, were developed for manufacturers, importers, vendors, technicians, contractors, and owners of solar PV systems and consumer devices. These regulations require all solar PV installers to be licenced by EPRA, with licencing tiered based on installation capacity: Class T1 for small systems or single battery direct current systems of up to 100 watts-peak (Wp); Class T2 for medium systems or multiple batteries, which may include an inverter; and Class T3 for advanced systems, including grid-connected and hybrid systems (Government of Kenya, 2012). These regulations, however, need to be updated to align with the 2019 Energy Act.

The **Draft 2017 Kenya Energy (Mini-Grid) Regulations**, prepared with the support of GIZ, will fill a significant gap in the policy framework for mini-grid installation, operation, and interaction with the centralised grid. These regulations are expected to reduce the risk for private investors and streamline processes. As mentioned above, the *2018 KNES* identifies mini-grids as a means of increasing electrification in the coming years, particularly in areas that are significantly beyond the reach of the current KPLC grid network (>15 km). However, the most promising sites for public sector mini-grid deployment, as identified under K-OSAP based on geospatial analysis, only target about 3% of households that cannot be served by the national grid. There is therefore potential for private sector mini-grids to bridge the gap and a need for additional policies to ensure that private sector mini-grid players operate legally.

Policy incentives

The policy on Feed-in-Tariffs (FiT) in Kenya has evolved over time. The country first adopted a FiT scheme in 2008 (revised in 2010 and 2012). In late 2016, the government announced a policy shift towards competitive energy auctions replacing the FiT scheme, without finalising the details. The *2019 Energy Act*, however, formally established the **Renewable Energy Feed-in-Tariff System**, whose objectives are: a) catalysing the generation of electricity through renewable energy sources; b) encouraging local distributed generation, thereby reducing demand on the grid and technical losses associated with the transmission and distribution of electricity over long distances; c) encouraging the uptake of, and stimulating innovation in, renewable energy technology; and d) reducing greenhouse gas emissions by decreasing dependency on non-renewable energy resources (Government of Kenya, 2019).⁵ Regulations for the operationalisation of the FiT system are, however, yet to be developed. While both the FiT and the auction scheme might only be of importance for those (private) mini-grid operators that intend to connect their mini-grids to the national grid in the long term, Kenya has introduced tax incentives that apply more broadly to the developers of renewable energy technologies. Under the Value Added Tax (VAT) Amendment Act of 2014, Kenya offers VAT and import duty exemption for several components of renewable energy technologies, including certain solar cells and modules and PV semi-conductor devices, as well as wind engines and hydraulic turbines (IEA/IRENA, 2016). The import duty incentive is administered at the East African Community level.

⁵ While the FiT system established under the 2019 Energy Act supersedes previous FiT regulations, details of the new FiT are yet to be finalised.

3 Future prospects for mini-grids in Kenya

3.1 The challenge of rural electrification

The Government of Kenya's target of 100% electrification by 2022 is widely recognised and mainstreamed in recent policy and strategy documents across sectors, including the 2017-2037 LCPDP, 2015 Draft Energy Bill, and 2018-2022 Draft Medium-Term Plan (MTP), as well as Kenya's NDC to the Paris Agreement.

Electrification rates have risen significantly in recent years; Kenya Power reported a **total electrification rate of 70% in 2017, up from 36% in 2014** (Kenya Power, 2017). Other estimates show that approximately 57% of households had access to electricity in 2017 (Infotrak, 2017). This improvement is largely due to extensive efforts to extend the grid to rural areas in recent years. The first official government-led Rural Electrification Programme started in the early 1980s. In 2006, the REA was established with the mandate to further accelerate the pace of electrification in the country through development and implementation of a range of programmes and projects. Particularly significant progress has been observed in school electrification; 95% of schools were reported to have access to electricity in 2016 (Daily Nation, 2016). 81% of schools got access through grid connections, with the remaining 19% connected to solar mini-grids or site-specific solar energy systems.

While progress towards increased access to electricity has been encouraging, **a wide gap remains between electrification rates in rural and urban areas; 43% of rural households** are estimated to have access to electricity, compared to **87% in urban areas**. Overall, an estimated four million households still lacked access to electricity in 2017, 3.6 million of which were in rural areas (Infotrak, 2017). The *2017 KNES Investment Plan* estimates a lower rate of access to electricity, identifying a need for 5.2 million new connections in the three-year period up to 2020 (NRECA International, 2017).

The Kenyan government seeks to close the existing electricity access gap by providing electricity services specifically to remote, low density, and underserved areas of the country. In a recent study carried out by Kenya Power and REA (in preparation for the K-OSAP project), 14 of the 47 counties in Kenya were identified as "underserved," according to the Constitution of Kenya, 2010. Together, they represent 72% of the country's area and 20% of its population. The underserved counties are characterised by a highly dispersed population, at a density four times lower than the national average. About 1.2 million households in these counties currently have no access to electricity (Kenya Power and REA, 2017).

3.2 Electrification options and costs

Multiple options exist, and are being pursued, for the electrification of non-connected households. These include **grid extension to rural areas, installation of mini-grid solutions, and installation of solar home systems**. The extent to which these options are appropriate and cost-effective solutions for ensuring the future connection of the 4-5.2 million non-electrified households in Kenya is dependent on policies, as well as energy demand profiles. The demand profile of the 2017-2037 LCPDP assumes that all urban and rural electricity demand will be supplied by the power plants connected to the national grid, implying that other options (i.e. mini-grids and solar home systems) may only be medium-term bridging solutions. However, in light of recent economic developments and the impact of decentralised energy on energy security and other socio-economic indicators, the potential of these solutions for medium- and long-term energy supply may be greater than previously assumed.

In order to evaluate the prospects for mini-grids in Kenya in near future, an understanding of the costs of system deployment and how they compare to those of grid extension is required.

However, the costs of off-grid systems are difficult to compare with those of on-grid systems; while on-grid generation units may be compared to each other through common indicators such as the levelized cost of electricity (LCOE) per unit of electricity supplied, such LCOEs cannot be calculated for mini-grids without many assumptions about highly uncertain factors, especially with regard to the rate of household connectivity and future household electricity demand. Furthermore, since major strategic objectives for rural electrification in

Kenya are based on the number of connected households, it is more relevant to discuss the costs of mini-grids and grid expansion projects in the context of the total capital costs per household connection, rather than in terms of the LCOE. This is the approach most commonly adopted in the few other studies that have assessed mini-grid costs in Kenya to date (Zeyringer *et al.*, 2015; Moksnes *et al.*, 2017; Vulcan, 2017), as well as in the *2017 KNES Investment Plan* (NRECA International, 2017).

Mini-grid options and costs

The installation of mini-grids in rural communities can connect households, public facilities, and businesses to decentralised electricity generation technologies, managed by government institutions, private enterprises, or community cooperatives. New mini-grid solutions are more likely to be based on renewable energy generation technologies (solar PV and wind) with battery storage, rather than diesel or other fossil fuel combustion, due to the usually superior commercial viability of these technologies in most rural areas in Kenya (Szabó *et al.*, 2011; Zeyringer *et al.*, 2015; Africa Progress Panel, 2017; Moksnes *et al.*, 2017).

Despite receiving increasing policy attention in recent years, mini-grids are not a major focus of the *2018 KNES*; only 2% of public investment is earmarked for mini-grids, which are planned to provide electricity access to 38,661 new households up to 2020 – less than one percent of the 5.2 million households targeted under the plan (Government of Kenya, 2018a).

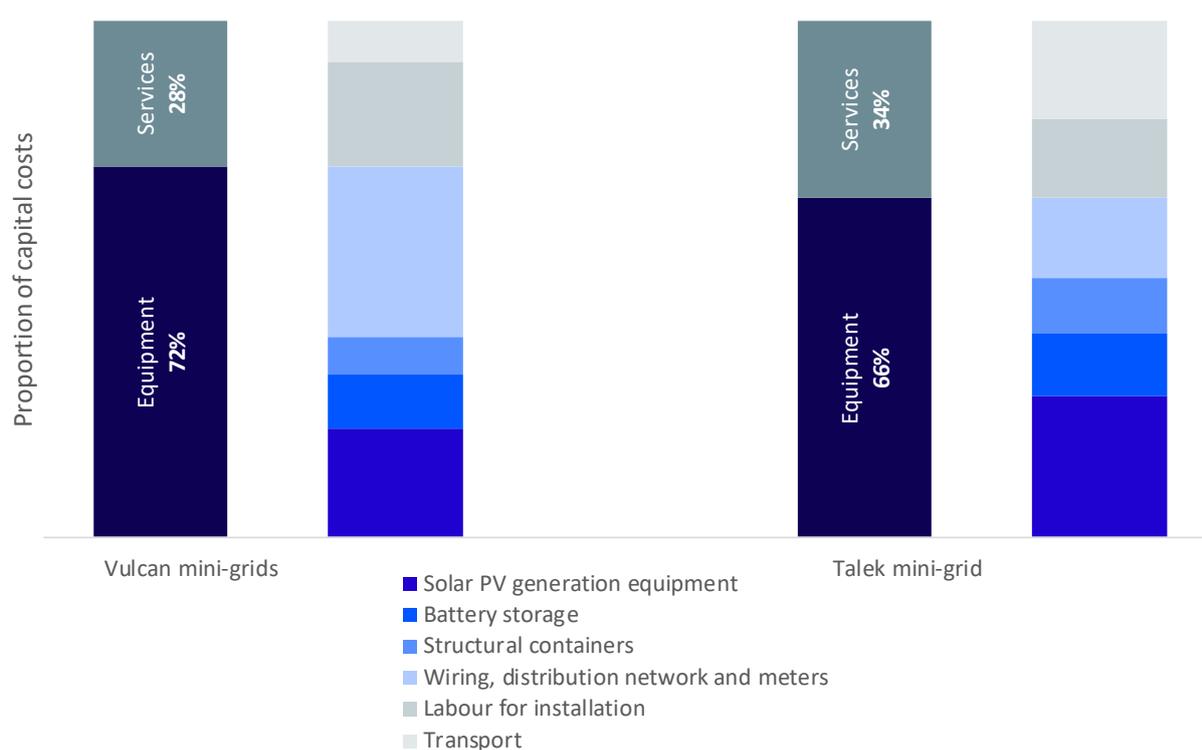
Price structures for end-users currently vary significantly based on the financial models employed by different systems. However, this will be more closely regulated by the *Draft 2017 Kenya Energy (Mini-Grid) Regulations*, which require all mini-grids with a capacity above 100 kW to apply the national uniform electricity tariff (KES 10 per kilowatt-hour (kWh) (USD 0.10/kWh) for consumption below 100 kWh per month and KES 15.80/kWh (USD 0.15/kWh) above 100 kWh in 2019), while smaller systems may charge an additional cost recovery fee, calculated using a determined methodology.

