ENERGY CATALYST

Trends in technical approaches to universal energy access

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Transforming Energy Access

This research is aimed at energy access innovators to provide an up-to-date overview of trends in technical approaches to universal energy access.

Hyperlinks are found throughout the report. Use these to be taken to relevant sections within this document, or to external resources like websites

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Introduction

> This primary questions of this research are:

What are some trends in different countries' technical approaches to universal energy access and the UN SDG 7 (affordable and clean energy) plans?

What happens to these plans as the market evolves beyond 'off-grid versus on-grid'?

The following report aims to answer these main questions whilst also addressing the sub-questions below:

- What is the role of geographic information in developing least costly access plans in off-grid areas? How reliable are the results?
- People are starting to work on models in which there is much greater coordination between the rollout of off-grid solutions and the development of the main grid. What does this mean in practice and what are the results so far?
- What are the drivers behind adopting off-grid solutions in areas that are notionally served by the grid?
- What are the limitations of 'central planning versus free markets'?

How do we define universal energy access?

> **There is no single universally-accepted and internationally adopted definition of energy access.**

> Due to a greater understanding of energy access, definitions have evolved over time; from binary metrics of electricity access, to complex assessments of both electricity access and access clean cooking, that include measurements of availability, capacity and technology.

> Since 2015, United Nations Sustainable Development Goal 7 (SDG 7) aims to ensure access to affordable, reliable, sustainable and modern energy services for all. The indicators 7.1.1 and 7.1.2 show how, for the purposes of SDG 7, the definition of energy access is a combination of both electricity access and access to clean cooking.

> In the next section, the energy access numbers are provided by the *Tracking SDG 7: The Energy Progress Report 2020* from databases maintained by the World Bank, IEA, IRENA the UNSD and the WHO. Different agencies and partners may have very sightly differing definitions of energy access, however, for the purposes of this report, energy access is defined as below.

Electricity Access:

'The ability of the end user to consume electricity for desired services'. Measured by:

1. **Access to Tier 1 and above,** as defined by the Multi-Tier Framework (MTF)

   AND/OR

2. **Binary measurements** in existing households surveys

Clean Cooking:

Households that rely primarily on the below fuels and technologies for cooking:

- **Clean cooking fuels and technologies**: electricity, liquefied petroleum gas (LPG), natural gas, biogas, solar, and alcohol-fuel stoves.
- **(Polluting fuels and technologies**: traditional stoves paired with charcoal, coal, crop waste, dung, kerosene, and wood)

TARGET	INDICATOR
7.1 • By 2030, ensure universal access to affordable, reliable, and modern energy services	7.1.1 • Proportion of population with access to electricity 7.1.2 • Proportion of population with primary reliance on clean fuels and technology for cooking
7.2 • By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1 • Renewable energy share in total final energy consumption
7.3 • By 2030, double the global rate of improvement in energy efficiency	7.3.1 • Energy intensity measured as a ratio of primary energy supply to gross domestic product

Source(s): IEA et al., 2020

Tiers of The Multi-Tier Framework (MTF)

- As one metric of electricity access relies on the use of the MTF, the MTF description of Tier 1 has been included here, right, to show the level of service required for electricity access.
- The MTF is an initiative that defines, collects and analyses energy access data and measures multiple dimensions of data to capture information about the quantity and quality of energy access across households, productive users and community facilities. This includes access to electricity and clean cooking with measures for: capacity, availability, reliability, quality, affordability, formality, health and safety and gender.
- Therefore, according to the definition on the previous slide, a household is only considered to have to electricity access when the electricity access meets or exceeds the requirements of Tier 1, shown right.
- (Further discussion of energy access definitions and the MTF follow in sections Trend 2 and Trend 4 below).

MINIMUM REQUIREMENTS BY TIER OF ELECTRICITY ACCESS

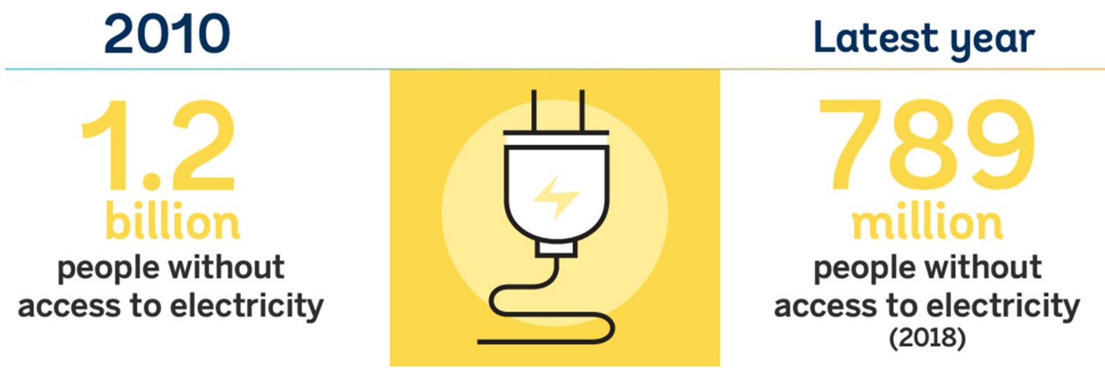
Tier 0	Tier 1	Tier 2
Electricity is not available or is available for less than 4 hours per day (or less than 1 hour per evening). Households cope with the situation by using candles, kerosene lamps, or dry-cell-battery-powered devices (flashlight or radio).	At least 4 hours of electricity per day is available (including at least 1 hour per evening), and capacity is sufficient to power task lighting and phone charging or a radio. Sources that can be used to meet these requirements include a SLS, a solar home system (SHS), a minigrid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), and the national grid.	At least 4 hours of electricity per day is available (including at least 2 hours per evening), and capacity is sufficient to power low-load appliances—such as multiple lights, a television, or a fan (see table 1)—as needed during that time. Sources that can be used to meet these requirements include rechargeable batteries, an SHS, a mini-grid, and the national grid.
Tier 3	**Tier 4**	**Tier 5**
At least 8 hours of electricity per day is available (including at least 3 hours per evening), and capacity is sufficient to power medium-load appliances—such as a refrigerator, freezer, food processor, water pump, rice cooker, or air cooler (see table 1)—as needed during that time. In addition, the household can afford a basic consumption package of 365 kWh per year. Sources that can be used to meet these requirements include an SHS, a generator, a mini-grid, and the national grid.	At least 16 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power high-load appliances—such as a washing machine, iron, hair dryer, toaster, and microwave (see table 1)—as needed during that time. There are no frequent or long unscheduled interruptions, and the supply is safe. The grid connection is legal, and there are no voltage issues. Sources that can be used to meet these requirements include diesel-based mini-grids and the national grid.	At least 23 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power very high- load appliances—such as an air conditioner, space heater, vacuum cleaner, or electric cooker (see table 1)—as needed during that time. The most likely source

Source: https://mtfenergyaccess.esmap.org/

Latest Global Energy Access Trends

Electricity Access: Progress, but insufficient for 2030

- Global population with access increased from **83% in 2010 to 90% in 2018.**
- However, on current trends, about **620 million people will remain without access in 2030.**



Clean Cooking: Below target

- **Almost 3 billion people** worldwide lack the ability to cook efficiently, cleanly, conveniently, reliably, safely, and affordably.
- On current trends, we will **fall short of SDG 7.1.2 by almost 30% in 2030.**

Source: IEA et al, 2020

Global Disparities

Global Regional Variation

Electricity access:

- Access in Latin America, the Caribbean, Eastern and South-Eastern Asia is approaching 98%. Central and Southern Asia are at 92%.
- **However, in Sub-Saharan Africa at least 50% of the population lack access; 70% of the total global access deficit.**

Clean cooking:

- The regions of South Asia, Eastern and South-Eastern Asia and sub-Saharan Africa contain the majority of the global access deficit.
- **Access rates and growth in access rates have increased in Eastern and South Asia in recent years, however, in sub-Saharan Africa, access has decreased due to stagnant growth in access rates and rapid population growth.**

Global Rural-Urban Divide

Electricity access:

- Urban areas -> electricity access is close to universal - 97%
- Rural areas -> 85% of the global electricity access deficit

Clean cooking:

- Globally 83 % of urban households have access to clean cooking compared to 37 % in rural areas.

- N.B. Regional variation also exists within the rural-urban divide e.g. the majority of the global urban electricity access deficit is in sub-Saharan Africa, where the majority live in low-income, fragile and conflict-affected countries.

Source: IEA et al., 2020

Global Trends and Data

- The previous slides are intended to provide a brief overview of global energy access trends so as to situate countries technical approaches to energy access in context.
- Please note:
  - The trends above are useful for providing a good overall picture and understanding of global energy access trends. However, the data often fails to show the full picture. For example, the data may fail to record instances where electricity connections have been counted as 'connected' but electricity access is still lacking due to reliability, bad quality or affordability. Therefore data on particularly electricity access should be considered in light of this. This is a problem noted by the SDG 7 Report authors and the issue is dealt with in detail in Trend 2 and 4 of this report.
  - However, lacking any alternative data, subsequent country specific electricity access rates mentioned in this report, unless stated otherwise, are taken from the SEforAll Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program. Clean cooking access rates are taken from the World Bank, SE4ALL, WHO Global Household Energy database. Both of these databases can be accessed at: https://data.worldbank.org
  - For each of the five key trends below, just as for the above global trends, there will be variations on a global to country level. The report will attempt to highlight these wherever possible but this should be considered throughout.

Trend 1

Off-Grid Distributed Renewable Energy (DRE): Filling the Gap

In the past 10 years, off-grid DRE has grown into a viable alternative to grid connection and is now considered a key component of achieving SDG 7 by 2030

Technological developments as well as business model developments have been key drivers of trend

What is Off-Grid Distributed Renewable Energy (DRE)?

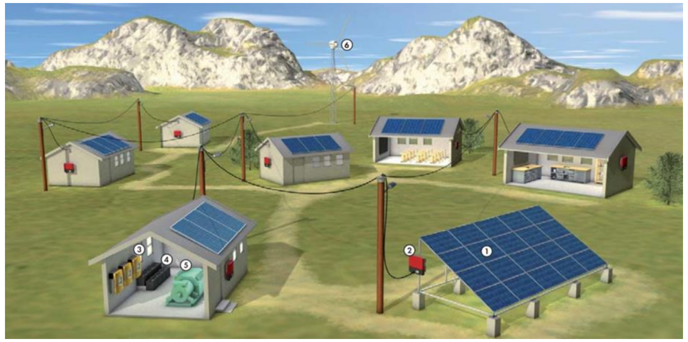
- DRE refers to renewable energy that is generated near to the point of use, as opposed to renewable energy generated at a central point for distribution across a large area. DRE is often off-grid but can also be on-grid. e.g. a grid-connected wind farm.
- For the purposes of this report, off-grid DRE refers to technologies that **produce electricity, are not grid-connected, and generate electricity close to use.**
- There is significant scope for electricity provided through off-grid DRE to impact clean cooking access e.g. electric cookstoves. However, the impact of off-grid DRE has overwhelmingly been seen in the area of electricity access. Therefore this section will focus on how off-grid DRE has fundamentally changed countries' technical approaches to electricity access in recent years.

Examples of Off-Grid DRE Systems

Pico-solar/solar lanterns*

Solar Home Systems (SHS)

Mini-grids (solar, hydro, biomass, diesel hybrid)



Increasing capacity, service and no. of users

*** As this report is concerned with electricity access, only those devices in this category that provide MTF Tier 1+ electricity access are considered.**

The Evolution of Off-Grid DRE in Numbers

The overwhelming majority of new electricity connections since 2000 have been achieved through connection to a national grid

6% of total new connections from 2010-17 were from off-grid and mini-grid systems (IEA 2017)

In 2018, more than 35 million people had access to Tier 1+ electricity services through standalone home systems or renewable-based mini-grids (IEA et al. 2020)

By 2016, about 100 million people had access to solar lights (<11 watts), 24 million people were using solar home systems (>11 watts) and at least 9 million people were connected to a mini-grid (IRENA 2019)

In 2019, 19,000 mini-grids installed in 134 countries provided electricity to around 47 million people (IRENA 2019)

Off-grid and mini-grid systems are projected to provide almost half of new electricity access by 2030 (IRENA 2019)

Off-grid technologies are the least-cost option for 71% of rural connections to meet SDG7 in 2030 (Lighting Global 2020)

The Off Grid Solar (OGS) sector alone is projected to serve 823 million users with OGS products by 2030 (Lighting Global 2020)

Principal Factors driving this trend

1. Recognition of Off-Grid DRE Potential

- For rural areas far from the national grid and with low demand, there is now widespread recognition that off-grid DRE technologies are often the most cost-effective and appropriate method of electricity connection.
- For example, in the remotest areas of sub-Saharan Africa, connections to the national grid can cost approximately USD 2,000 per connection and the likely low demand for electricity in these areas, at least initially, make them financially unattractive to struggling national utilities. In contrast, off-grid DRE can match demand more appropriately and has been shown to be a least-cost alternative to grid connection; between USD 500 - 2000 per connection for mini-grids and large SHSs (80W replaced twice in 20 years) (pico-solar and small SHS products would lower the cost even further). (Greentech Media 2018)

2. Technological Developments in Off-Grid DRE

- In the past 10 years, there have been significant technological innovations and improvements in:
  - Generation – solar PV, wind and hydro efficiency
  - Component size and performance – for inverters, load controllers, smart meters, control systems, batteries
  - Appliance efficiency – LEDs, TVs
  - Software capability and performance – remote monitoring
- The result of these improvements has been more reliable, efficient and appropriately designed off-grid products.