The upfront capital costs and operational costs of renewable energy mini-grids are highly variable across different types of mini-grids. The sophistication of systems and the technologies employed vary significantly, with major implications for capital investments. Despite the variation in the capital costs of different types of mini-grids, most relevant studies consider the costs for relatively small-scale systems that are based on solar PV and can provide 24-hour electricity access through battery storage, which is representative of most new mini-grids implemented in Kenya in the past two years, as well as most of the potential private sector mini-grids in the pipeline.

Analysis of nine mini-grids based on solar PV with battery storage, implemented by Vulcan and SteamaCo between 2014 and 2016, indicated that the average upfront capital costs of these systems amounted to approximately USD 1,430 per customer connection (Vulcan, 2017). These cost estimates are in line with those reported in the *2017 KNES Investment Plan*, which estimated a cost of USD 1,346 per connection (NRECA International, 2017). However, Vulcan (2017) points out that these are the reported costs for systems installed in previous years and estimates that fast technology learning curves are likely to have brought this cost down to **approximately USD 1,000 (KES 102,500) per connection for systems installed in 2017**. This latest cost information is reflected in the *2018 KNES*, which estimate a cost of USD 856 per connection. The trend is also reflected in observations from the Africa Mini-Grid Developers Association (AMDA) on mini-grid investments in East Africa and specifically in Kenya. Based on project data from private mini-grid developers operating in Kenya and Tanzania, AMDA notes that mini-grids' per connection costs are decreasing as the sector expands. The average cost per connection in 2017 was USD 1,163 and decreased to USD 934 in 2018. These costs are projected to decrease even further to USD 600–700 in 2020 (AMDA, 2018). Any comparison of these costs per connection should consider the following factors: i) the type of connections and level of service varies across these systems; ii) some, but not all, of the estimates include the cost of generation; iii) some estimates are arrived at retrospectively, while others are based on geospatial analysis; and iv) the load density (kW/square kilometer (km²)) and consumer density (connections/km²) vary across sites.

Figure 4 shows how these costs break down to different capital cost components, comparing the reported average costs of the mini-grids from the Vulcan and SteamaCo portfolio (Vulcan, 2017) with the costs of the Talek Power Company mini-grid in Narok County⁶, which are relatively similar. Physical equipment accounts for the major share of the costs, of which the most significant costs are the solar PV generation equipment, battery banks, and distribution network and metres. Services, including labour costs for installation and transportation, account for the remaining costs. The cost breakdown gives an indication of the potential for further cost reductions for renewable energy mini-grids; while all cost components are expected to decrease significantly in the case of increased and more efficient implementation of mini-grids, the cost components with the greatest potential for reductions – solar PV generation equipment, battery banks, and labour for installation – currently account for more than 50% of upfront capital costs. Vulcan (2017) estimates that total mini-grid costs could decrease by more than 50% in the near future, compared to the reported costs of systems implemented between 2014 and 2016. Assuming a similar rate of household connectivity, this could translate to an **average cost of approximately USD 700 (KES 72,000) per customer connection** in the coming years, which is consistent with AMDA's projections (USD 600-700 per connection in 2020). The cost per connection may be far lower if the reduced capital costs lead to incentives for more household connections, which become marginally less expensive. On the other hand, factors such as tiers of access and technical standards when compared with the grid could raise the cost significantly.

Figure 4: Breakdown of reported mini-grid costs (based on Vulcan, 2017)



Grid extension and intensification options and costs

The extension of the grid to rural areas can connect households, public facilities, and businesses to centrally generated electricity supply. Grid extension refers to the installation of long medium-voltage lines to extend the grid into new areas, while grid intensification entails the installation of shorter medium- or low-voltage lines (up to 1.5 km) to connect clusters of households in the immediate vicinity of the existing distribution network. Once national grid infrastructure is available in a local area, rural households are required to pay a one-off

⁶ Based on information received directly from the project developers in October 2017.

connection fee of KES 15,000 (USD 146 in 2019), with electricity then charged at the national uniform tariffs, an average of KES 15.80/kWh (USD 0.15/kWh) in 2019 (ERC, 2018).

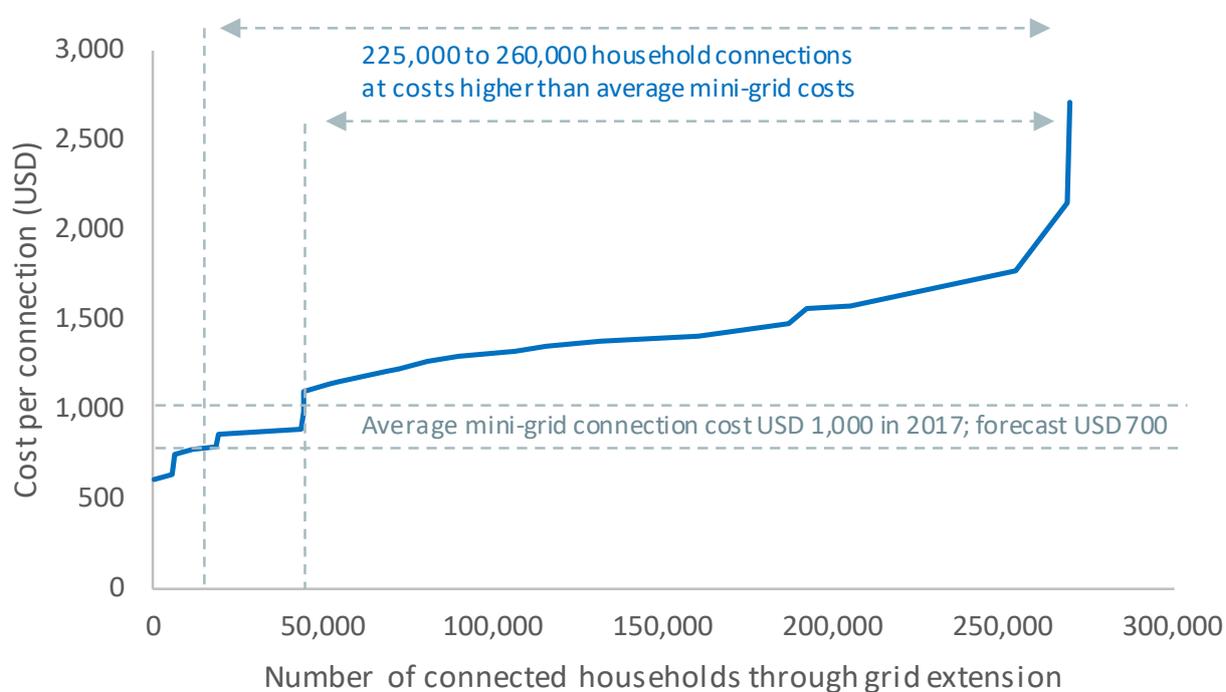
The **Last Mile Connectivity Programme**, supported by the African Development Bank and implemented by Kenya Power since 2016, is targeting up to 800,000 new household connections within two years through grid extension, the installation of new transformers, and subsidies for household connections (KPLC, 2016).

Grid extension and intensification account for approximately 98% of planned public investment under the 2017 *KNES Investment Plan*. Approximately 275,000 and 2.8 million new connections are planned to be achieved through grid extension and intensification, respectively, in the three-year period up to 2020 (NRECA International, 2017).

While grid extension has received significant national focus in recent years, this option becomes increasingly expensive as electrification efforts target increasingly remote communities. While the specific costs of grid extension projects depend on the location of the community and the distance from the existing grid network, analysis of recent rural electrification grid projects indicates that new household connections through grid extension have been achieved at an **average capital cost of approximately USD 2,427 (KES 250,000) per connection** (Lee *et al.*, 2016). This is well above the estimated average connection costs for mini-grids.

In the 2017 *KNES Investment Plan*, the estimated costs for grid extension are lower, at an average of USD 1,377 per household (NRECA International, 2017). Figure 5 depicts the estimated investment cost per household connection for grid extension projects to cover a certain number of households, based on the 2017 *KNES Investment Plan*. As seen in the graph, a high proportion of the household connections would be achieved at higher costs than those of mini-grids. Depending on assumptions for the learning rate of mini-grid technologies, between 225,000 and 260,000 households planned for coverage through grid extension may be more cost-effectively served through mini-grids.

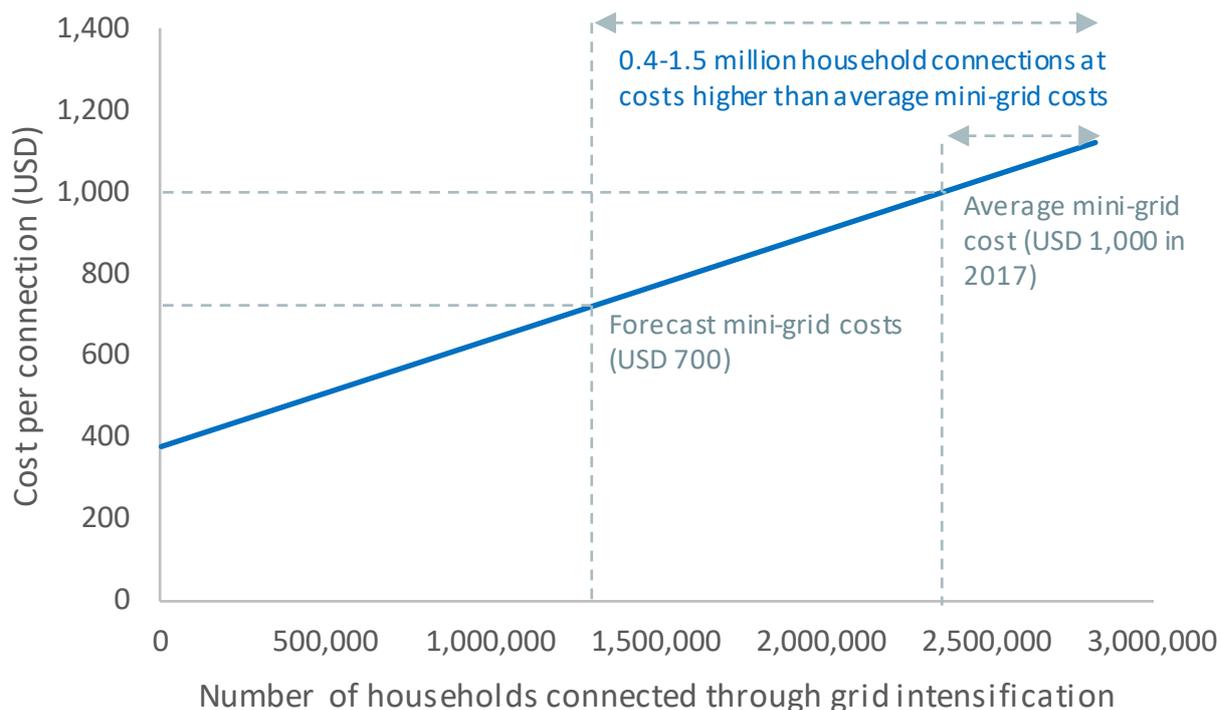
Figure 5: Investment costs associated with grid extension projects between 2018 and 2020, based on the 2017 *KNES Investment Plan*



Similar to grid extension, the cost of grid intensification projects depends on the distance of the households to be connected from the local transformers. Specific costs vary significantly, as grid intensification can involve the connection of households that are situated less than 100 metres or over one kilometre away from a local

transformer. For the 2.8 million planned connections through grid intensification between 2017 and 2019, the *2017 KNES Investment Plan* indicates that connection cost within a 600-metre radius is USD 500 on average, while for connections beyond a 600-metre radius, the average cost is USD 1,234 (NRECA International, 2017). Figure 6 presents the trend line for the average connection cost of all planned grid intensification projects⁷, showing that 0.4-1.5 million households planned for connection through grid intensification may be more cost-effectively served through mini-grids.

Figure 6: Investment costs associated with grid intensification projects between 2018 and 2020, based on the 2017 KNES Investment Plan



Unlike the capital costs of renewable energy mini-grids, those of grid extension and intensification are unlikely to decrease significantly in the near future, since the technologies and equipment typically used for grid extension and intensification are mature and may have reached the peak of their economies of scale. On the contrary, continued efforts to increase the electrification rate through grid extension are likely to lead to higher costs per household connection as communities situated further away from existing grid infrastructure are targeted, as indicated in the *2017 KNES Investment Plan* by the correspondingly increasing costs of grid extension (seen in Figure 5).

In addition to the high costs of grid extension in rural areas, concerns related to electricity reliability also become increasingly relevant in more remote areas, where infrastructure is more vulnerable to natural disturbances and costlier to repair. The utility's response time to supply disruptions also tends to be much longer in remote areas, due to multiple reasons, including accessibility. Recent research on rural electrification in Kenya indicates that, for many rural households and businesses that have access to the national grid, blackouts remain a pervasive issue that has proven difficult to resolve (Enslev, Mirsal and Winthereik, 2018). In contrast, renewable energy mini-grids with battery storage offer more reliable electricity supply in rural areas. In doing so, they endow the rural area with a range of secondary benefits related to improved energy access.

⁷ A trend line is used to estimate costs for grid intensification, due to the lower amount of available cost information in the 2017 KNES Investment Plan, compared to the information on grid extension project costs.

Solar home solution options and costs

The installation of solar home solutions can provide households and businesses with electricity generated on-site, e.g. through roof mounted PV panels. These technologies may provide a cost-effective solution for lighting and powering basic appliances with a light electricity load and for the most remote locations (Moksnes *et al.*, 2017). Due to their limited capacity, however, these solutions are not well-suited to providing electricity for public institutions such as schools or health clinics.

Solar standalone and home solutions were estimated to be used by approximately 700,000 households in 2017. The *2017 KNES Investment Plan* identifies solar home solutions as the only viable option for electrifying more than 2 million households, at a cost of approximately USD 210 per connection. The *2017 KNES Investment Plan* assumes that these costs will be covered through private purchase of solar home solutions, and therefore they are not included in the public investment planning (NRECA International, 2017). However, it is important to keep in mind that the electrification of households through solar home solutions largely depends on the ability and willingness of people to pay for these systems.

Summary of system options for public investment

Table 3 summarises the costs of the electrification system options outlined in the previous sections. The information indicates that under the latest cost estimates for mini-grid projects, between an estimated 625,000-1,760,000 of the household connections planned through grid extension and intensification under the *2017 KNES Investment Plan* may be more cost-effectively implemented through mini-grids.

Table 3: Cost comparison of options for planned household connections under the 2018 KNES (based on: Government of Kenya, 2018a)

System	Planned household connections (2018-2020)	Estimated average cost per household connection (2018-2020)	Household connections that may be more expensive than mini-grid connections
Mini-grids	38,661	USD 700 – 1,000 (Vulcan, 2017)	n.a.
Grid extension	299,601	USD 1,273 (2018 KNES) USD 2,427 (Lee et al., 2016)	225,000 to 260,000
Grid intensification	3,133,308	USD 598 (2018 KNES)	400,000 to 1,500,000
Total			625,000 to 1,760,000

3.3 The potential role of mini-grids in the Kenyan electricity sector

3.3.1 Potential for mini-grid roll-out in Kenya

Based on the assumption that decreasing costs can make mini-grids a more cost-effective means of achieving household connections than grid extension, a number of independent studies estimated the feasibility of mini-grids compared to on-grid systems and the potential scale of mini-grid roll-out in Kenya.

Various factors are influential in determining the feasibility and potential scale of mini-grid implementation in Kenya. Mini-grids are most feasible in locations where the size of the community and the volume of projected electricity demand are sufficient to ensure adequate revenue for the repayment of capital expenditure, but not large enough to justify the cost of grid extension, which is dependent on the distance of the community from the central grid (IED, 2013; DfID, 2014; Opiyo, 2016; Moksnes *et al.*, 2017). The availability of renewable energy resources in the local area is also a factor that positively impacts the feasibility of mini-grids in any

given location.⁸ Economic activity, level of household income, and system expansion potential are often considered as factors that provide a good indication of projected electricity demand (MOEP, 2016).

The 2014 World Energy Outlook (WEO) estimated that mini-grids would be the most viable option for electrification in approximately half of non-connected rural areas worldwide, with more than 140 million households worldwide projected to obtain new electricity connections through mini-grids under the WEO's New Policies Scenario (IEA, 2014).

Estimates of the potential of mini-grids in Kenya vary across studies, the results of which are summarised in Table 4. According to these results, mini-grids may offer the most feasible or cost-effective option for the electrification of and long-term electricity provision to 1-2.1 million households in Kenya; this is roughly in line with the findings of Section 2.2, which estimated approx. 0.6-1.8 million households. A range of 0.6 million to 2.1 million households represents 16-53% of the remaining non-electrified households in Kenya in 2017, or 18-58% of the non-electrified households in rural areas. The large range of results across studies indicates uncertainty concerning the potential feasibility of mini-grids in Kenya, depending on the approach taken and assumptions made. The range, however, confirms the consensus across all studies regarding the potentially significant role of mini-grids in rural electrification.

The estimates of mini-grid potential given below in Table 4 are based on the current characteristics of settlements in rural Kenya and the cost optimum pathways for long-term electrification. Two factors indicate that the potential of mini-grids may be even higher than the estimates from the studies. First, all of the studies in Table 4 assume that mini-grids are no longer viable below a certain population density threshold, after which standalone solar home systems provide the most realistic supply option for such remote households. However, some stakeholders argue that the establishment of mini-grids in rural areas with more dispersed populations could encourage the growth of more concentrated communities and markets in these locations, and thus, the potential of mini-grids might be greater than anticipated. Second, even in areas where mini-grid solutions are less likely to be the most cost-effective option in the long term, they may still be viable in the short or medium term as a bridging solution, until grid extension is feasible and within the capacities of the responsible institutions. .

⁸ Comparing the costs of off-grid diesel and solar PV, Szabo et al. (2011) found highly favourable solar radiation potential in almost all areas of Kenya.

Table 4: Overview of studies of mini-grids' potential for electricity supply in Kenya

Study	Summary & mini-grid potential
Carbon Africa Limited et al. (2015) <i>Kenya market assessment for off-grid electrification</i>	This study assesses the commercial viability of mini-grids without external support (e.g. government subsidies). The results indicate that mini-grid operations are more likely to be commercially viable in relatively higher income rural communities, accounting for approximately one third of currently non-electrified communities, although the viability could increase significantly if the capital expenditure (CAPEX) were reduced through market forces or government intervention. The study does not assess what this means in terms of households; a third of currently non-electrified rural communities would likely cover approximately one million households ⁹ .
DFID (2014); IED (2013) <i>Green Mini-Grids Africa business case</i>	A study conducted for DfID using Geographic Information System (GIS) data and a number of criteria based on the economic cost of electricity supply calculated the potential for mini-grids in Kenya to be around 23% of total connections across the population. This is equivalent to 2.1 million rural households , approximately 58% of the non-electrified households in 2017.
MOEP (2016) <i>Current activities and challenges to scaling up mini-grids in Kenya</i>	A recent study from the Kenyan Ministry of Energy and Petroleum re-quotes the finding from IED (2013) that mini-grids could account for approximately 23% of total connections in Kenya (see further details above).
Moksnes et al. (2017) <i>Electrification pathways for Kenya</i>	The authors analyse a high electricity demand scenario in line with the 2015-2035 PGTMP, finding that under a cost-optimal approach, 4.95 million Kenyans could be served by mini-grids up to 2030. This represents approximately 1.2 million rural households ¹⁰ , around 30% of the non-electrified households in 2017.
Opiyo (2016) <i>A survey informed PV-based cost-effective electrification options for rural sub-Saharan Africa</i>	Looking at the economics of different electricity supply options and household willingness to pay specifically in the Kendu Bay area of Kenya, this study estimates that a cost-effective scenario for 100% rural electrification would result in approximately 36% of the remaining non-electrified rural households being served by community-based solar PV mini-grids; scaled up to the national level, this would be equivalent to approximately 1.3 million rural households .
Zeyringer et al. (2015) <i>Analyzing grid extension and stand-alone photovoltaic systems for the cost-effective electrification of Kenya</i>	This study compared the cost of grid extension to stand-alone solar PV applications (including both mini-grids and solar home systems) for spatial areas across Kenya, based on distance from the grid and anticipated electricity demand, concluding that off-grid solar PV systems would be the most cost-effective electricity supply option for 17% of households in Kenya in 2020, equivalent to approximately 2 million households . The study is based on relatively old data on system costs that do not fully capture the technology learning rates in recent years, particularly for PV and batteries. The rate of off-grid solar PV applicability may therefore be even higher if this data were to be updated.