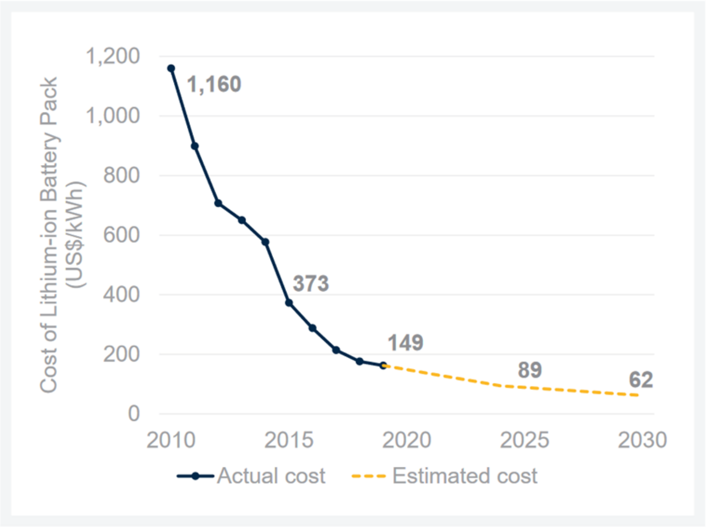
3. Cost Decreases in Components and Products

- There have been large cost decreases in certain off-grid DRE components, such as lithium-ion batteries, as shown in the graphs, right. This has resulted in a decrease in manufacturing costs and subsequent reduction in retail costs to consumers, particularly for solar-battery based products (Lighting Global, 2020).

4. Increase in Donor and Private Finance

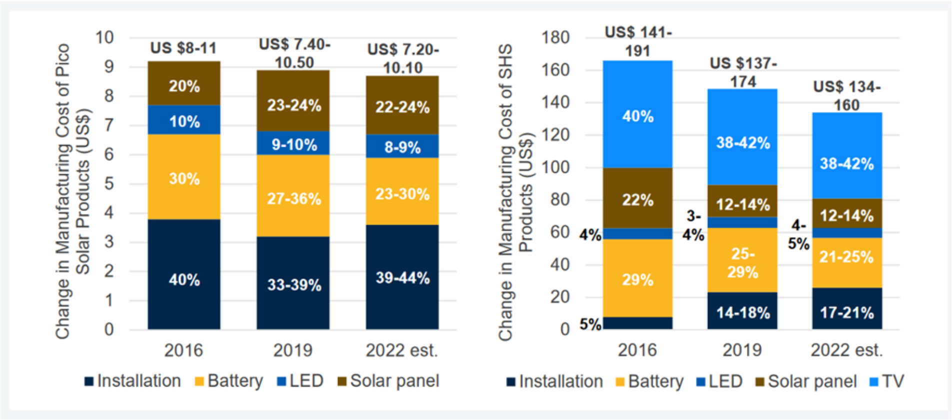
- Development finance institution (DFI) programmes for off-grid energy have increased in number and size, and have helped drive the adoption of off-grid DRE technologies. The World Bank alone has increased funding for specifically off-grid solar and energy access-related technical assistance from USD 386 million in 2015-17 to USD 800 million in 2018-19 (Lighting Global, 2020).
- The World Bank's Rural Electrification and Renewable Energy Development (RERED) project in Bangladesh that has supported the installation of over 1 million SHSs since 2012 (World Bank, 2020).
- Investment in all off-grid solutions increased from USD 46 million in 2015-16 to USD 430 million in 2017, mainly from donors, private equities, and venture capitalists (SEforAll, 2019a).

Figure 20: Lithium-Ion Battery Pack Prices (US$/kWh)



Source: Lighting Global, 2020

Figure 21: The Changing Manufacturing Costs of Pico and SHS Products

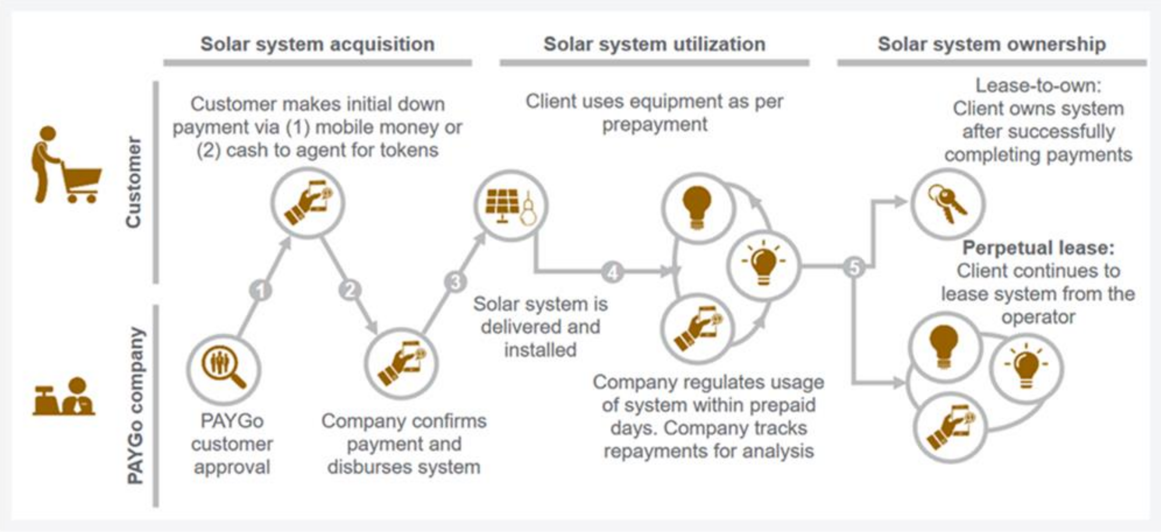


Source: Lighting Global, 2020

5. Innovative Financing Models: Pay-As-You-Go (PAYG)

- The development of the PAYG business model has contributed significantly to the increase in off-grid DRE in recent years; between 2015 and 2020, approximately 8 million people gained energy access with technologies supported by a PAYG business model (IRENA, 2020).
- Despite decreases, the upfront cost of technologies such as SHSs continues to remain high. The PAYG model has closed the affordability gap for many by spreading the cost of the system over affordable monthly payments; sometimes even at or below current energy expenditure. For SHS suppliers, the PAYG model has enabled companies to provide financial products and management at scale.
- Key to the development of the PAYG model has been increased consumer awareness, access to finance enabled through mobile payment systems and mobile technology which allows remote monitoring of devices and cut-offs for missed payments.

Figure 27: The PAYGo Business Model



Source: Lighting Global, 2020

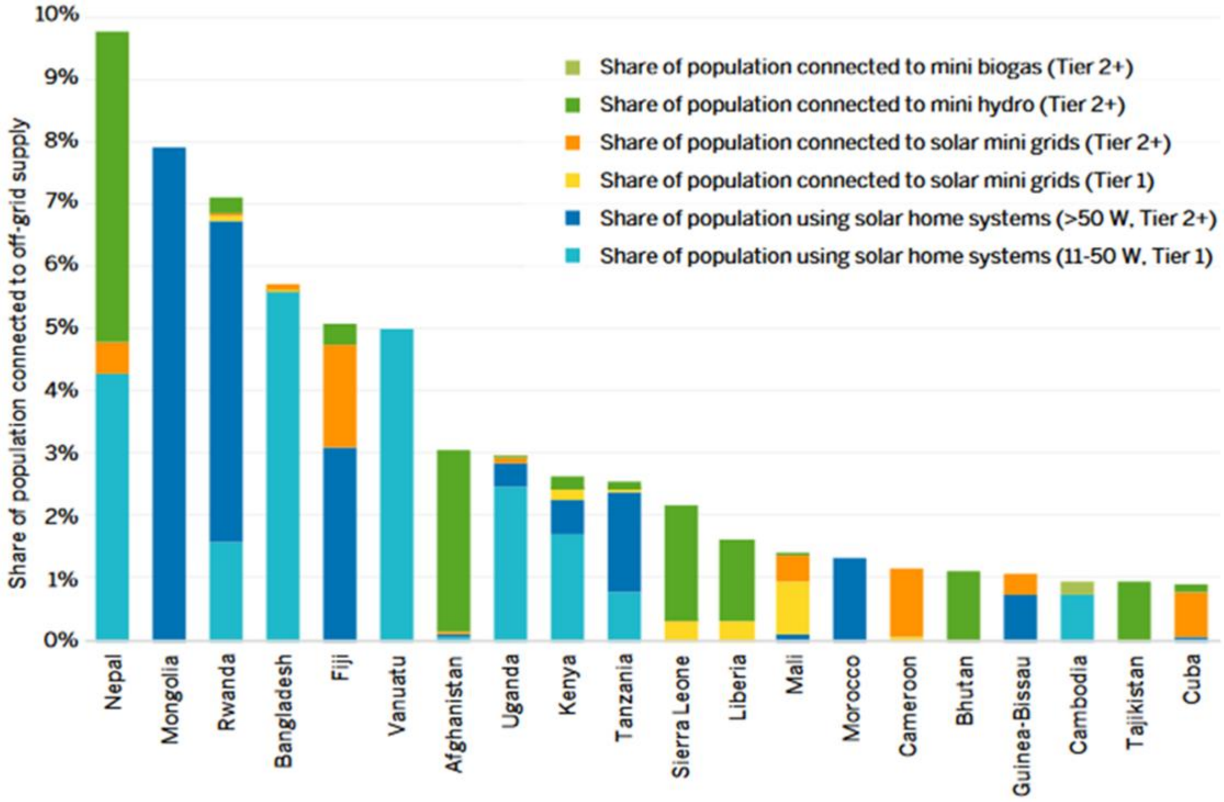
6. Market Share

- In the early years of market development, deployment of off-grid solar increased rapidly as companies pursued aggressive growth strategies in certain geographies to increase market share in competitive markets (Lighting Global, 2020).

Impacts on Countries' SDG 7 Plans

- The overall result of this trend has been an increased uptake of off-grid DRE in energy access deficit countries. This trend looks set to continue as countries are increasingly incorporating large-scale deployments of off-grid DRE in their energy access plans, as shown below (for details see Annex 1).

FIGURE 1.12 • Top 20 countries with the highest rates of access to off-grid supply (Tier 1 or higher), 2018



Source: IEA et al., 2020

Kenya	Kenya Off-grid Solar Access Project: **distribute 250, 000 solar home systems (SHS)** to power households, schools, health facilities and agriculture by 2030
Ethiopia	Electrification Program (2017): geospatial least-cost roll-out plans, fast-paced extension of the grid to reach 65% of the population with the grid and **35% with decentralised systems by 2025; public-private off-grid programme for 6 million households**
Nigeria	The World Bank's Nigeria Electrification Project will leverage private sector investments in solar mini grids and standalone solar systems, incl. **$150 million for 850 solar hybrid mini grids that will bring electricity to 1.5 million people**
Myanmar	Pre-electrification and electrification plans expect **492,000 households to be connected with SHS and mini-grid technologies**

Challenges & Opportunities for Off-Grid DRE

1. Investment Gaps

- Current projections estimate that at least USD 52 billion per year of investment, from governments, private sector and international donors will be required to reach universal electricity access by 2030. Only half has been committed and only 1.3 percent of this investment is in off-grid solutions (Wood Mackenzie et al. 2019). This number will need to increase rapidly if off-grid DRE growth is set to achieve targets set for 2030.

2. Unrealistic Expectations and Off-Grid Solar Market

- The majority of the gains and expectations for off-grid DRE rely on off-grid solar products. However, there are concerns that the off-grid solar market will be unable achieve the required growth to achieve SDG 7 by 2030. Lighting Global estimate that the sector will need to grow at an average of 13% over the coming years; double the current projected (Lighting Global, 2020).
- Key to this growth will be new investment in the sector. Market investment and deployment is concentrated in a few big-players, in concentrated geographies, who will need to balance increasing market share with increasing profitability in order to attract investors and continue sector growth. The insolvency of Mobisol in 2019 represents a cautionary tale for investors and policymakers alike (Financial Times 2019).

3. Impact of COVID-19

- The impact of the COVID-19 pandemic represents a severe risk to the energy access sector as a whole. Analysis from IEA shows the number of people without electricity access rising in 2020 for the first time since 2013. In part this is due to the rise in poverty levels caused by the pandemic; estimates show that 100 million people worldwide who were already considered connected, may be forced back into energy poverty by the end of 2020 (IEA 2020). In addition, surveys have highlighted the perilous situation for many off-grid energy access companies and global sales of off-grid solar products fell 26% in the first half of 2020 alone (Endev 2020 and GOGLA 2020). The pandemic has also forced governments and development partners to divert resources to pandemic response resulting in lack of financing for off-grid electricity access projects (IEA 2020a).

4. National Utilities

- Some national utilities, already struggling for financial viability, may not be willing to allow competition for customers from off-grid DRE companies. National grids are also seen by some governments as prestige projects and therefore, despite potential for DRE, the building of the national grid may remain the focus for governments at the expense of off-grid DRE.

5. Inequity of Off-Grid Energy Access

- Research has shown that access to energy through off-grid energy products is unequal across both poverty and gender, potentially limiting the ability of countries to reach SDG 7 by 2030. Access from off-grid DRE so far has favoured wealthier customers over poorer customers and in addition, it appears that as companies mature, poorer customers decrease as a proportion of their customer base (60 Decibels 2020). Governments and stakeholders should be conscious of this trend when designing energy access policies supporting off-grid DRE as this trend may risk those in the last-mile being left behind.

6. Subsidies

- One way in which countries can address such inequities is through subsidies. Studies have shown that subsidies have been crucial to successful electricity access programmes in the past. The decrease in costs of off-grid DRE will not be enough to bridge the affordability gap for the last-mile rural poor and therefore subsidies will likely be necessary (Davies et al. 2020). The provision of subsidies to private companies remains controversial. Initiatives such as the SEforAll's Universal Energy Facility and Endev's results based financing (RBF) financial support project in Rwanda, are beginning to show how subsidies can be deployed to support rural off-grid electrification.

Trend 2

Data, Data, Data

Improved data collection methodologies and technologies have increased capacity for energy access planning

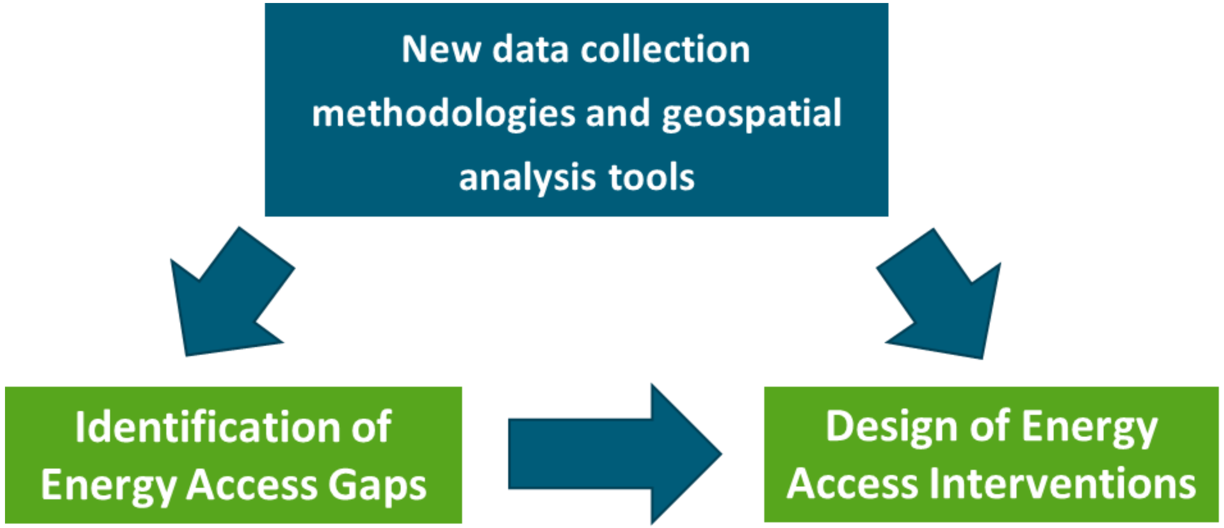
Developing and deploying these strategies will be key for countries to achieve SDG 7 by 2030

The Evolving Data Landscape

- Access to data has fundamentally shaped countries technical approaches to universal energy access. The challenge of achieving universal energy access is dependent upon country specific variables; there is no one-size-fits-all approach and each country will have it's own unique social, political, geographical and technical dynamics. The challenge for planning universal energy access is to take into account these dynamics and develop the optimal approaches. Access to data is crucial to this endeavour. Lack of access to large, reliable and open datasets has constrained attempts to reach SDG 7 however, this is changing as better methodologies and analysis tools become available.
- This section will highlight two analytical tools which have impacted countries' technical approaches to universal energy access:

1. The Multi-Tier Framework (MTF)
2. Geospatial analysis

- These two tools have enabled increasing identification of gaps in progress towards universal energy access and the design of more comprehensive energy access interventions. Deployed together these tools have already, and will likely increasingly in the future, support countries technical approaches to universal energy access.



1. The Multi-Tier Framework (MTF)

- Over the past decade there has been a move away from previous narrow and binary definitions of energy access to more complex measurements and tools of analysis. The move towards new energy access data collection frameworks is supporting both the global tracking of SDG 7 and countries' approaches to reaching universal energy access. Developed by the World Bank and partners in 2015, the MTF is the most prominent example of this shift.
- As an example of the change in approaches, the question samples below show the difference between questions from a standard Living Standards Measurement Survey (LSMS), left, and the MTF, right. Standard household living surveys, such as that below, have approximately 5 -20 questions directly related to energy access. The MTF in contrast has over 400 questions directly related to energy access across capacity, availability, reliability, quality, affordability, formality, health and safety and gender. As a result, MTF data has far greater granularity than previous surveys.

15.	16.		17.		18.	19a.	19.	20.	21.
Do you usually use a chimney, hood or other exhaust system while using this cookstove specified in Q13? YES..1 NO...2	In the last 12 months, what are the fuels your household commonly used for this cookstove specified in Q13? PROBE & SELECT TWO MOST USED FUELS IN ORDER OF MOST USED KEROSENE....................1 COAL/LIGNITE................2 CHARCOAL....................3 WOOD........................4 SOLAR.......................5 ANIMAL WASTE/DUNG...........6 CROP RESIDUE/PLANT BIOMASS..7 SAW DUST....................8 COAL BRIQUETTE..............9 BIOMASS BRIQUETTE..........10 PROCESSED BIOMASS(PELLETS)/ WOODCHIPS..................11 ETHANOL....................12 BIOGAS.....................13 LPG/ COOKING GAS...........14 PIPED NATURAL GAS..........15 ELECTRIC...................16 GARBAGE/PLASTIC............17 OTHER (SPECIFY)............18		How much did you spend on the[FUEL TYPE] for this stove in the last month/in a typical month when you use the stove? ENTER THE ACTUAL AMOUNT SPENT, NOT THE MARKET VALUE OF THE FUEL IF NONE/RECEIVED FOR FREE, RECORD 0		In the past 12 months, did members of this household suffer from any harm, injury or health problem, or was any property of the household damaged as a direct result of cooking with this cook stove? YES....1 NO......2 IF NO >> Q19	In the last 12 months, what harm/injury happened from this cookstove? PROBE & SELECT ALL THAT APPLY IN ORDER OF SEVERITY DEATH.................2 PERMANENT PHYSICAL DAMAGE TO ANY PERSON IN THE HOUSEHOLD.....3 BURNS/FIRE/POISONING.4 SEVERE COUGH/ RESPIRATORY PROBLEM..5 FIRE WITH NO INJURY..6 OTHER (SPECIFY)......7	Do you have electricity from any source in your household? YES...1 NO.....2 IF NO >> Q27	What are ALL the sources of electricity that is used regularly in your household? SELECT ALL THAT APPLY PHCN/NEPA.........1 LOCAL MINI GRID...2 GENERATOR.........3 SOLAR HOME SYSTEM.4 SOLAR LANTERN/ LIGHTING SYSTEM...5 RECHARGEABLE BATTERY...........6 INVERTERS.........7 OTHER (SPECIFY)...8	What is the MAIN source of electricity that your household uses most of the time? PHCN/NEPA.........1 LOCAL MINI GRID...2 GENERATOR.........3 SOLAR HOME SYSTEM.4 SOLAR LANTERN/ LIGHTING SYSTEM...5 RECHARGEABLE BATTERY...........6 INVERTERS.........7 OTHER (SPECIFY)...8
	1ST	2ND	1ST	2ND					

Sample Questions from Nigeria Living Standards Survey , Nigeria Bureau of Statistics, 2019

WORLD BANK MTF ENERGY SURVEY CONFIDENTIAL Final Version for Rwanda ID: |__|__|__|__|__|__|__|

	I.18		I.19		I.20	I.21	I.22	I.23	I.24	I.25	I.26	I.27
Cookstove ID	In the last 12 months, what are the fuels you used on this cookstove? **CODE:** Kerosene....1 Coal/lignite....2 Peat....3 Charcoal....4 Wood....5 Solar....6 Animal Waste/Dung....7 Crop Residue/Plant Biomass....8 Saw Dust....9 Coal Briquette....10 Biomass Briquette....11 Processed biomass (pellets)/ woodchips....12 Ethanol....13 Biogas....14 LPG/cooking gas....15 Piped Natural Gas....16 Electric....17 Garbage/plastic....18 Other, specify....555		In the last 12 months, how often was the [FUEL TYPE] available? ***Read aloud options*** **CODE:** Always available......1 Mostly available......2 Sometimes available......3 Rarely available......4		In the last 12 months, have there been times when the cooking time is longer than usual due to a weak flame? **CODE:** Yes......1 No......2	How much time do household members spend **preparing the cookstove and fuel for each meal** on average [including setting up the fuel and turning on the stove but not including gathering fuel or cooking time]?	In the last 7 days, how many days did you use this cookstove?	In the last 7 days, on average, how many times did you light this cookstove **per day?**	In the last 7 days, on average, how much time did your household use this cookstove **per day** to cook or reheat meals (do not include boiling water) in the…			In the last 7 days, on average, how much time did your household use this cookstove **per day** to boil water (for cooking, washing, and drinking)?
									MORNING	AFTERNOON	EVENING	
	A. Most Used *Single response*	B. Second Most Used *Single response*	A. Most Used	B. Second Most Used		MINUTES	DAYS	NUMBER OF TIMES	MINUTES	MINUTES	MINUTES	MINUTES
1												
2												
3												
4												
5												

Sample Questions from MTF Energy Survey , World Bank 2018

> The data gathered allows disaggregation of energy access into Tiers (as shown right) for both electricity access (top) and clean cooking (bottom).

> The data has allowed governments and utilities to:

a) Set appropriate targets, based on conditions, budgets, timelines

b) Balance improving energy access to existing users and providing new connections

c) Disaggregate between appropriate technologies, targeted in the most cost-efficient way

"The MTF identifies and analyses the main reasons why households are not using electricity, or why their usage is limited (i.e. by capacity, reliability or affordability issues), and then recommends a set of measures to remove such constraints. MTF, therefore, not only allows for a nuanced tracking of SDG 7 targets, but also helps governments fine-tune their policies and approaches for reaching them. " (ESMAP 2020a)

> The data for Cambodia, Ethiopia, Myanmar, Nepal, Rwanda, São Tomé and Príncipe, and Zambia is available online at the MTF website (https://mtfenergyaccess.esmap.org/countries).

> The MTF therefore represents strong progress in the advance of energy access measurement; moving away from binary measurements to more complex definitions with accompanying tools for measuring energy access. However, there are critics of the MTF.

Multi-Tier Framework for Measuring Access to Electricity

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3[b]	TIER 4	TIER 5
Capacity	Power capacity ratings (W or daily Wh)	Less than 3 W	At least 3 W	At least 50 W	At least 200 W	At least 800 W	At least 2 kW
		Less than 12 Wh	At least 12 Wh	At least 200 Wh	At least 1 kWh	At least 3.4 kWh	At least 8.2 kWh
	Services		Lighting of 1,000 lmhr per day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability[a]	Daily Availability	Less than 4 hours	At least 4 hours		At least 8 hours	At least 16 hours	At least 23 hours
	Evening Availability	Less than 1 hour	At least 1 hour	At least 2 hours	At least 3 hours	At least 4 hours	
Reliability		More than 14 disruptions per week			At most 14 disruptions per week or At most 3 disruptions per week with total duration of more than 2 hours"	(> 3 to 14 disruptions / week) or ≤ 3 disruptions / week with > 2 hours of outage	At most 3 disruptions per week with total duration of less than 2 hours
Quality		Household experiences voltage problems that damage appliances				Voltage problems do not affect the use of desired appliances	
Affordability		Cost of a standard consumption package of 365 kWh per year is more than 5% of household income			Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		
Formality		No bill payments made for the use of electricity				Bill is paid to the utility, prepaid card seller, or authorized representative	
Health and Safety		Serious or fatal accidents due to electricity connection				Absence of past accidents	

Multi-Tier Framework for Measuring Access to Cooking Solutions

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Cooking Exposure	ISO's voluntary performance targets (Default Ventilation) PM2.5 (mg/MJd) CO (g/MJd) gn	>1030 >18.3	≤1030 ≤18.3	≤481 ≤11.5	≤218 ≤7.2	≤62 ≤4.4	≤5 ≤3.0
	High Ventilation PM2.5 (mg/MJd) CO (g/MJd)	>1489 >26.9	≤1489 ≤26.9	≤733 ≤16.0	≤321 ≤10.3	≤92 ≤6.2	≤7 ≤4.4
	Low Ventilation PM2.5 (mg/MJd) CO (g/MJd)	>550 >9.9	≤550 ≤9.9	≤252 ≤5.5	≤115 ≤3.7	≤32 ≤2.2	≤2 ≤1.4
Cookstove Efficiency	ISO's voluntary performance Targets	≤10%	>10%	>20%	>30%	>40%	>50%
Convenience	Fuel acquisition and preparation time (hours per week)	≥7		<7	<3	<1.5	<0.5
	Stove preparation time (minutes per meal)	≥15		<15	<10	<5	<2
Safety		Serious Accidents over the past 12 months				No serious accidents over the past year	
Affordability		Fuel cost ≥5% of household expenditure (income)				Fuel cost <5% of household expenditure (income)	
Fuel availability		Primary fuel available less then 80% of the year				Available 80% of the year	Readily available throughout the year

Source: ESMAP, 2020a

- Unfortunately, as of 2020, the MTF has only been rolled out in 20 countries globally. Tracking the indicators for SDG 7 therefore remains largely reliant on data from the standardised household surveys and demand-side data from governments, utilities and private companies (IEA et al., 2020).
- Whilst recognising the positive contribution of the MTF towards moving away from binary approaches, critics have argued that the MTF is:
  - Too complex and conceptually muddled to be a useful for tracking energy access on a global scale and requires too much data
  - Too detailed and prescriptive for national policy and planning purposes
  - Lacking the correct metrics and measurements to capture certain dimensions and attributes. (Shonali Pachauri and Narasimha D Rao, 2020)
- This has led to the development of further refined models and the integration of questions into existing household surveys, thereby overcoming some of the criticisms highlighted above (Shonali Pachauri and Narasimha D Rao, 2020).
- Overall, the debates around energy access measurement and definitions look set to continue. However, the key point is that data collection and energy access data methodologies are moving in the right direction and will continue to be an important tool for countries technical approaches to reach universal energy access.