⁹ The number of households estimated is based on the assumption that, of the 3.6 million currently non-electrified households in rural areas (Infotrak, 2017), approximately 350,000 are situated in remote areas outside of communities with feasible densities (based on the results of Moksnes et al (2017)), which means that about 1.4 million people would be best served by standalone home solutions, even at a high level of electricity demand, due to their isolation).

¹⁰ The 2015-2035 PGTMP estimates there will be an average household occupancy of 4 people in rural areas by 2030 (Lahmeyer International, 2016).

3.3.2 Implications for national electricity sector planning

Recent independent studies point out that the costs of the planned grid extension projects under the *2017 KNES Investment Plan* may be higher than the expected mini-grid costs, and mini-grids could represent the most cost-effective option for electrification of 660,000-2.1 million rural households.

Despite this high range, as calculated in recent studies, the potential for mini-grids is estimated at only 38,661 household connections in the *2018 KNES* and is therefore not explicitly included in the demand and supply calculations of the 2017-2037 LCPDP. This may be an indication that the potential of mini-grids to contribute to the overall national electricity supply nexus is not yet well understood or may be significantly underestimated due to outdated information on system costs.

The 2017-2037 LCPDP demand forecast for the reference scenario is built on the assumption that the average annual household electricity demand in rural areas will be approximately 270 kWh by 2030. In the case that between 660,000 and 2.1 million households were electrified through mini-grids and not connected to the national grid, the **annual load on the national grid would be reduced by approximately 180-570 GWh**.

This indicates high potential that may not be fully considered in current electricity sector planning. For comparison, coal is projected in the reference scenario of the 2017-2037 LCPDP to supply 603 GWh of electricity in 2030¹¹.

While these estimates are only illustrative, they indicate that a more thorough and up-to-date assessment of the potential of mini-grids and their role in overall national electricity supply may be needed and in Kenya's interest. Significant cost savings may be achieved when reconsidering currently planned investments in grid expansion and power generation capacity additions, which may not represent the most cost-optimal approach for national electrification.

3.4 Challenges and opportunities for scaling up renewable energy mini-grids

Even though there is great potential to scale up renewable energy mini-grids across the country, the implementation of these systems has been rather limited. In particular, private project developers continue to refer to prevailing financial and policy conditions as barriers to investment. Some of the major barriers, along with opportunities for policy interventions, are summarised below.

Low level of government support and high investment risk for private project developers

While the private sector has shown a considerable appetite for mini-grid development in other countries, private investment in mini-grids in Kenya remains limited due to uncertainty concerning the financial viability of potential projects. The theoretical analysis of financial viability is based on current or future capital costs, which have reduced drastically in recent years, and are set to fall further. However, since most existing mini-grids in Kenya were installed in previous years, with considerably higher capital costs than those in the current scenario, there are only a limited number of practical experiences that can demonstrate a successful business case. Furthermore, the investment risk is compounded by the high uncertainty around electricity demand projections and willingness to pay (GIZ, 2016; Vulcan, 2017). Analysis of a mini-grid project portfolio operated by Vulcan and SteamaCo shows that policy instruments to increase demand growth reliability and subsidise connections in the short term could reduce project payback periods from over 30 years to just 5.5 years, resulting in an attractive ten-year internal rate of return (IRR) of 15% (Vulcan, 2017). The subsidy required to create these conditions is USD 500 per connection, significantly lower than the average non-recoverable

¹¹ Although the planned coal power plants, according to committed projects, will technically be able to generate approximately 6,000 GWh in 2030, the 2017-2037 LCPDP plans for the coal plants to operate at a lower capacity and supply only 603 GWh in the reference scenario, or 2,626 GWh in the vision scenario, due to the more competitive dispatch costs of other electricity generation options (Government of Kenya, 2018b).

costs incurred for rural connections through grid extension (Vulcan, 2017). These benefits, however, need to be weighed against the high cost-reflective tariffs that need to be charged in order to improve the business model. In some cases, the cost-reflective tariffs are up to 5 times the national domestic tariff.

Uncertainty regarding the potential interaction of mini-grids and national grid infrastructure in the event of future grid expansion

The prospect of national grid extension could be perceived as a threat to the viability of mini-grid installations for potential investors, in the case that future grid extension to a community served by a mini-grid acts as a competitor for a limited electricity demand base (AfDB, 2016). This issue has been effectively addressed in other countries through the design of policy instruments that specify conditions under which the interaction of mini-grids and the national grid creates opportunities for the operators of both entities. For example, certainty about the ability to sell generating capacity and community-level grid infrastructure to grid operators at a later date could significantly improve the economic viability of mini-grids for potential investors. Provisions for this are included in the *Draft Kenya Energy (Mini-Grid) Regulations 2017*, which, if they come into force, may provide more certainty for potential grid operators.

Lack of clear strategy for the deployment of mini-grids and grid extension projects

Despite the significant potential role that mini-grids could play in Kenya's electricity sector, they are under-represented in energy planning documents, including the *2017 KNES Investment Plan*. Furthermore, uncertainty about grid extension plans is a considerable barrier for private and public mini-grid developers. A timeline of grid extension projects has been included in the 2015-2035 PGTMP, but the level of detail is low, and the level of commitment and certainty of implementation, unknown (GIZ, 2016). Further details on grid extension planning, with clear reference to well aligned plans for a mini-grid deployment strategy, may mitigate this uncertainty.

Extensive licencing procedures for private sector project developers

Procedures to obtain a licence for mini-grid operation in Kenya are often lengthy, bureaucratic, and unpredictable, representing a further risk and disincentive for private investment. Other countries have successfully addressed this issue by waiving licence requirements for the smallest-scale operations and streamlining licencing procedures for other projects (AfDB, 2016). The *2017 Draft Kenya Energy (Mini-Grid) Regulations* aim to address this issue, proposing a simplified process for mini-grids below 100 kW.

Lack of information on rural energy markets

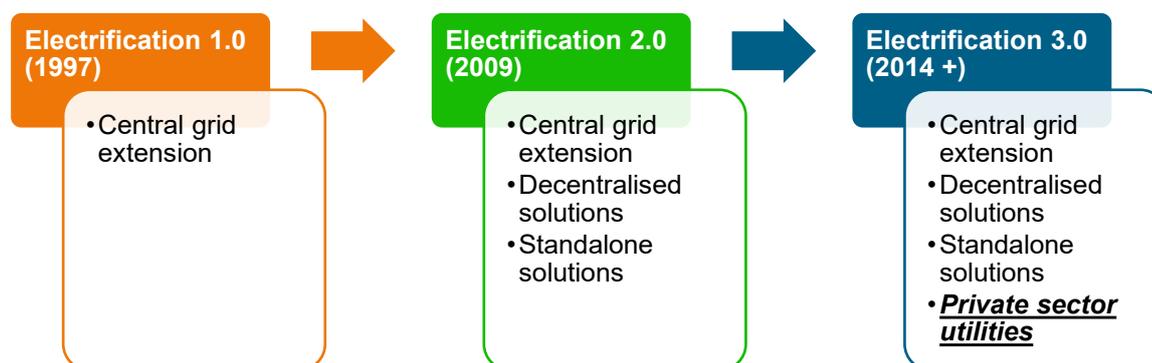
The lack of accurate information on the precise number and location of off-grid communities, as well as income and consumption patterns in rural areas, makes it difficult to estimate electricity demand and create a business case for mini-grid projects. Enhanced information exchange amongst existing projects, along with better access to the most recent household surveys in rural areas, would significantly improve the ability to get reliable information on rural energy markets.

4 Potential role of private sector mini-grids

4.1 Historical context

The global history of electrification points to a high dependency on public resources and promotion of centralised approaches to electrification. The *1997 Kenya Rural Electrification Master Plan (REMP)*, covering 46 of the then 68 districts, focused on national grid extension, without fully integrating decentralised electrification or standalone options. This approach changed in the *2009 REMP*, which incorporated off-grid electrification approaches. Due to this shift, more than twenty mini-grids were constructed and commissioned by REA (now REREC) and are currently managed by Kenya Power. REA's *2008 Strategic Plan (2008-12)* estimated that 63% of all households were within sub-locations connected to the grid, demonstrating a fairly high potential access rate, in spite of the low connectivity rate (REA, 2008). Due to the high cost of grid extension, REA adopted a strategy to connect all trading centres and to have these serve as nodes for providing electricity services. More recently, through the Last Mile Connectivity Project (LMCP), Global Partnership for Output Based Aid (GPOBA) slum electrification project, and K-OSAP project, the government's approach has expanded beyond merely extending the central grid to adopting more appropriate and responsive approaches to electrification, including decentralised solutions (see Figure 7 below). In addition to the inclusion of decentralised approaches, private sector built and operated mini-grids now form part of the electrification portfolio. Five private sector mini-grid developers have received licences to operate independent utilities.

Figure 7: Expanding the definition of rural electrification¹²



Electrifying remote rural areas is capital intensive. Addressing the inadequate access affecting millions of people across Sub-Saharan Africa within the SDG 7 timeframe requires an incremental approach that strengthens existing forms of electrification and supports new and innovative approaches. While public resources will remain a key part of this effort, concerted effort is needed to harness substantial private investment in rural electrification and, thus, bridge the funding gap. Remote areas, far away from a centralised grid and with concentrated loads, are best electrified using mini-grids. This has been the strategy preferred under many rural electrification programmes across Africa.¹³ Mini-grids are the least-cost option of electrifying between 100 million and 300 million people in Africa (Tilleard, Davies and Shaw, 2018) and should therefore be integrated into rural electrification plans. The choice of operator varies; mini-grids can be public utility operated, private sector operated, community operated, or hybrid. While the technical feasibility is proven across all these approaches, the ability to scale up under the second category is limited by, among other factors, the lack of viable business models that can attract substantial private investment. Unclear or unsupportive policy environments, limited access to finance, foreign exchange risks, limited understanding of

¹² Graph by EED Advisory.