2. Geospatial Analysis Tools

- Electrification planning has always relied on geographic tools of some kind, however, the capabilities of geospatial analysis tools have increased substantially in recent years. These new tools have already changed countries' approaches to energy access and have the potential in the future to produce more reliable, cheaper and up-to-date data than currently available.
- A growing network of satellites is enabling energy specific big-data collection on a global scale. Improved technologies have increased available datasets in areas such as: energy infrastructure, natural resources, socio-economic factors – incl. population density and distribution, and night-time lights. These increased datasets have largely been due to improvements in GIS and remote sensing technologies (Korkovelos et al., 2019).
- Examples of the potential of this technology include:
  - The Global Horizontal Irradiation (GHI) dataset provides solar irradiance data gathered from earth orbiting satellites combined with meteorological models. This resource provides solar resource and photovoltaic power potential to stakeholders that can inform the suitability and sustainability of solar solutions in a given region (available at: https://globalsolaratlas.info/map)
  - A team from Duke University's Energy Data Analytics lab have trained machine learning algorithms to automatically identify electricity infrastructure in satellite imagery. Data for existing infrastructure in some countries is non-existent or difficult to maintain; this tool has the potential for the system to be mapped in a fraction of the time and cost (Duke University, 2019)
  - The VIIRS is an instrument aboard the Suomi National Polar-Orbiting Partnership (Suomi NPP) launched in 2011 that collects data that allows observation of night-time lights. Importantly this can be used to show the location of electrified settlements. This data can be used in combination with other datasets to support electrification planning (LAADS DAAC 2021).

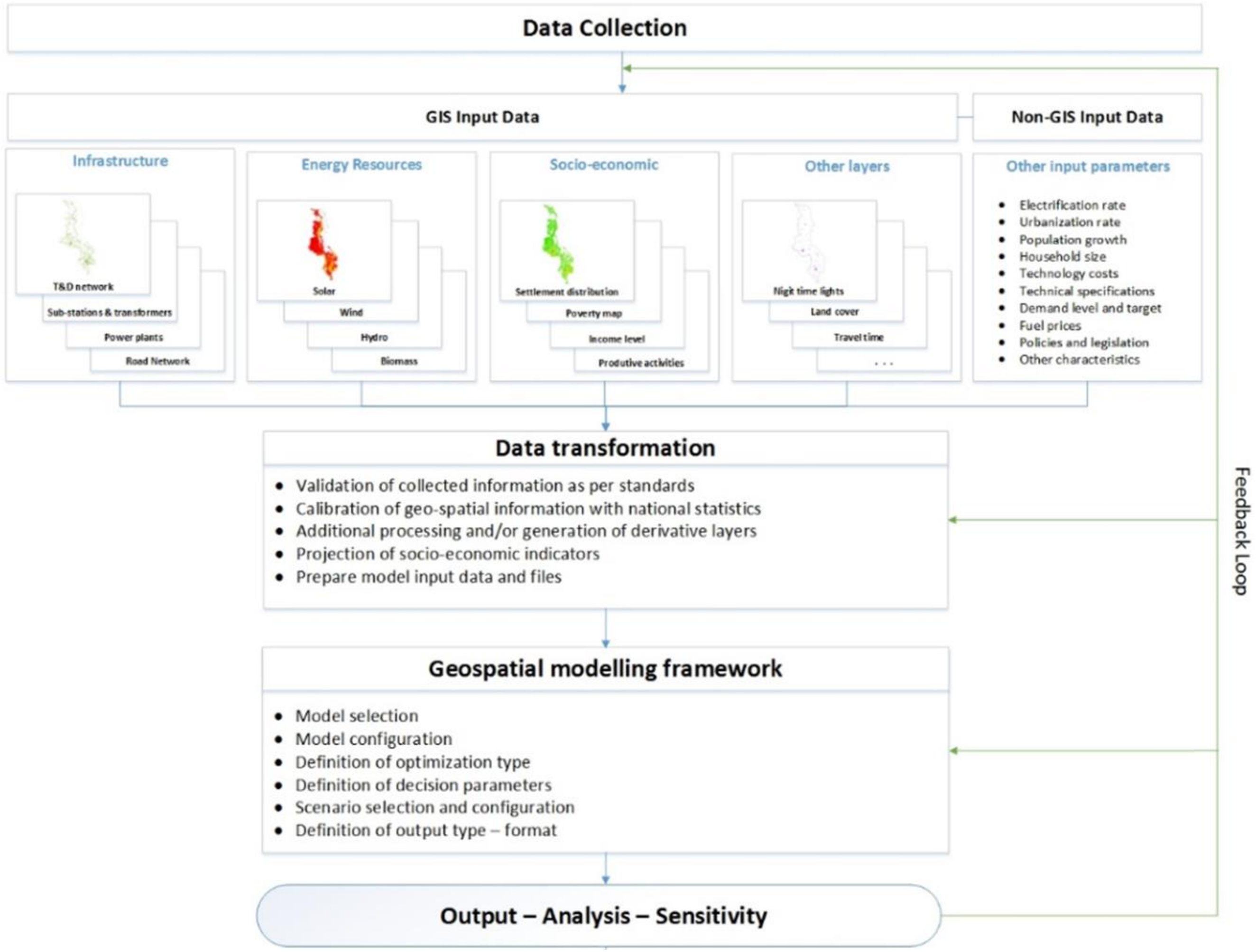
- Countries are already utilising geospatial tools in energy access planning. The overall increase in the availability of GIS-based data has stimulated the development of advanced GIS modelling tools that utilise geospatial information to support electrification planning in particular. A number of these tools have been deployed to develop geospatial least-cost national electrification plans or complement national plans through off-grid systems design. Examples of some of these tools and geographies where they have been deployed are shown below.

Name of Tool	Institution	Example Geographic Area Deployed
The Reference Electrification Model (REM)	Massachusetts Institute of Technology (MIT)	Rwanda, Uganda, Kenya, Colombia
The Open Source Spatial Electrification Tool (OnSSET)	Kungliga Tekniska Högskolan (KTH)	Latin America, Africa
IMPROVES-RE	Intelligent Energy Europe (EU)	Burkina Faso, Cameroon, Mali, Niger
Global Electrification Platform	ESMAP, World Bank	Global
Network Planner	Colombia University	Liberia, Ghana, Kenya Senegal
RE2nAF	Joint Research Centre (European Commission)	Africa
Off-Grid Market Opportunities Tool	International Finance Corporation (IFC)	Sub-Saharan Africa
GEOSIM	Innovation Energie Developpement (IED)	Not-specified
Hybrid Optimisation Model for Multiple Energy Resources (HOMER)	Homer Energy (originally developed in partnership with NREL)	Not-specified
RETScreen	Natural Resources Canada	Not-specified
Energy Access Explorer	World Resources Institute	Uganda, Tanzania, Kenya

Source: Korkovelos et al., 2019

- Though each modelling framework in the previous slide will utilise a different methodology, the flowchart, right, shows a standard plan of how a modelling framework might utilise both GIS and non-GIS data to develop least-cost electrification models for countries.
- It is important to note here how the GIS and non-GIS data intersect to create national plans. GIS data could be collected on the ground manually or gathered through one of the remote sensing techniques described earlier. However it is important that both GIS and non-GIS data sources input into the modelling.
- The non-GIS data should include demand level data, such as that collected through the MTF framework.
- An example of how this can work in reality is Ethiopia's National Electrification Plan (NEP).

Conceptual flowchart of GIS electrification modelling frameworks



Source: Korkovelos et al., 2019

Example: National Electrification Plan - Ethiopia

- In November 2017, the Government of Ethiopia launched the National Electrification Plan (NEP) that targeted universal electrification by 2025 through an ambitious least-cost pathway of both on-grid and off-grid technologies. Importantly, the plan is utilising both the MTF survey and geospatial modelling techniques.
- The MTF survey, conducted into 2017, was the first comprehensive energy access data gathering conducted in the country. As an example of the usefulness of this survey, the MTF revealed was that grid access was 10% higher than initially estimated and that there existed a large amount of informal connections that needed to be regularised.
- The geospatial analysis utilised, among other technologies, remote sensing of satellite imagery to identify and locate building structures countrywide. This revealed that 75–80 % of the population resides within 5 km of existing MV lines, 90 percent lives within 10 km and 95–96 percent of the current and future national population are within 25 km – key insights for developing a least-cost electrification plan.
- The result of both these tools was that, according to the NEP 2.0 published in 2019:

> "While these GIS tools can identify "where" and "what kind" of technologies (grid versus off-grid), and "when" they are least cost, the MTF approach supports the identification of "how much service" is needed to achieve the grid and off-grid targets. Combined, the GIS and MTF approaches enable the simultaneous targeting of beneficiaries by location and service, moving away from a binary approach to access of electricity service (haves versus have-nots) to a more service-centric approach, which sets at its centre how much service need is to be provided for the achievement of universal access and where." (Ministry of Water, Irrigation and Energy, National Electrification Plan 2.0, 2019)

Challenges for Energy Access Data

1. Increasing the availability of demand side data

> Demand-side data is incredibly important for the development of geospatial energy plans. Equally, as shown in the table right, it is often one of the most limited areas of data available. Whilst the development of the MTF is positive, more work is needed to address criticisms raised and ensure the collection and availability of demand-side data.

Figure 1: List of Key Inputs to Geospatial Electrification Planning

Step	Category	Dataset	Availability	Additional Comments
STEP 1 Identify unelectrified households, institutions, etc.	Population	Population density & distribution (e.g. location, number and size of households/buildings)	Largely available	Several good sources exist that capture population density and distribution, with increasing levels of granularity (though not all are open access)
		Population growth and expected urban-rural migration	Limited	There is a risk that these data become outdated very quickly. Time series can be used to better understand patterns.
	Socio-economic	Productive uses (location of agricultural centres/value chains, telecom towers, C&I customers)	Partially available	Location of agricultural centres can be inferred from location of commercial centres and presence of commercial crop types in the country.
		Social services (location and type of schools, clinics)	Partially available	Ministries of Health and Education may have valuable datasets on location and energy status of institutions
	Access Status	Electrification status (in terms of tiers of access, including quality and reliability) for households, schools, clinics, etc.	Partially available	Often estimated through night-light datasets, supplemented by household surveys (esp. to measure quality and reliability, which may result in stacking of power solutions)
STEP 2 Calculate & characterize demand	Socio-economic	Ability and willingness to pay (the income level and/or energy expenditure in an area - $/km2)	Limited	Difficult to capture, and limited information is currently available around ability vs willingness to pay for electricity services
		Access to finance institutions	Limited	This is important information for mini-grid developers and off-grid SHS providers, supplementing information around creditworthiness
	Demand	Electricity demand (effective, latent and over time) for different locations or types of settlements and customers	Limited	
STEP 3 Determine energy potential & options	On-grid Infrastructure	High-voltage lines (existing & planned)	Largely available	Requires information on country-specific HV datasets as there are often discrepancies between global/continental HV datasets and country-specific ones
		Medium-voltage lines (existing & planned)	Partially available	Requires information on country-specific MV datasets as there are often discrepancies between global/continental MV datasets and country-specific ones
		Low-voltage lines (existing & planned)	Limited	
		Substation & transformers (existing & planned)	Limited	Datasets could be validated through a feedback loop from existing interventions (mini-grid)

Source: SEforAll 2020

2. Keeping data up-to-date

> Energy planning is a years-long process. As such, it is important for data to be kept up-to-date to reflect the dynamic nature of data inputs.