¹³ Several countries have a Rural Electrification Programme/ Strategy that incorporates mini-grids, including Senegal, Cameroon, Nigeria, Tanzania, Niger, Sierra Leone, Mali, Kenya, and Zambia, among others.

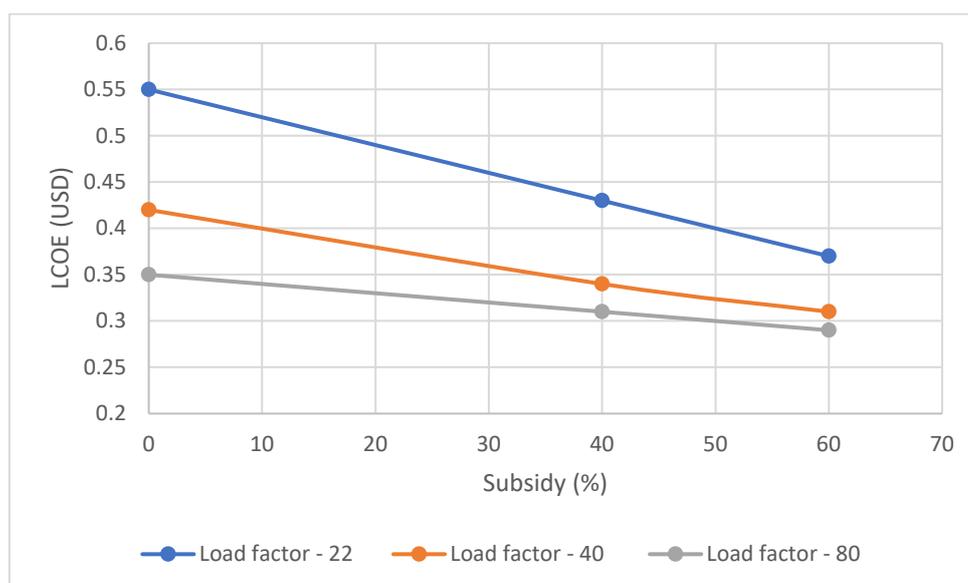
the market, a lack of technical standards, and previous dependency on public finance for rural electrification also constrain private investment. Incentivising private investment in rural electrification is therefore critical to increasing access to electricity in Sub Saharan Africa.

4.2 Cost reduction options

Cost-reflective tariffs, when determined by mini-grid operators, are almost always higher than those offered by the main utilities. In Kenya, the approved private sector mini-grid tariffs range between USD 0.5 and 0.85/kWh (Hendricksen, 2019), compared to the much lower national domestic tariff, set at USD 0.10/kWh (KES 10/kWh) for the first 100 kWh consumed per month (ERC, 2018). This puts the private sector mini-grids at a disadvantage. Furthermore, the national utility receives subsidies at multiple levels, including connection subsidies and tariff cross-subsidies for areas powered by public sector managed mini-grids. For private sector mini-grids to be competitive, similar incentives need to be provided. Traditionally, public sector funding arrangements have placed an emphasis on inputs and activities with linkages to the desired outcomes and impacts (World Bank, 2018a). There is now a growing consensus that Results-Based Approaches (RBA), including Results-Based Financing (RBF)¹⁴, have the potential to improve resource allocation by addressing inefficiencies, providing a stronger focus on much needed results and crowding in private investment. The Green Mini-Grid (GMG) Facility in Kenya provides these types of results-based incentives. There are four main advantages to this approach: (i) transferring part of the risk to the implementing partner; (ii) promoting transparency and accountability; (iii) improving effectiveness by focusing on results; and (iv) supporting innovation and allowing flexibility in pathways for achieving results (EED Advisory, 2019). This also crowds in upfront private investment. In an RBF scheme, payment is triggered by an independently validated result, which ensures that private investment precedes public finance, thus lowering the risk and occurrence of misappropriation of funds set aside for electrification. Pricing such subsidies is, however, a difficult process, as the CAPEX can vary greatly across mini-grid projects. Estimating the average cost of a connection depends on a range of factors, including area load density (kW/km²), consumer density (connections/km²), consumption density (kWh/km²), and installation cost (USD/W). These factors, in turn, are influenced by the load profile, total load, system design, source of electricity, and other factors (e.g. taxes, supporting infrastructure, ease of doing business, and cost of finance). A recent World Bank benchmarking report found that the cost of connecting one customer to a solar PV powered mini-grid varied significantly, ranging globally from USD 681 to USD 4,346 (World Bank, 2017a).

Similarly, the LCOE is determined by several factors, with the load factor, which is influenced by the peak load, and load variability being key. The load factor has a significant impact on the cost of electricity; higher load factors translate to more efficient use of the capital investment, lowering the cost of electricity, while lower load factors have the inverse effect. An independent study on mini-grids demonstrates that a shift in the load factor from 22% to 80% can lower the cost of electricity by almost 50% (from USD 0.55/kWh to USD 0.29/kWh) depending on the percentage contribution of available subsidies, as shown in Figure 8 below (ESMAP, 2019).

¹⁴ RBF is part of a group of financing mechanisms including Output Based Aid, Payment by Results, and RBA, collectively known as Results-Based Financing Approaches.

Figure 8: Impact of load factor and subsidies on LCOE¹⁵


Subsidies and other financial incentives are important in enabling private sector mini-grids to take on a more mainstream role in accelerating the pace of electrification across Africa, in line with SDG 7.

4.3 Incentivising private investment: case studies

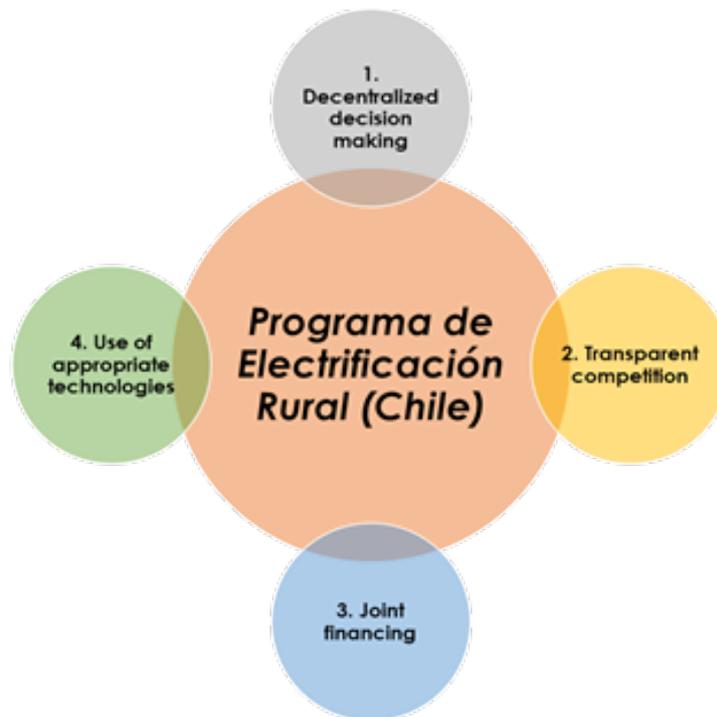
Chile National Programme for Rural Electrification (Programa de Electrificación Rural, PER)

In the early 1990s, only 53% of the rural population in Chile had access to electricity, compared to 97% of the urban population (Feron, Heinrichs and Cordero, 2016). Rural electrification efforts were all publicly funded within a constrained funding environment. Other sources of funding were needed if the rural electrification gap was to be bridged. The private sector was seen a potential source of additional capital. The Rural Electrification Programme (REP), administered by the National Fund for Regional Development, was set up in 1994 to facilitate competitive private investment in decentralised electrification. The programme's design principles are depicted in Figure 9 below. The aim of the programme was to transform rural electrification into an attractive business opportunity for which the government would provide subsidies, supplemented by grants from international organisations and user contributions. Typically, the connection cost was split between the users, companies, and the state in a 10:20:30 ratio. To transform the electricity sector, the government privatised the electric utility companies but did not give them monopolistic concessional rights. The government provided a one-time direct subsidy for the project investment through a competitive bidding process, which was evaluated based on a cost-benefit analysis, the proportion of investment by the bidding company, and the project's social impact. This led to an increase in the electrification rate in rural areas from 53% in 1992 to 76% in 2000 (World Bank, 2000b). Chile has now attained universal access to electricity.

According to a review by Alejandro Jadresic (World Bank, 2000a), the principles of the programme design that led to its success included: 1) decentralised decision making (the sub-national government sets priorities and selects the best offers); 2) joint financing (funding was shared by the government, companies, and users); 3) competition (the bidding process was simple and transparent, with an emphasis on social impact and cost-effectiveness); and 4) use of appropriate technologies (innovation in generation and distribution was used by the companies to advance their competitive edge).

¹⁵ Graph by EED Advisory, with data from ESMAP, 2019.

Figure 9: PER’s design principles (based on World Bank, 2000a)



Nigeria Universal Electrification Project: Promoting solar hybrid mini-grids

The Nigeria Universal Electrification Project, which is being implemented by the Nigerian Rural Electrification Agency with support from the World Bank, has the objective of “increasing access to electricity services for households, public education institutions, and micro-, small-, and medium-sized enterprises throughout Nigeria” (REA, 2019). The project has four components, including two that seek to promote the uptake of solar hybrid mini-grids, through provision of i) a minimum subsidy tender and ii) performance-based grants. USD 80 million and USD 70 million, respectively, have been set aside for these incentives.

The minimum subsidy tender allows private companies to bid for 250 identified mini-grid sites in the Niger, Sokoto, Ogun, and Cross River states, shown in Figure 10. Feasibility details, including population clusters, number and type of productive loads, and estimated load profiles will be provided at the bidding stage. 20,000 households and 1,000 small- and medium-sized businesses are expected to be electrified under the project.

Figure 10: Target states under the minimum subsidy tender (Nigeria Universal Electrification Project)



The performance-based grant is made available on a rolling basis, and private developers are required to identify sites, carry out the feasibility studies with support from Rural Electrification Agency zonal offices, obtain required licencing and permit documents, and construct the mini-grids. The incentive is fixed at USD 350 per connection and disbursed on a first-come-first-served basis once the connections are made (REA, 2019).

The two approaches are designed to test the efficacy of disbursing incentives to private sector developers, with one based on price discovery using an auction styled approach (minimum subsidy tender) and the other based on a predetermined, fixed price. The programme in Nigeria is the largest private sector mini-grid subsidy programme in Africa and is expected to yield useful lessons for similar interventions (REA, 2019).

5 Impacts of renewable energy mini-grids

The analysis presented up to this point has found that mini-grids may be the most cost-effective option for providing electricity access to 660,000-2.1 million households in rural Kenya. In addition to the economic analysis, the broader benefits that renewable energy mini-grids could have in terms of synergies with other SDGs and national objectives need to be examined.

Box 1: Non-financial benefits of renewable energy mini-grids

Many arguments for renewable energy mini-grids, as compared to diesel based mini-grids, are financial or economic in nature. These arguments emphasise the continuously decreasing costs of energy storage and increasing affordability of renewable energy technologies, as well as the fact that renewable energy-based mini-grids involve little to no fuel costs (except in the case of biomass-based systems). Furthermore, renewable energy-based mini-grid developers can access capital outside of the traditional power sector, including from international climate finance. Apart from financial and economic benefits, renewable energy mini-grids also have clear environmental and social benefits (UNIDO, 2017), in terms of the reliability of electricity, sustainability, and health. Renewable energy mini-grids run on locally available renewable energy sources like solar, wind, biomass, or run-of-the-river hydropower, thus avoiding exposure to volatile fuel prices and logistical limitations and improving the reliability of electricity supply. Furthermore, the use of locally available renewable resources ensures a sustainable approach to electricity generation through resource efficiency and the use of low-emission technologies. The resulting reduction of local (and global) air pollution has direct positive health effects on the local (and global) population.

It can be argued that most synergies with SDGs and other national objectives can be achieved by increasing access to electricity in non-electrified rural areas, regardless of whether this electricity is provided by a renewable energy based mini-grid, a diesel based mini-grid, or the national grid. However, this analysis focuses on the impacts of renewable energy mini-grids in rural electrification, as compared to national grid extension. It qualitatively assesses the impact of mini-grid electrification on six sustainable development indicators, namely, employment and industrial development, energy security, provision of healthcare, water security, climate change mitigation, and climate change adaptation. A quantitative assessment is undertaken for the first indicator, employment and industrial development, by applying the Economic Impact Model for Electricity Supply (EIM-ES) developed by NewClimate Institute.

5.1 Employment and industrial development

The comparable costs of renewable energy-based mini-grid installation and national grid extension indicate that the scale of employment generation from these two options is likely to be very similar. However, differences are likely to be found in the share of domestic and local job creation and associated impacts on industrial development. Grid extension is performed through major infrastructure projects, which are often executed, and at least partially staffed, by foreign contractors.¹⁶ Renewable energy mini-grids, on the other hand, are often smaller-scale projects that require the local workforce for assembling, constructing, and maintaining the respective systems. In Kenya, regulations require that all solar PV installers, most of whom are local experts, be registered with EPRA. The country also has a solar PV assembly plant in Naivasha that could directly benefit from increased sales due to heightened demand, which would translate into an increase in employment opportunities. In this section, the *EIM-ES* from the *Ambition to Action* project¹⁷ is used to estimate the impact of solar mini-grid projects on employment.

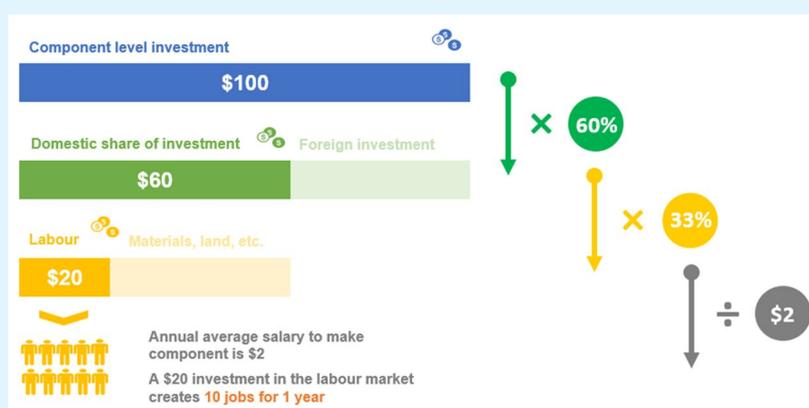
¹⁶ For example, the Ministry of Energy announced in November 2017 that 23 contracts with 12 firms, including foreign firms, had been signed for the implementation of a new phase of the LMCP (Kamau, 2017).

¹⁷ The co-benefit tools of the *Ambition to Action* project have been developed by NewClimate Institute and the Energy Research Centre of the Netherlands (ECN) to quantitatively estimate the impacts of energy sector pathways on various socio-economic indicators. These tools and their methodologies were developed in collaboration with national experts and validated with national governmental and non-governmental stakeholders.

Box 2: The Economic Impact Model for Electricity Supply (EIM-ES)

The EIM-ES is a spreadsheet-based economic model used to estimate the *domestic* employment impacts of investments in new electricity generation capacity within a country. The model covers all relevant electricity generation technologies – both low carbon and fossil fuel-based plants – in order to provide an assessment of employment creation under different future pathways for the development of the electricity sector. The technology coverage is simple to adjust within the model and can be tailored to the country of interest.

The analysis is based on investment cost data, disaggregated, where possible, into its component parts for new electricity generation capacity. Based on input data and underlying assumptions, the model calculates the share of each investment that is spent domestically and the share of that domestic investment that is directed to the labour market. The direct employment impact is then estimated by dividing the domestic labour market investment by an average annual salary that is representative for the work carried out. The model apportions the direct jobs created over time based on assumptions related to the duration of the various tasks and services. For example, construction jobs may last for 2 to 5 years, depending on the technology. Jobs created to provide operational and maintenance services, in contrast, typically cover a much longer period of time, tied to the expected lifetime of the asset. Accordingly, differentiation can be made between short-term employment for supply, construction, and installation and longer-term employment for operation and maintenance.



Direct employment creation over time is the key focus of the model (e.g. for manufacturing equipment, construction of plants, professional services, etc.). In addition, the tool calculates indirect and induced employment impacts by drawing on input-output tables for the economy. Input-output tables reflect the interdependencies of sectors across the economy, based on national statistics, and provide an order of magnitude of the wider economic impacts of investment in electricity generation. **Indirect** jobs refer to those created in secondary sectors upstream in the supply chain (e.g. in the metallurgical or mining industries). **Induced** jobs are created across all economic sectors as a result of an investment stimulus (e.g. the salaries of those that directly and indirectly benefit from the investments are spent on other, unrelated activities, such as housing, restaurants, healthcare, etc.).

The level of accuracy of the analysis depends somewhat on the quality of data inputs and the extent to which they reflect the country-specific context. Where country-specific data points are either missing or unreliable, we can draw on regional and international information, adjusted, where relevant, to the target country. The model is designed to enable sensitivity analysis on key data inputs to evaluate the extent to which they influence the final results.

For every **1 MW of solar mini-grid capacity installed, our analysis finds that over 800 full-time-equivalent job-years would be created** for Kenyan workers. This includes 485 short-term jobs (for approx. 1 year) related to the capital expenditure and approximately 14 annual jobs related to ongoing operational expenditures for a period of approximately 25 years or the lifetime of the installed mini-grids.

Table 6 below gives a breakdown of the employment opportunities for solar mini-grids in different categories. It is clear from the table that the largest impact on employment occurs in the manufacturing and supply sector. This is mostly for electrical components for the distribution network, solar arrays for electricity generation, battery banks for energy storage, and structural containers. Most of the job creation for these expenses will take place domestically, but a significant proportion of the more advanced components (e.g. solar modules and advanced electrical components) may be imported. The job creation impact in these industries could therefore be even higher if local industries were developed to internalise a greater proportion of the manufacturing supply chain:

- For solar mini-grids, generation equipment is imported but assembled locally.
- Industries that manufacture and supply the batteries for electricity storage in solar mini-grids exist in Kenya, and, therefore, associated jobs are likely to be mostly domestic.
- Structural containers for housing generation equipment, electrical components, and offices are usually constructed with locally available materials, particularly cement and steel. As such, labour requirements for the supply of structural containers are likely to be mostly local.
- Equipment and materials for the distribution network will most likely come from local manufacturers in Kenya. More specialised electrical components such as metres, inverters, and charge controllers will usually also be produced domestically, although more complex equipment could be sourced from abroad.

We do not quantify the employment impacts of grid extension projects in this report as an alternative to developing solar mini-grids, due to limited data availability to support the assumptions that would be required. However, the comparability of costs in Section 2 indicates that if the Kenyan electricity access goals are achieved via national grid extension instead of mini-grid projects, this will also create jobs. While both approaches would result in job creation to some extent, the development of solar mini-grids is likely to entail the following advantages for creating both rural and local Kenyan jobs:

- The job creation associated with solar mini-grids is more likely to include a larger proportion of jobs in rural areas—especially in construction, community services, and ongoing onsite business administration, along with jobs from induced effects—, enhancing rural economic development. By comparison, the extension of the national grid to these areas will not likely lead to a significant direct impact on rural employment, since the requirements for these types of jobs are more limited.
- The jobs created in solar mini-grid projects are more likely to be for Kenyan workers than in the case of grid extension. The analysis in Table 6 shows that there is a significant role for local workers in all sectors related to solar mini-grid implementation, especially considering that all solar PV installers have to be registered by EPRA and a majority are local experts. In contrast, in large-scale infrastructure projects like grid extension projects, short-term jobs in professional services and construction may be more likely to be filled by foreign workers.
- The supply chain and job creation is likely to result in greater opportunities for industrial development due to a) the rural economic development opportunities associated with the higher share of rural employment generation; and b) the potential for the further development of high-tech renewable energy manufacturing industries in Kenya—in addition, due to the specialised nature of this equipment, there is the potential for more investment in the development of related export industries to serve neighbouring countries and the region as a whole.