3. Making geospatial data work for clean cooking

> Currently, geospatial data is concentrated in the electricity access area. More work is needed to ensure geospatial planning can support clean cooking access strategies.

4. Filling data gaps and improving data quality at low cost

> Data collection often remains a costly exercise. However, the advances in remote sensing and computer driven analytics discussed above can help to fill in some of the gaps in energy access data, often at a lower cost.

Trend 3

Regulations, Policies and Electrification Plans: Towards Integrated Approaches

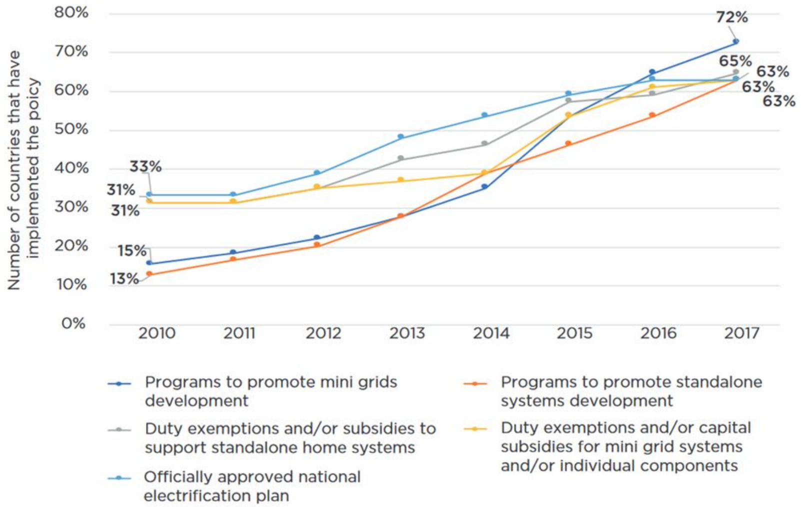
Enabling regulatory environments for energy access are crucial to reaching SDG 7 by 2030

Countries have moved towards more integrated approaches to energy access however, further integration is possible

Progress

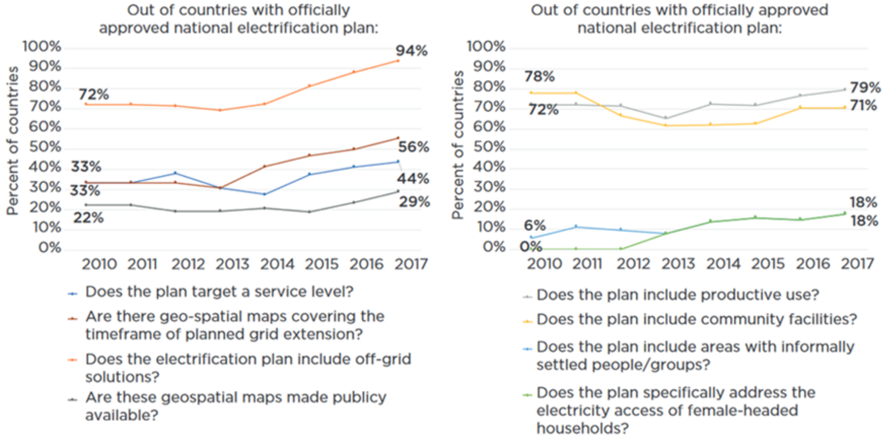
- The right regulatory and policy frameworks are crucial to countries' plans for reaching universal energy access targets by 2030.
- The Regulatory Indicators for Sustainable Energy (RISE) database tracks regulatory indicators from 133 countries. Since 2010, 75% of access-deficit countries established some key policy or regulation required to expand electricity access, with more than a quarter now having comprehensive policy and regulatory frameworks (World Bank 2018).
- Importantly, there has been an increase in the number of countries with electrification plans that include both off-grid solutions (Trend 1) and geo-spatial maps (Trend 2). This shows that national technical approaches to energy access are moving towards more comprehensive, data-driven integrated approaches.
- For clean cooking, there has been increasing traction for planning and policy frameworks including in the areas of emissions, efficiency and safety standards.

FIGURE 3.5 PERCENTAGE OF COUNTRIES WITH TOP FIVE FASTEST-MOVING POLICIES FOR ELECTRICITY ACCESS, 2010-2017



Source: World Bank 2018

FIGURE 3.17 IMPROVING SCOPE OF ELECTRIFICATION PLANS: PERCENTAGE OF COUNTRIES WITH QUALITATIVE AND INCLUSIVE PLAN ELEMENTS, BY SUB-INDICATOR, 2010 – 2017



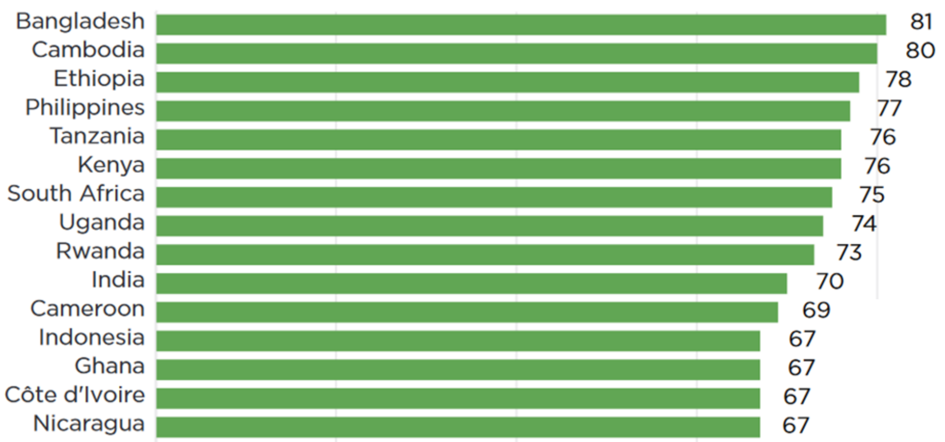
Source: World Bank 2018

Impacts of Electricity Access Planning

- Evidence suggests there is a strong correlation between good regulatory environments and increases in electricity access rates. Five of the fifteen countries with the highest RISE electricity access scores are also those that have achieved the some of the best annualised increases in electricity access from 2010 - 2018 – Cambodia (8%), Kenya (7%), Uganda (4%), Bangladesh (4%) and Rwanda (3%) (IEA et al. 2020 & World Bank 2018). Countries such as Indonesia and India*, who are moving towards 100% electricity access are also amongst the top RISE scorers.
- Having said that, countries such as Nepal and Afghanistan, that have 94% and 99% access rates respectively, have done so with below-average RISE scores rated "significant room for improvement". In addition, countries such as Papua New Guinea (5%) South Sudan (3%) and Central African Republic (3%) have achieved these relatively promising annualised increases despite their RISE score rated "very limited frameworks for access" (IEA et al. 2020 & World Bank 2018).
- Therefore, there is an overall recognition that energy access planning is crucial to meeting electrification targets. However, plans and regulations in themselves are not sufficient. They must be well implemented and progress should be checked, updated and reported; according to RISE only half of the countries monitored track progress and report on the roll-out of the plans. Additionally, countries should focus on ensuring the financial sustainability of utilities as well ensuring other regulatory measures are similarly correctly implemented, monitored and enforced (World Bank 2018).

*However, India is a good example of how energy access data can be misleading, see pg. 41

Top 15 RISE 2017 Electricity Access Scores, Access-Deficit Countries



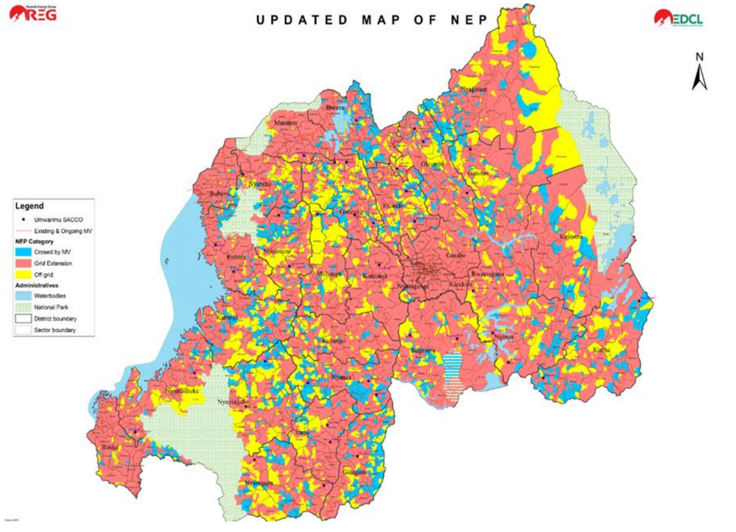
Source: World Bank, 2018

Electrification Planning: Rwanda

- Rwanda has achieved high increases in electricity access rates, from 15% in 2013 to 35% in 2018, thanks to a strong regulatory environment and energy access initiatives. Rwanda has policies in place for the most important areas of electricity access planning: an approved national electrification plan (NEP) for universal electrification by 2024 that is regularly updated and reported on, regulations for both on-grid and off-grid expansion, programmes for off-grid promotion, duty exemptions for off-grid components, and an approved least-cost geospatial map for universal energy access.

- However, there are issues with the geospatial map that could delay the deployment of off-grid solutions. For example, the off-grid area of the map has been divided into separate areas for SHS and mini-grids. This has constrained the ability of the off-grid market to compete freely for customers in the off-grid area, particularly considering some areas of the map designated for mini-grids appear to have too little demand for mini-grid solutions and may be more suitable to SHSs. In addition, regulatory requirements for mini-grids are time consuming and have delayed roll-out and the map may not provide investors with the confidence it is supposed to; the map is subject to revision and the compensation mechanism for grid arrival, pertinent to mini-grids, is yet to be finalised and tested.

Connection Method 2024		% Total Connections
On-grid		52%
Off-grid	SHS	38.2%
	Mini-grids	9.8%



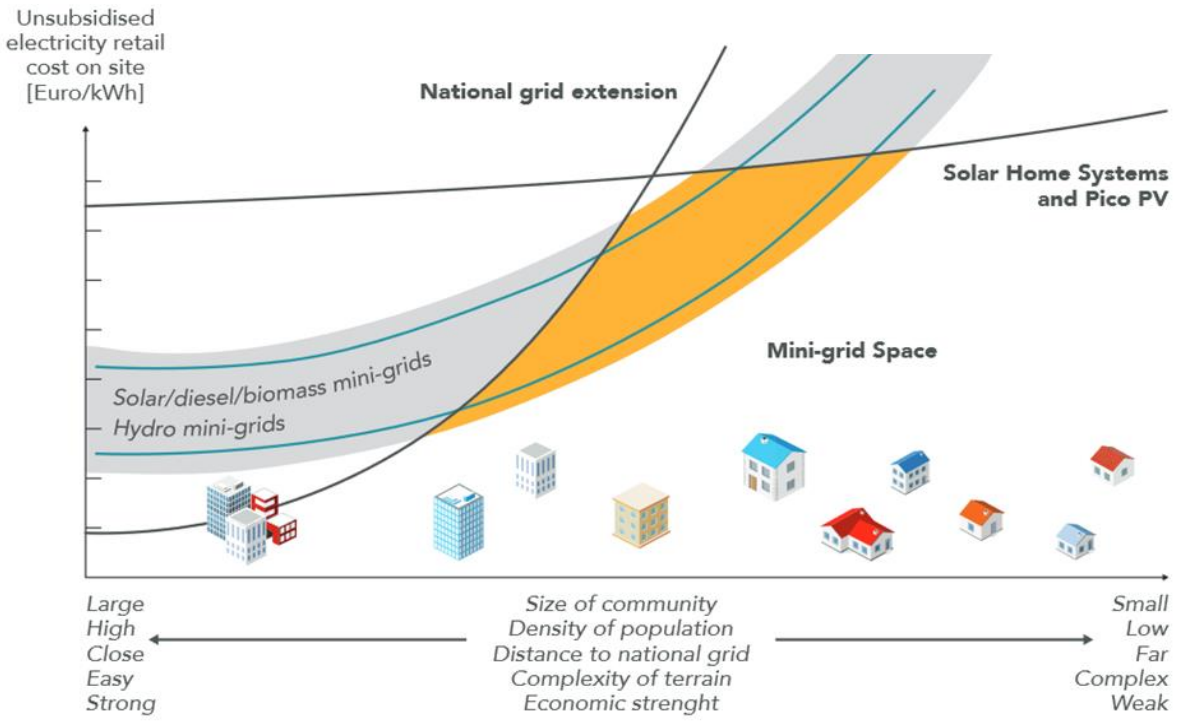
Source: reg.rw, 2020

Integrated Pathways (a) – SEforAll: Universal integrated energy planning

- The examples of Ethiopia and Rwanda, have demonstrated the trend towards more integrated approaches to energy access planning. Drawing on the trends of increased off-grid DRE and data sources, countries have been able to create far more comprehensive approaches, something Sustainable Energy for All (SEforAll) call universal integrated energy planning.
- SEforAll see universal integrated energy planning as a power tool that can direct resources most effectively and efficiently by integrating inclusivity, data and clean cooking agendas (SEforAll 2020).
- SEforAll Integrated Pathways for Universal Electricity Access characteristics include:

1. Placing access to electricity in the context of sustainable development and human needs
2. Considering all technological approaches and delivery models
3. Relying on high-level commitment and support for an inclusive, coordinated planning process
4. Including supportive policy measures, that facilitate investment and are market enabling

Integrated Planning: A set of inclusive planning approaches and policy measures that support using grid, mini-grid and off-grid technologies to provide electricity and the associated energy services necessary to meet human needs and contribute to sustainable development (SEforAll, 2019)



Adapted from the EUEI PDF, Mini-grid Policy Toolkit, 2014.