Table 5: Solar mini-grid-related employment opportunities (shown as total jobs, including direct, indirect, and induced jobs)¹⁸

Short term employment for supply, construction, and installation (1 MW system)	
 <p>107 jobs in Kenya for 1 year</p>	<p>Professional services</p> <p>Approximately 20% of the total 107 jobs created in this domain are direct jobs for project preparation tasks, which includes project design, site planning, civil engineering planning, public relations, legal processes, and environmental assessments, among other administrative procedures. The other 80% are indirect and induced jobs created as a result of the solar mini-grid investment across all sectors. These jobs will mostly be filled by Kenyan professionals, who have a competitive advantage due to knowledge of and experience with local processes and legislation.</p>
 <p>256 jobs in Kenya for 1 year</p>	<p>Manufacturing and supply</p> <p>Manufacturing and supply account for most jobs from solar mini-grid investments. These jobs are created through the manufacturing and supply of electricity distribution equipment and electrical components, followed by solar panel arrays, batteries, and structural containers. The industries that manufacture, supply, and transport these materials include a mix of professional, skilled, and non-skilled jobs. Approximately a third of the employment impacts in manufacturing industries are driven directly by the projects, while the remaining two thirds are from indirect and induced jobs associated with supply chain activities.</p>
 <p>52 jobs in Kenya for 1 year</p>	<p>Construction</p> <p>Construction, assembly, and installation of generation equipment, housing structures, and distribution equipment will require skilled workers such as electricians and construction supervisors. It will also create job opportunities for unskilled workers to assemble structures and carry out other construction tasks. These jobs will usually be local. Over 80% of these jobs are directly driven by the projects, while the remainder are indirect and induced jobs created due to the investment across all sectors.</p>
 <p>70 jobs in Kenya for 1 year</p>	<p>Other sectors</p> <p>A large number of jobs associated with the project's capital expenditure will be created through indirect or induced effects in a broad range of other sectors. This includes community-based and personal services in local areas driven by the economic activity, indirect job creation in the primary industries for resource extraction and processing, and induced impacts in all sectors.</p>
Long-term employment for operation and maintenance	
 <p>4 jobs in Kenya for 25 years</p>	<p>Community services, business administration, and other sectors</p> <p>Local staff will be needed for daily operational tasks and interaction with mini-grid customers. This may involve a combination of tasks suitable for skilled and unskilled workers. Half of these jobs will be directly in solar mini-grid operations, while the remainder will come from indirect and induced impacts.</p>

¹⁸ Table by NewClimate Institute, based on quantitative analysis from the EIM-ES of the A2A project.


7 jobs

in Kenya for 25 years

Manufacturing, supply, and construction

Around half of the long-term jobs created are in services related to the manufacturing and supply sectors for replacement and repair of components – in particular, battery banks, electrical components for the distribution network, and solar panel arrays. There will be a relatively small ongoing employment impact in the construction sector, mostly related to the dismantling and installation of large replacement components in the case of repairs and upgrades. Half of these jobs are direct jobs generated by the solar mini-grid projects, with the remainder coming from indirect and induced impacts. Jobs across the supply chain include a mix of professional, skilled, and unskilled positions.


3 jobs

in Kenya for 25 years

Professional service industries

Ongoing job creation in professional services includes direct job creation in financial and legal support for business operations, as well as indirect job creation in associated businesses such as the communications industry (mobile money and telecommunications costs) and real estate (site rent) and jobs induced in other professional sectors.

5.2 Energy security

The International Energy Agency defines energy security as “uninterrupted availability of energy sources at an affordable price” (IEA, 2019). As is the case for much of Sub-Saharan Africa and elsewhere in the developing world, the secure provision of energy for all is a central development goal for Kenya and is also expressed in the internationally agreed SDGs (SDG 7-affordable and clean energy for all and SDG 9-industry, innovation, and infrastructure).

With about 30% of its electricity coming from thermal sources, Kenya is dependent on imported fossil fuels to meet its electricity demand. This makes the country susceptible to oil market volatility. Renewable energy mini-grids offer significant improvements in energy security on multiple fronts. First, they *reduce the overall load on the national grid*, which, in turn, reduces the country's dependency on energy imports, including diesel, gas, and, in the future, high-grade coal. As indicated in Section 2.3.2, if mini-grid deployment is pursued for the 660,000-2.1 million households identified, rather than grid extension, annual load on the national grid system would be reduced by approximately 180-570 GWh per year. Were this demand to be fulfilled with coal-generated electricity, it would require **coal imports of 55-175 thousand tonnes per year, at an annual cost of approximately USD 5.5–17.3 million** (KES 550–1,742 million)¹⁹.

Second, renewable energy mini-grids can provide a more *reliable* source of energy to rural areas than grid extension. Since the systems are decentralised, operators are expected to be more responsive to supply interruptions than the national utility, especially regarding major repairs. Rural areas in Kenya with electricity access via grid extension remain affected by persistent, unplanned power outages and voltage fluctuations (Enslev, Mirsal and Winthereik, 2018; Odarno et al., 2018). The causes of these defects are diverse – faulty transmission infrastructure (e.g. transmission poles collapsing) and overburdened repair services, large distances between the power plants and communities, mismanagement of the central grid, theft and vandalism, the occurrence of natural disasters such as floods and storms, and so on. Mini-grids, on the other hand, are able to avoid many of these supply and transmission issues and reduce exposure to potential outages that affect the central grid. When compared to grid extension, renewable energy mini-grids with battery storage (representative of most new deployment) have a greater capacity to provide 24-hour service, thereby providing more consistent, reliable electricity supply to the end-user (Yadoo and Cruickshank, 2012).

Third, as mentioned in the preceding sections of this study, mini-grid deployment may represent the most *cost-effective* option for the electrification of and long-term electricity provision to 660,000-2.1 million unelectrified

¹⁹ Using the South African average export coal price from September 2018 (USD 98.84 per ton).

households. Thus, for a fixed level of investment in electricity infrastructure, a *greater number of households* are likely to be supplied with electricity.

5.3 Healthcare

Secure electricity access is a key prerequisite for the provision of healthcare services, as it is needed for a wide range of basic medical services, including lighting for medical procedures, emergency night-time care, refrigeration of blood and vaccines, equipment sterilisation, and many other basic tasks. Reports from the World Health Organisation (WHO) indicate that the relationship between electricity access and health coverage has been neglected, and the provision of secure electricity access to unelectrified communities is likely to lead to significant gains in healthcare (WHO, 2014).

The provision of universal healthcare is a key development goal for Kenya. It is emphasised in its international commitments (SDG 3-good health and well-being) and is a core component of the Kenya Vision 2030. Most recently, it has also been incorporated into President Uhuru Kenyatta's "Big Four" action plan, with the target of achieving universal coverage of basic healthcare services by 2022.

Recent WHO survey data collected indicates that, as of 2017, **43% of the Kenyan population lacked timely access to healthcare**²⁰ (WHO, 2017). Moreover, in the existing healthcare facilities, insufficient energy access has been a persistent issue (Franco *et al.*, 2017):

- **25% of Kenyan medical facilities lack energy access**
- **Only 19% of Kenyan medical facilities have reliable energy access**, with the greater proportion of population and facilities without reliable supply being in rural areas.

Renewable energy mini-grids can play a role in improving healthcare in these areas by ensuring reliable power supply. There are several advantages of using mini-grids over grid extension to electrify healthcare facilities in rural and unconnected areas:

- As indicated in Section 2.3.2, electrification through mini-grids is likely to be **cheaper** (in terms of CAPEX) than grid extension in most rural settings. This means that **more connections to medical facilities** could be achieved with the same amount of investment.
- As discussed in Section 3.2, grid-connected rural areas are significantly more vulnerable to power outages and voltage fluctuations than those serviced by mini-grids. Mini-grids can ensure **reliable electricity provision** and therefore could also lead to **more reliable healthcare provision**; medical centres powered by mini-grids could treat more patients, operate for longer periods of time, and offer a broader range of services that are not viable without a constant and reliable source of electricity.

Similarly, mini-grid electrification of healthcare facilities has several advantages over the use of standalone diesel generators, which are frequently used as backup units for grid-connected facilities and, in other instances, as a primary power source, i.e. in public mini-grids run by KenGen. Standalone diesel generators not only contribute to ambient air pollution but are also prone to mechanical breakdown and often left unrepaired; in a recent study in Kenya, it was found that fewer than 30% of diesel generators were functional (Zeyringer *et al.*, 2015). Additionally, the lack of robust transport infrastructure in rural areas constrains the supply of diesel to these power stations, thus increasing their unreliability.

Alongside the role mini-grids can play in supplying stable power to healthcare facilities, the healthcare facilities themselves can also serve as "anchors" for distributed electricity generation systems. A 2014 WHO report identified the capacity of healthcare centres in rural areas to serve this purpose (WHO, 2014). Healthcare centres offer pre-existing infrastructure for housing solar PV panels, batteries, and electricity metres. They are also often centrally located within rural communities, allowing them to function as ideal distribution nodes.

²⁰ Determined from the Universal Health Coverage (UHC) Service Coverage Index for Kenya: 57.0 for 2017.

5.4 Water security

The internationally agreed upon SDGs include the target to achieve universal and equitable access to safe and affordable drinking water for all by 2030, through supporting and strengthening the participation of local communities in improving water and sanitation management. In Kenya, water security remains a major issue for health and economic development, with approximately 41% of Kenyans relying on unimproved and unreliable water sources, mostly in rural areas (Water.org, 2018). Beyond the direct health burdens associated with unreliable water supply, many rural Kenyans, including children, spend up to one third of their day fetching water from available fresh water sources, with negative implications for economic development prospects and educational outcomes (The Water Project, 2018).

The Northern and Eastern parts of Kenya, which are predominantly arid and semi-arid, often suffer most from water scarcity, leading to natural resource-based conflicts. These regions also have some of the lowest electrification rates in the country, yet they receive some of the highest annual solar irradiation—between 2,300 and 2,500 KWh/m²²¹. Renewable energy mini-grids can be used to pump water from the existing boreholes and create a supply network within the rural areas, thus enhancing water access. Under the government's K-OSAP project, solar water pumps have been included as a sub-component to promote water access (REA, 2017).

Moreover, several solar mini-grids already installed in Kenya have helped alleviate problems related to water security, by providing a cost-effective means of collecting and storing water; large solar canopies are often fitted with rainwater collection systems connected to large storage tanks. Such installations include small-scale solar mini-grids in the villages of Kitonyoni in Makueni County and Oloika in Kajiado County, developed under the *Energy for Development* programme. The mini-grids integrate a rainwater collection system into the solar canopy, which can store water for use throughout the year. These villages do not otherwise have a reliable water supply source (Energy for Development, 2015).