Source: SEforALL, 2019

Integrated Pathways (b) – Power for All, Utilities 2.0

- A further integrated approach to universal energy access is Power for All's Utilities 2.0. Funded by the Rockefeller Foundation, Utilities 2.0 is a strategic initiative of Power for All and a coalition of partners to accelerate the end of energy poverty. Utilities 2.0 seeks to challenge conventional approaches to energy access and advance the role of "off-grid" DRE as a legitimate part of the global power supply.
- In this view, traditional Utility 1.0 models are seen as monopolistic, unidirectional, and siloed. With digitization, decentralization, and data Utilities 2.0 can enable grid and non-grid energy to collaborate and maximize connections.
- Driven to these conclusions by similar concerns to that of SEforAll above, Utilities 2.0 sees as a primary driver the fact that many utilities in energy access deficit countries are failing to meet provision of service obligations and only two out of 39 utilities in SSA are profit-making (Power for All, 2019). Therefore Utilities 1.0 will leave many people without access.
- Utilities 2.0 is a framework to support grid and non-grid electricity in optimizing national energy systems and reaching SDG 7 by 2030.

Utilities 2.0: Vision

Utilities 2.0 is designed to combine centralized and decentralized technology into an integrated, intelligent, and interactive energy network that can deliver customer-centric, clean energy solutions to end energy poverty at the lowest cost, in the fastest time.

Utility 1.0: The 2.0 Opportunity

Centralized Strengths	Decentralized Strengths
Infrastructure	Modularity
Incumbency	Competition
Scale	Agility
Low-cost, long-term debt	Range of investors, options
Significant customer base	Customer-centric brands
Billing and collection	Ancillary services + products
Capacity + "deep bench"	Innovation

Source: Power for All, 2020

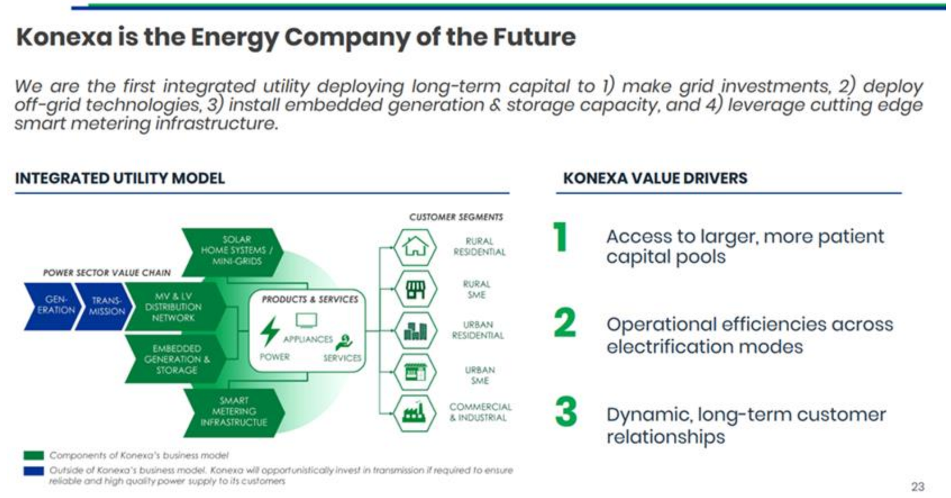
Integrated Pathways (c) – What do Utilities 2.0 look like in practice?

- Describing itself as the energy company of the future, Konexa is pioneering an integrated distribution concept in partnership with Kaduna Electric and Kano Electric in Northern Nigeria. The main aim of Konexa is to break the cycle of lack of capital and low collection rates that have restricted the industry. They aim to do this through restoring financial flows to the distributors.

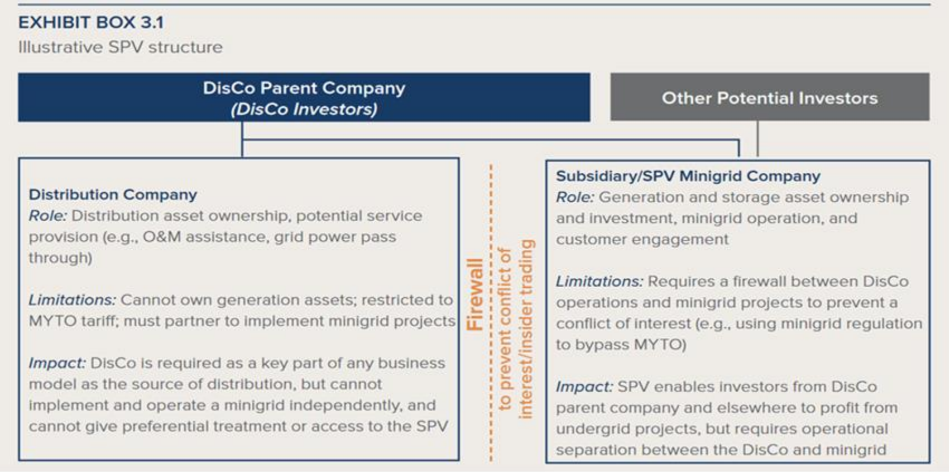
- The approach consists of the deployment of a combination of both SHS and mini-grids, off-grid DRE, in combination with grid infrastructure investments and meters installation. Konexa are also collaborating with the REM geospatial modelling analysis tool to focus their efforts.

- The Rocky Mountain Institute business model, right, shows how an SPV structure might govern the relationship between distributor and a mini-grid company for example. This model is specifically designed, similarly to Konexa, as a way to limit distribution financial losses and put them on a pathway to financial sustainability and increase universal energy access (Shell Foundation, 2019).

- Utilities 2.0 sees this model as the business model of the future for national utilities. Results will show whether this approach can be scaled up across access deficit countries and whether this structure will be adopted by more utilities in the future.



Source: Power for All, 2020



Source: Rocky Mountain Institute, 2019

Challenges & Opportunities for Regulations, Policies and Electrification Plans

1. Regulatory and Policy Progress

- Despite progress with regulatory and policy frameworks in recent years, there still remains work to be done. According to the RISE, 54% of the remaining population who lack electricity access live in countries with weak regulatory frameworks (World Bank, 2020). This will have to improve markedly to achieve universal energy access targets by 2030. In addition, it remains to be seen if integrated approaches continue to be adopted by countries. In particular it will be important to see how countries can effectively utilise the new data techniques to design their regulations, policies and energy access plans.

2. Regulatory and Policy Enforcement

- Good regulatory and policy environments are not enough to ensure reaching SDG 7 by 2030; it's important that these new regulations and policies are effectively enforced. This requires effective regulatory bodies as well as licensing, monitoring and compliance tools to ensure correct implementation (World Bank, 2020). The Global Electricity Regulatory Index (GERI) complements the RISE indicators and provides further insight on countries' regulatory governance and substance: https://www.afdb.org/en/documents/electricity-regulatory-index-africa-2020. Overall, these resources are good guides for the big picture, however, often the most effective means of gaining insight into the reality of the ground is speaking to those with experience in country such as companies with similar experience, industry bodies or regulatory bodies themselves.

3. Clean Cooking

- Clean cooking is often overlooked as key area for energy access regulations and policies. This is reflected in the fact that the majority of countries, 85%, do not have advanced policy framework for clean cooking. Having said that, 56% of the population without clean cooking access now live in countries with advanced policy frameworks (World Bank 2020). This is mainly due to advances in countries like China, India, Ethiopia, Indonesia and Kenya who between them have more than half the global clean cooking access deficit population.

Trend 4

Under-the-Grid

Increased visibility has shown that certain connection data hides energy access deficits

Providing energy access to people under-the-grid will be a key concern for reaching SDG 7 by 2030

Under-the-Grid

- A majority of energy access data still relies on binary definitions of energy access. This is particularly the case for electricity connections – people are deemed either connected or not-connected. However, new energy access definitions, data collection methodologies and available data have revealed that some people previously deemed 'connected to electricity' are sometimes either not connected at all or not seeing the full benefits of electricity access. These electricity connections have often been described as 'under-the-grid'.
- The new data collection methodologies have shown that these under-the-grid connections may lack access because the household:
  - Falls within the area of a distributor but has not been provided with an electricity connection. This could be down to issues around legality, ownership, low demand, and housing type; factors particularly acute in informal settlements
  - Electricity is unreliable, inconsistent or of low-quality which makes the electricity unavailable or unusable for long periods of time
  - Finds either the electricity or the connection itself unaffordable despite the fact the grid is nearby. (Rocky Mountain Institute 2020)
- The issue of under-the-grid is a worldwide problem. In general, South Asia and West Africa, despite having higher electrification rates on average, have the largest share of people with unreliable grid connections, although 34% of grid-connected people also have unreliable grid connections in sub-Saharan Africa (Lighting Global 2020). Globally, it is estimated that more than 2 billion people live with blackouts for more than 100 hours a year and 1 billion with more than 1,000 hours (IFC 2019).

Further than Under-the-Grid

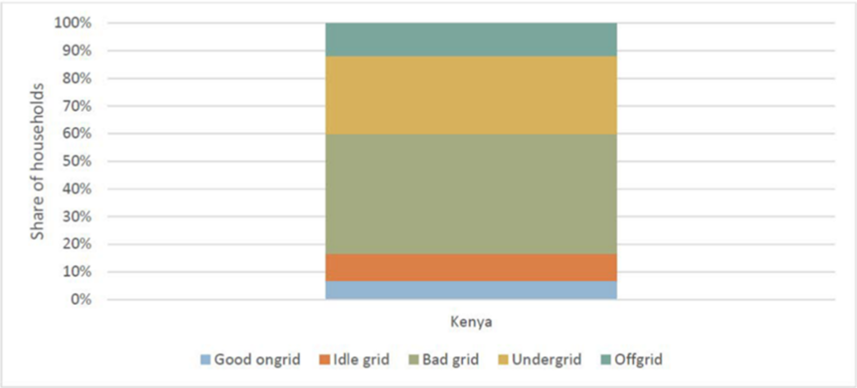
- Research from M-KOPA and the Shell Foundation in Kenya has shown the prevalence of the problem of under-the-grid. In addition, the data collected has been further segmented into idle grid, customers with electricity connections who are unable to afford appliances, and bad grid, customers with electricity connections that experience frequent and extended outages.
- According to this data, under 10% of Kenyan households are considered to have a good on-grid connection. In addition, the prevalence of under-the-grid and bad grid is most acute in peri-urban and rural areas.
- This data is a good example of how new data insights are not only highlighting issues with previous metrics of electricity connection, but importantly providing evidence of the challenges people face in benefitting from electricity access.

Table 1: five customer segments

Grid status	Off grid	Under grid	Idle grid	Bad grid	On grid
Customer circumstances (domestic and small enterprise)	Live far from the grid	Live close to the grid, could be connected but current costs too high and capital intensive	Connected (through rural electrification programmes) but cannot afford appliances	Connected to the grid but suffer unreliable connections: frequent and extended outages	Connected to the grid

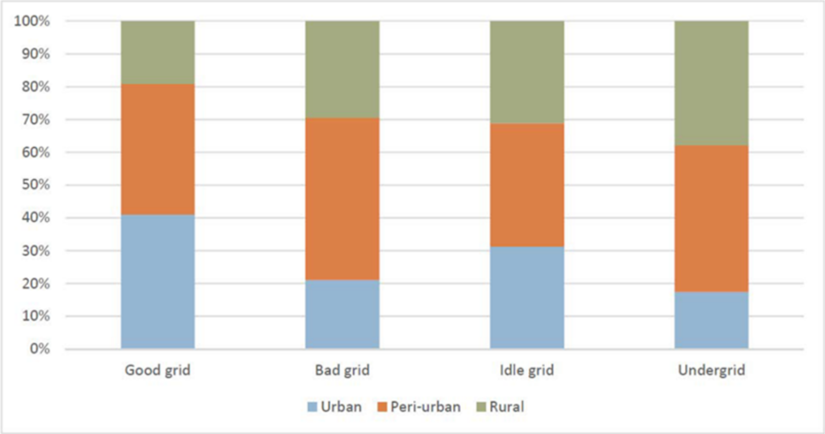
Source: Shell Foundation 2017

Figure 1: Percent of Kenyan households in each grid connection category



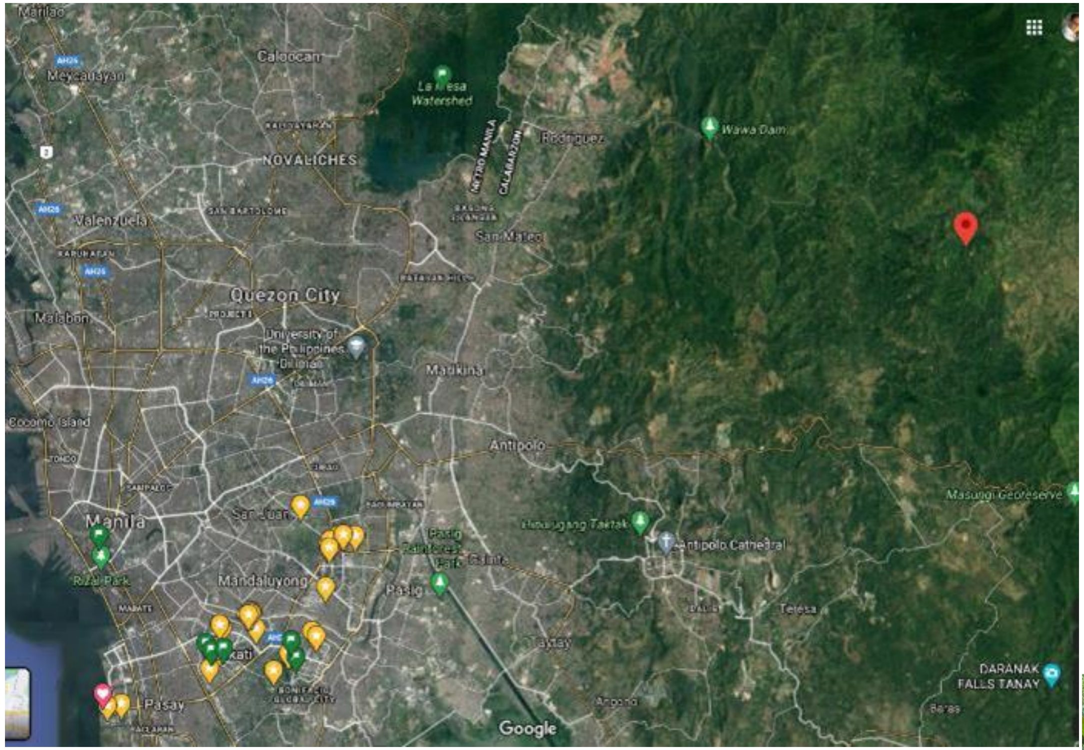
Source: Shell Foundation 2017

Figure 3: Percent of households urbanised by each grid connection category



Source: Shell Foundation 2017

Under-the-Grid: Manila: Between Two Barangays

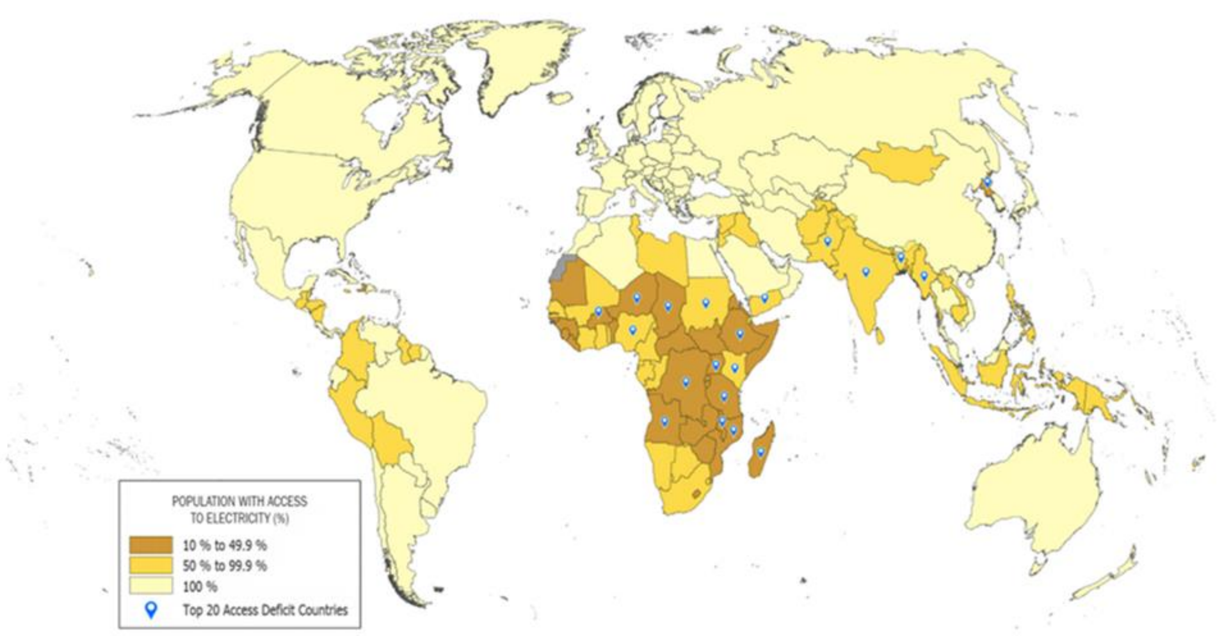


- The communities shown by the red pin, left, near Manila, Philippines, illustrates the issue of under-the-grid connections.
- These few communities, only approximately 2 hours from the capital of Manila, remain unelectrified as they are caught between 2 barangay jurisdictions each of which is not taking responsibility for the electrification of the communities.
- As shown in the pictures, the communities are relying on off-grid DRE solutions to power their households and businesses.

Electricity Access vs. Unreliable Supply

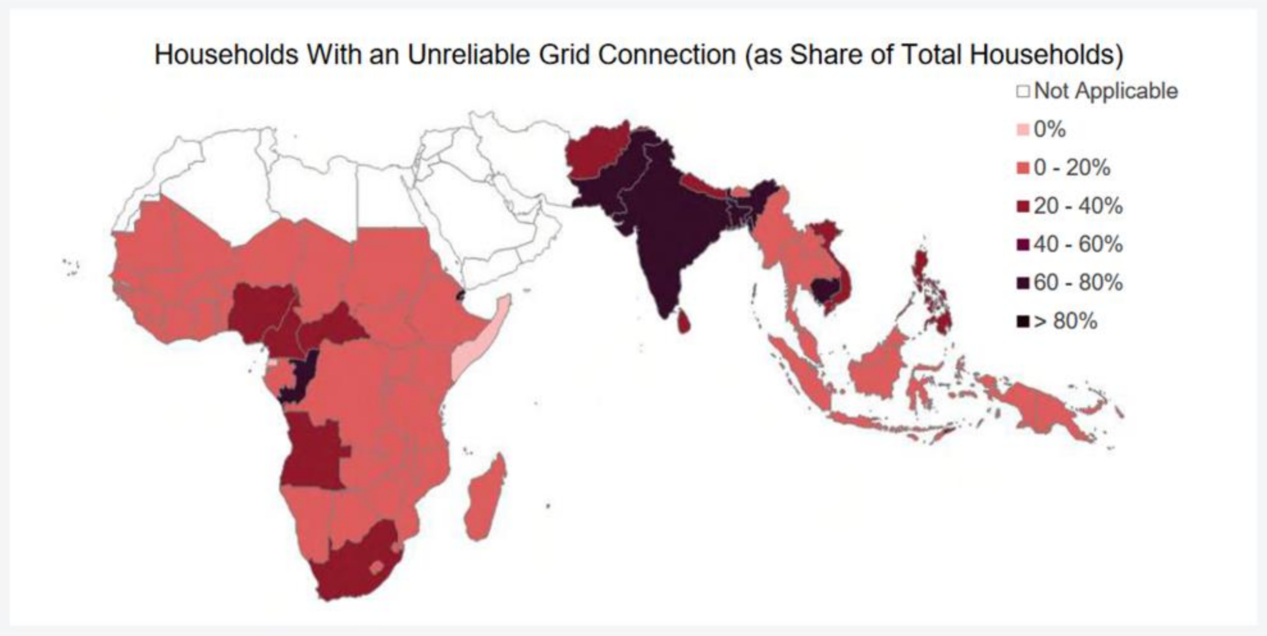
- The two maps below are a good illustration of the problem with unreliable grids and electricity access data. The map on the left shows India's population with between 50 - 99.9% electricity access; according to the SEforAll Tracking Framework India has an electrification rate of 99%. However, the map on the right shows how the number of households with an unreliable grid connection is over 80%.
- In India, non-grid sources (both solar and diesel generators) continue to compose 16% of the rural energy mix for households and 40% for enterprises, suggesting the grid does not provide necessary supply for the demand in the country (Lighting Global, 2020).

FIGURE ES.2 • Share of population with access to electricity in 2018



Source: ESMAP 2020

Figure 36: By Percentage, Many Households in Asian Countries Still Receive an Unreliable Supply

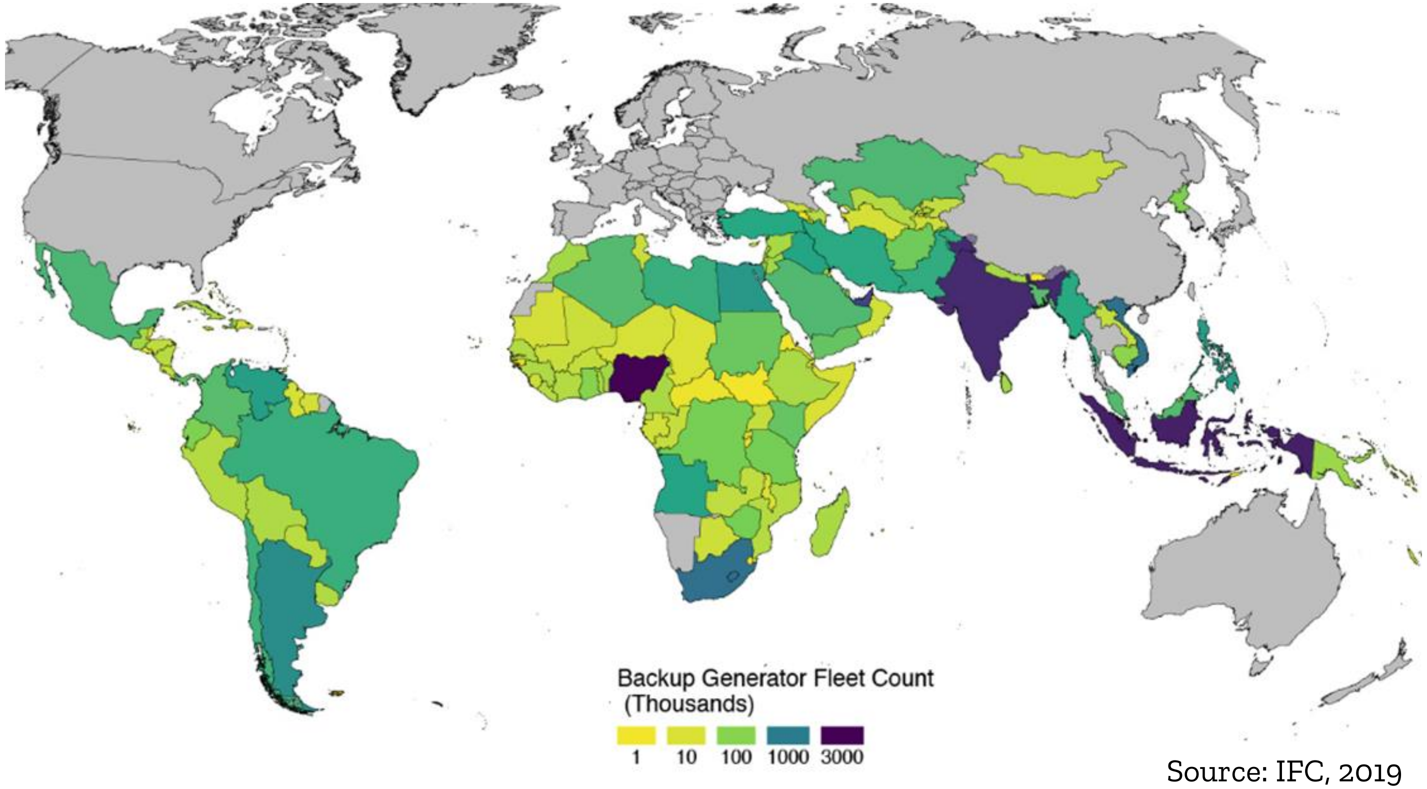


Source: Lighting Global 2020

Back-Up Generators: Evidence and Opportunity

- Further highlighting the under-the-grid issue is the market for backup generator sets. Globally it is estimated that there are 25 million generators deployed in countries shown in the map, right; 75% of which are deployed at sites that have a grid connection (IFC 2019).
- The majority of these generators sets run on diesel fuel and are noisy, polluting, have negative health consequences and can be costly to run. They are very important however for many businesses, productive users and institutions.
- Therefore, not only does this highlight the issue of grid reliability, it also shows the opportunity for other solutions, such as off-grid DRE to serve this market.

Backup Generator Fleet Count Estimates 2016



Source: IFC, 2019

Challenges & Opportunities for Under-the-Grid

1. Off-grid DRE

> Off-grid DRE systems, can not just provide cleaner, safer and cheaper energy access for under-the-grid customers, they can replace current backup generators and be regarded as genuine alternatives to grid connection. Analysis from the Rocky Mountain Institute, top right, shows how mini-grids and SHSs can are suitable alternatives for under-the-grid customers energy needs.