It is anticipated that climate change will exacerbate the water scarcity problem in Kenya. Its impact will include reduced and less predictable rainfall and the depletion of natural underground water reservoirs, particularly in the most arid areas (Xinhua, 2015). Infrastructure and equipment are required to enhance the efficiency of rainwater collection systems in order to improve water supply in rural areas.

5.5 Climate change mitigation

The deployment of renewable energy mini-grids **may have significant potential to reduce greenhouse gas (GHG) emissions**, an important planning objective set forth in multiple policy documents, including the National Climate Change Action Plan (NCCAP), the 2017-37 LCPDP, and Kenya's NDC to the Paris Agreement.

As mentioned in Section 1.2.2, future deployment of mini-grids in Kenya will be predominately based on renewable energy sources – namely, solar and wind. This is largely due to rapidly decreasing capital expenditure and abundant resource availability. Electricity provided via grid extension has an emissions profile subject to the composition of the national generation portfolio, which, in 2019, was approaching 70%²² generation from renewable energy sources. However, the electricity mix may become more reliant on fossil fuel-based power in the future, should the proposed Lamu coal power station proceed to the construction phase. According to the generation forecasts in the 2017-2037 LCPDP, GHG emissions will reach 0.31-4.1 megatonnes of carbon dioxide equivalent (MtCO_{2e}) in 2030, depending on different demand scenarios. If the full capacity of the planned coal plants were to be utilised, annual emissions could exceed 5 MtCO_{2e} in 2030.

²¹ The data comes from the SolarGIS map for Kenya: SolarGIS© 2016 GeoModel Solar. It shows the average annual sum of direct normal irradiation for the period 1994-2010. A link to the map can be found here: <https://www.get-invest.eu/market-information/kenya/renewable-energy-potential/>.

²² Based on data from KPLC on installed capacity as of October 2019, provided in a bilateral meeting.

The future deployment of mini-grids may play a role in offsetting this demand for coal-based electricity. If 660,00-2.1 million households were powered by mini-grids rather than the national grid, this could reduce the load on the national grid by 180-570 GWh. If this were to entirely offset coal-based generation, due to coal having the highest electricity dispatch cost, emissions could be reduced by **0.15-0.48 MtCO₂e**. Under the reference demand case of the LCPDP, where coal is forecast to supply 363 GWh in 2030, the role of coal in the energy mix could be entirely negated if renewable energy mini-grids were rolled out instead.

5.6 Climate change adaptation

Adaptation and improved resilience to the dangerous impacts of climate change are important planning objectives for Kenya, as expressed in both the latest NCCAP and the National Adaptation Plan (NAP), as well as Kenya's NDC to the Paris Agreement. The 2015-2030 NAP highlights the need to improve the resilience of vulnerable populations to climate shocks through adaptation and risk reduction strategies (GoK, 2016).

The deployment of decentralised energy systems such as mini-grids in unelectrified rural areas enhances the resilience of communities to the impacts of climate change. Mini-grids ensure a degree of autonomy from the national grid. In the event of a climate-related natural disaster affecting the national grid, such as severe storms or droughts (leading to reduced hydroelectricity capacity, for example), mini-grids can ensure that the communities they serve continue to have electricity access, which can improve the community's ability to cope with the local effects.

6 Taking renewable mini-grids to the next level

This synthesis has shown that the potential for mini-grids may be extensive and underestimated in Kenya. While the *2018 KNES* identifies a role for mini-grids to power 38,661 households, this report finds that mini-grids may be a more cost-effective option than grid extension for electrifying 660,000–2.1 million rural households, supplying 180–570 GWh of electricity in 2030. This would also lead to a range of benefits in terms of energy security, employment, health, water security, and climate change mitigation and adaptation.

The following concrete action points could be pursued to enable renewable mini-grids to advance to the next level, thus allowing Kenya to realize the associated benefits. Due to the benefits entailed for climate change mitigation, international climate finance proposals may also be a potential option for (co-)financing specific actions.

Potential actions for planning processes

1. **Conduct a thorough, up-to-date comparative assessment of the costs of mini-grids and grid extension for rural electrification** using spatial analysis techniques to determine the cost-optimal approach for all rural areas. The rapidly decreasing costs of renewable energy and energy storage technologies make such an exercise essential on an annual basis, using the latest figures.
 - **Consider integrating a shadow carbon price into the comparative cost assessment**, using information on the mitigation potential of mini-grids. Similar processes could also be used to internalise the perceived value of other benefits from mini-grids, such as employment, energy security, and health.
2. **Formulate a clear strategy for mini-grid development** that is integrated, or at least aligned, with plans for grid expansion. This strategy could define the role of mini-grids in short-, mid-, and long-term plans for national electrification, as well as policy measures planned to achieve this.
3. **Integrate the strategy for mini-grid development into the next iteration of the National Electrification Strategy**, to ensure that resources are efficiently allocated and give a clear signal to investors.
4. **Integrate the strategy for mini-grid development into the next iteration of the LCPDP** to ensure that the demand forecasts for centralised grid generation do not double count the demand that will be met with mini-grids.

Potential actions to support private investment

The costs of mini-grid deployment for private developers are artificially increased by transaction costs and the high level of perceived investment risk. Simple actions can be taken to de-risk investments and reduce transaction costs.

5. **Conduct a thorough assessment of rural energy markets** to enhance information on potential demand profiles in specific areas and estimate potential customers' ability to pay. This will both reduce the perceived risk of private investment and the transaction costs for developers, who would otherwise need to undertake this assessment themselves as a first step.
6. **Streamline administrative processes for prospective project developers** to reduce transaction costs and uncertainty regarding lead times for initial processes. Clear policies on grid integration in cases where mini-grids overlap with the central grid are needed.
7. **Identify the most effective financial instruments to maximise investments in rural electrification**, which will entail comparing the economic benefits of subsidising the national utility versus potential private investment. This should include an analysis of the cost-effectiveness of the subsidies, ability to leverage more resources, and non-financial impacts of different pathways, among other variables.

8. **Conduct a comparative analysis of various business and management models to determine the optimal role of the private sector** in mini-grid development, ranging from i) limited (e.g. only engineering, procurement, and construction (EPC) services) to ii) basic (e.g. EPC services and partial operation) to iii) advanced (e.g. EPC services and full operation), in various contexts.

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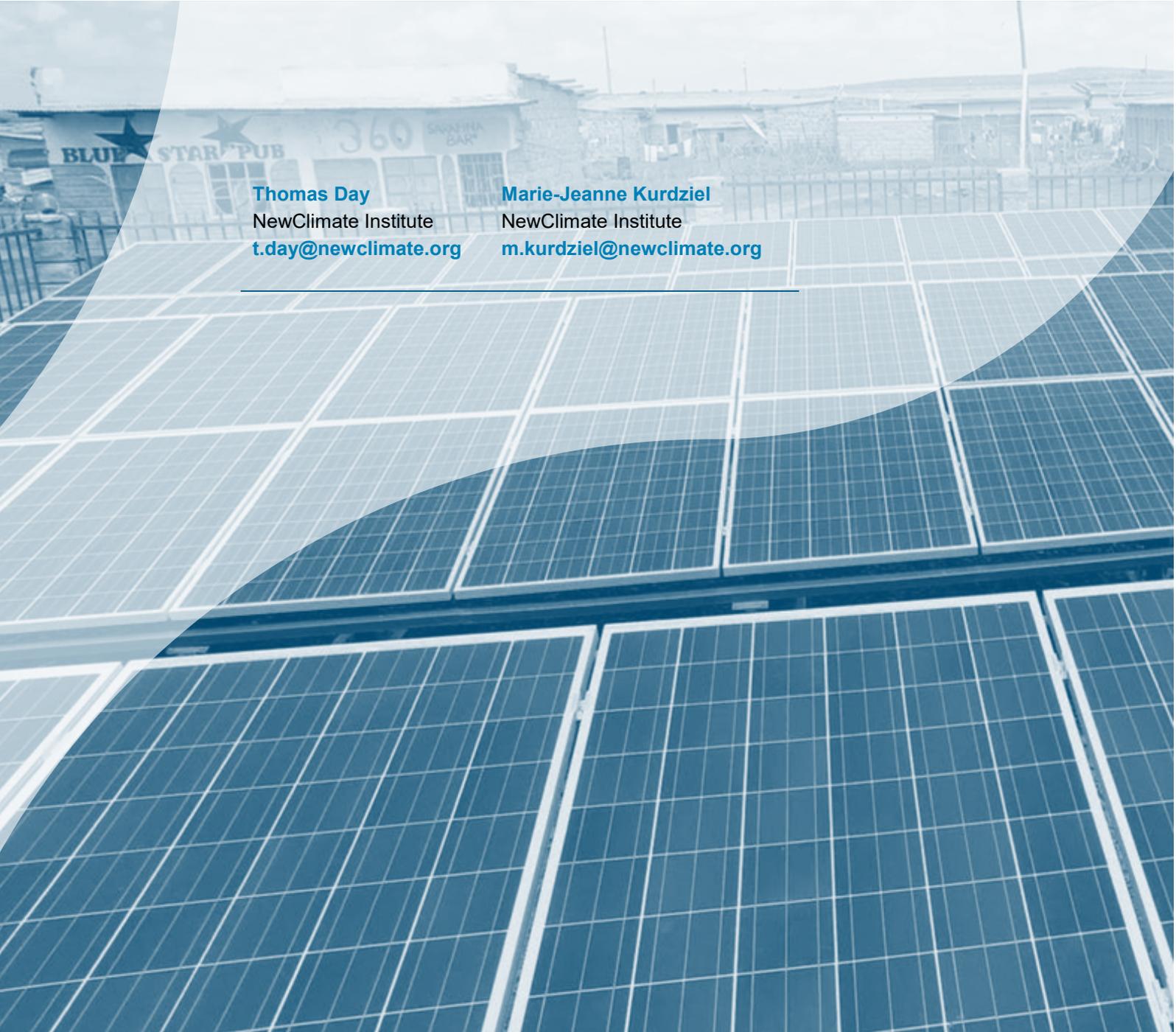
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