COMPARISON OF ELECTRICITY OPTIONS FROM CUSTOMER PERSPECTIVE

	COST OF CONNECTION (UP-FRONT COST)	COST OF ELECTRICITY (ONGOING COST)	AVAILABILITY AND RELIABILITY	ABILITY TO SUPPORT PRODUCTIVE-USE EQUIPMENT
MAIN GRID	●	●	○	◐
MINIGRID	◐	◐	●	●
SOLAR HOME SYSTEM	◐	○	◕	◔
DIESEL OR PETROL SELF-GENERATION	○	◔	◐	◕

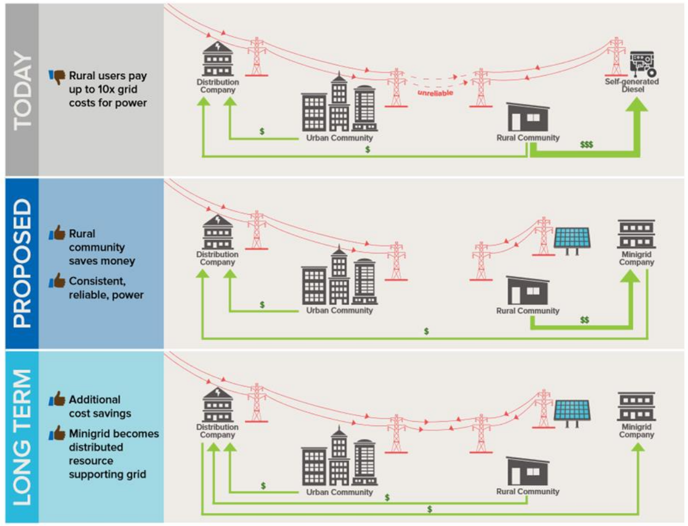
● Highest-performing ○ Lowest-performing

Source: RMI, 2019

2. Data and Integrated Approaches

> Better data combined with integrated energy access plans can further support targeted interventions for under-the-grid. Improved data will allow for further identification of the issues people face in gaining full energy access and new business models, such as that shown bottom right, can support the role of off-grid DRE in supporting integrated approaches to energy access.

FIGURE 1
INTEGRATING MINIGRIDS IN UNDERGRID COMMUNITIES



Source: RMI, 2019

3. National Utilities & Electrification Plans

> Electrification plans often focus on adding more connections, which is good for rural access rates, however this can come at the expense of grid strengthening, improving service and reliability that will ensure people are able to fully benefit from electricity access. In addition, cash-strapped national utilities often lack the required financial resources to carry out required grid improvements.

Trend 5

Energy Access Beyond Households: Institutions and Productive Use

Providing energy access for institutions and productive users is a crucial area for policymakers to reach universal energy access

There is significant potential for off-grid DRE to provide energy solutions to these users

Energy Access for Institutions

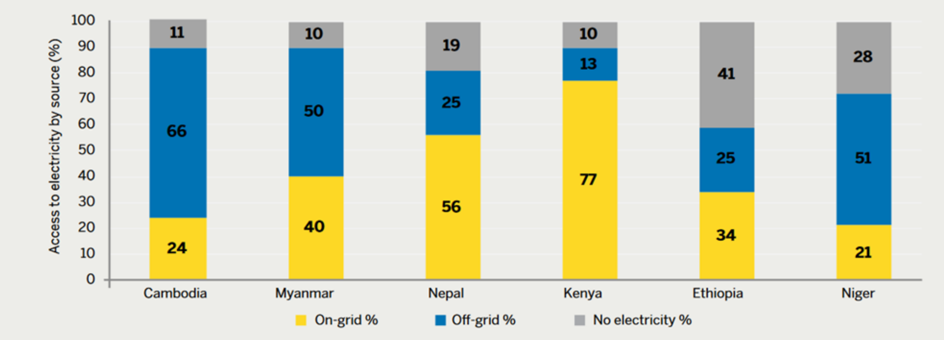
- Countries approaches to universal energy access should take into account not just household connections but also the connection of institutions and productive users (PU). This is not only important for reaching SDG 7 but for a variety of other SDGs such as jobs, health, education and gender. Currently countries are including the connection of institutions and PUs in energy access plans however, there is much further scope for countries to include institutions and PU in energy access plans.

- In 2013 it was estimated that approximately 1 billion people globally rely on health facilities without access to electricity (Practical Action 2013). In India alone in 2018 it was estimated 580 million people relied on health facilities without an electricity supply (SEforAll 2020b).

- Health institutions mainly utilise electricity for lighting, air-cooling systems and refrigerators for vaccines. Countries are already supporting the deployment of off-grid DRE, particularly solar PV and hybrid systems, to electrify institutions such as health centres. In Uganda 15% of health centres use solar energy and in Sierra Leone 46% of hospitals are combining solar PV with other forms of energy (WHO 2015). The United Nations Development Programme (UNDP) Solar Health initiative has supported solar PV at 900 health centres across 11 countries (UN 2019). The current COVID-19 pandemic is further highlighting the urgent need for safe, reliable and affordable electricity at health centres across the world.

- However, one study has estimated that 60% of health facilities in low and middle-income countries lack access to a reliable electricity supply (Bartram and Cronk 2018). In MTF countries surveyed, shown right, 25% of health institutions remain unelectrified and, of those that are electrified, 28% have reported damage to equipment caused by poor quality electricity and 25% reported that unscheduled outages have affected their ability to deliver essential health services (IEA et al. 2020). A further WHO survey found that a third of medical equipment failures were caused by inadequate power supply (WHO 2010).

FIGURE B1.3.2 • Electrification of health institutions in selected MTF countries, by source



Source: IEA et al., 2020

Productive Use Leveraging Solar Energy (PULSE)

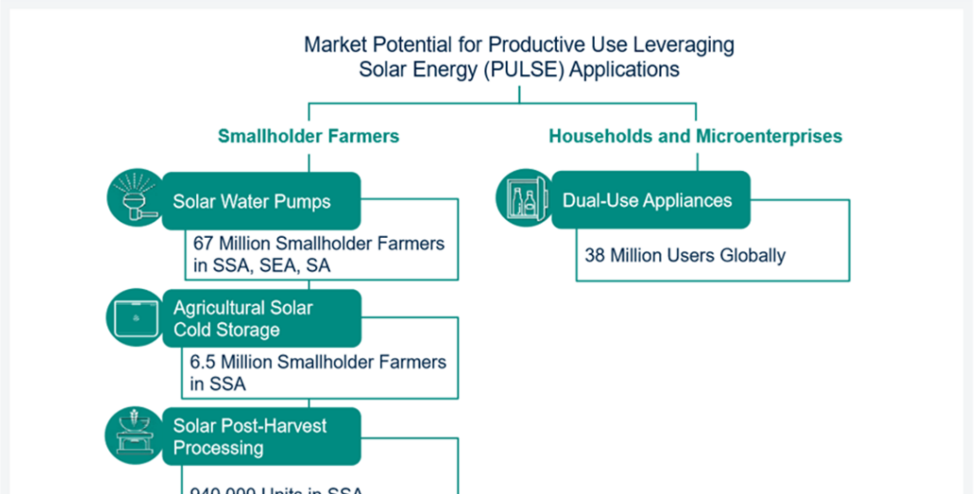
- Electrifying PUs is important because it has the ability to improve metrics across a range of indicators for SDGs including economic growth, job creation and gender. Therefore, policymakers are increasingly looking for least-cost pathways to electrifying these users.
- The key drivers for this trend are similar to those already mentioned including:
  - technology improvements
  - poor quality and unreliable power
  - new business models incl. PAYG
  - agricultural production and small businesses becoming more mechanised.
- In particular countries are turning to solar products to bridge these gaps; called productive use leveraging solar energy (PULSE) solutions. There exists significant potential across a diverse range of applications and industries including water pumps, milling machines and refrigeration, as shown right.

	Irrigation Pumps	Cooling	Agro-processing
Large	> 5 Ha While technologies exists there are limited large scale applications in practice	>10,000 L Typically applied as walk-in cooling, technologies are available at an aggregated scale, but uptake remains low	> 10 MT/day The main examples that exist are mini-grid applications as like-for-like replacement of grid-based processing
Medium	2 – 5 Ha The majority of supplier distributors are targeting this scale and uptake is reasonable depending on the geography	2000 – 10000 L Fewer technologies in this category as providers are either looking at large aggregated systems or smaller individual systems	2 – 10 MT/day The main examples that exist are mini-grid applications as like-for-like replacement of grid-based processing
Small	< 2Ha Technologies are well developed and available but affordability and market development are barriers	100 – 2000 L Productive uses typical adapt refrigeration intended for small retail enterprise use, uptake is low	1 – 2 MT/day Incumbent technologies exist but the system size is prohibitive for standalone applications
Very Small	< 1 Ha Recent product development has increased affordability, precedents are emerging in some markets and are starting to scale	<100 L Productive uses typical adapt refrigeration intended for household use and uptake is low	< 1 MT/day There are limited standalone technology choices and use cases are unproven

Commercial readiness: High Mid Low

Source: Lighting Global, 2019

Figure 45: Overview of Current Market Potential for PULSE



Source: Lighting Global, 2020

Productive Use Example

- As shown in the diagram, right, there are many opportunities for PU energy access interventions in the maize value chain in sub-Saharan Africa. Activities such as irrigation, drying, shredding and milling are all areas where off-grid DRE could service the value chain. Some activities, such as irrigation, may currently be done manually. Others, such as milling, are likely powered by diesel generators and therefore represent opportunities for energy access interventions.

- Further research has shown how the productive use of energy can support energy access targets by lowering the cost of deployment for mini-grids for example. The table, right, shows how large PU load users can support the reduction in levelized cost of energy (LCOE) for mini-grids, improving the business model for developers. Therefore energy access for PU is not only positive for the PU user, but also has the potential to spur further energy access initiatives such as mini-grids.

	Production	Local Processing	Marketing
PUE Activities	• Irrigation • Animal fodder production • Drying • Shelling • Winnowing • Storage	• De-hulling • Dry milling • Wet Milling • Cleaning and packaging (whole grain /maize flour/maize bran)	• Flour fortification • Animal feed production • Cereal production • Baking • Brewing beverages • Making popcorn • Packaging
Machinery	• Irrigation pump (0.2kW) • Electric motor (up to 7.5 kW) • Shredder (0.2 kW) • Dryer (0.2 kW) • Sheller (0.2 – 1 kW) • Winnowing and sorting machine	• Huller (3 kW) • Plate mill / Hammer mill (0.75 kW - 7 kW) • Electric motor (up to 7.5 kW) • Packaging machine (2 kW)	• Flour mixer (1.1 kW – 3 kW) • Electric oven (6kW) • Brewing machines (up to 10 kW) • Packaging machine (2 kW)

Source: Energy 4 Impact, 2020

Table 2. Results of Comparison of the LCOE of Heavy Residential and Business Load Profiles

RESULTS SUMMARY	RESIDENTIAL HEAVY			BUSINESS HEAVY		
	Diesel only	**PV + battery**	**PV + battery + diesel**	**Diesel only**	**PV + battery**	**PV + battery + diesel**
Total life-cycle cost	$150,567	$161,616	$142,168	$138,876	$122,369	$114,136
Total CAPEX	$39,395	$112,383	$45,737	$29,037	$79,122	$44,565
Total operating expenditures	$111,173	$49,233	$96,431	$109,839	$43,247	$69,571
LCOE	**$0.90**	**$0.96**	**$0.85**	**$0.83**	**$0.73**	**$0.68**

Source: NREL, 2018

Challenges & Opportunities for Connecting Institutions and Productive Users

1. Off-grid DRE for Institutions

- Off-grid DRE technologies represent a viable alternative to grid connection for many institutions and PU. They can be cleaner than current generators used by facilities, more cost-effective, reliable and easily deployable to hard to access areas. However, there are still challenges remaining for off-grid DRE deployment at institutions and PU. Current challenges due to the pandemic are similar to those outlined above for off-grid DRE in general, but others are long-term challenges including, high costs for solutions, limited availability of accessible funding and technical requirements for equipment (WHO 2015).
- Having said that, during the COVID-19 pandemic there are funds being deployed specifically to support the solarisation of healthcare centres (Power for All, 2020a) and SEforAll have published a catalogue a providers of energy for healthcare solutions: https://www.seforall.org/system/files/2020-11/PHC-solutions-catalogue-v4-SEforALL.pdf

2. Off-grid DRE for PU

- As shown above, there is significant opportunity for off-grid DRE solutions to support countries technical approaches to universal energy access. However, current sectors such as PULSE are nascent and fragmented, across technologies and geographies. Much of the technology is in early development and, where proven technologies exist, the cost of products is still high and products lack established distribution networks to markets. The development of these issues will directly influence countries technical approaches to reaching universal energy access.

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Annex 1 – Links to Countries Electrification Plans

- Kenya Off-Grid Solar Access Project: https://snv.org/project/kenya-off-grid-solar-access-project-kosap
- Ethiopia National Electrification Plan: https://www.powermag.com/wp-content/uploads/2020/08/ethiopia-national-electrification-program.pdf
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