TFE Energy

Energy Access, Data and Digital Solutions

DISCLAIMER

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The case study process involved interviews and ongoing exchanges over the course of the research work. It proved to be the heart of this study. Then, we thank the 34 market experts with whom we discussed ideas. A full list of interviewees can be found in the Appendix.

Finally, we would like to thank the experts who took time to review this report: Drew Corbyn (GOGLA), Jens Jaeger (ARE), Jose Ignacio Briano (Enzen), Kerstin Fritzsche (IASS), Simon Bittner (Groots), Shefali Kothari (clean energy startup strategist), Svet Bajlekov (AMMP Technologies), Benjamin Attia (Wood Mackenzie), Cristiano Cialone (ESA), David Arndt (DEG), Peter Lilienthal (HOMER Energy), Jessica Stephens (AMDA), Bboxx, Jacob Lewandowski (d.light), Salman Zahir (IFC), SparkMeter, Alessandro Pietrobon (Zola Electric), George Kibala Bauer (GSMA Mobile for Development Utilities), Avi Jacobson (SunFunder), Carol Litwin (AfDB), Dimitris Mentis (WRI), Stefan Zelazny (Engie Mobisol), Emily McAteer (Odyssey Energy Solutions), Ruchi Soni (GMG Partnership) and those who prefer to remain anonymous.

Image provided by PowerGen Renewable Energy

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KEY DEFINITIONS

Digital ecosystem	The technological environment in which digital technologies interact. Here focusing on data collection, transfer, storage and actionable analysis.
Digital payments	All non-cash payment solutions, in which the payer initiates the payment electronically. They include mobile money and cryptocurrencies.
Digital solutions	Digital products or services offered in the market, that are enabled by digital technologies.
Geospatial layer	Geographic datasets that are visualized on a map.
GSM	A mobile telecommunication standard, that refers to second generation (2G) cellular network protocols.
Internet of things (IoT)	A system of interconnected devices that communicate over a network to collect, share, store, analyze and report data.
LoRa (long range)	A long range, low power wireless communication technology that enables a two-way data transfer in IoT settings.
Mini-grids	A distributed energy system that generates electricity at a centralized point from one or a combination of sources and distributes to end-customers through a low- or medium voltage grid.
Mobile money	An account used to store and manage money, that is linked to a mobile phone and cellular subscription.
Off-grid electrification	Provision of electricity independent from the national grid, with mini-grids, solar home systems or solar lanterns.
Off-grid solar (OGS) products	Solar photovoltaic-powered off-grid energy products, including solar home systems and pico-solar products.
Pay-as-you-go (PAYGO)	A business model that allows end-customers to pay for a product in install-ments instead of upfront.
Pico-solar products	An OGS product offering basic energy services (usually lighting and mobile device charging) with peak capacity up to 11Wp.
RF mesh	Communication infrastructure used to remotely collect data from smart meters.
Solar home system (SHS)	An OGS product with peak capacity ranging from 11Wp to 350Wp, powering lights and other appliances.
USSD	A GSM protocol that enables communication between a mobile device and a mobile network operator.
Vertical integration	The involvement of a firm in multiple stages of the value chain, as opposed to specializing in a single stage.

EXECUTIVE SUMMARY

Over 1 billion people have no access to modern energy services. Another 1 billion receive very unreliable power. This is a key limiting factor for development, putting at risk the educational, health, aspirational and security needs of more than a quarter of the global population. The challenge is recognized by the global community and the provision of universal access to modern energy by 2030 is a fundamental Sustainable Development Goal (SDG7) of the United Nations.

Significant leaps are made towards this goal, by extending the grid, through distributed grids (mini-grids) and via the sale of off-grid solar products. Some countries, such as Vietnam, have been particularly successful. However, in many other regions, especially in parts of Sub-Saharan Africa, universal electrification is still a distant dream.

If we stay on our current trajectory, we will resoundingly fail to achieve universal energy access in the next 10 years. And that is even at basic, subsistence levels of energy consumption of 360kWh per household per year[1], a number nowhere near the levels of energy needed to power agriculture, commerce or small-scale manufacturing and thereby create the millions of new jobs needed to support rapidly growing populations. It is also not enough energy to power the more complex irrigation systems or cold-storage facilities needed to safeguard food supplies in regions already affected by climate change.

We need to find ways to significantly accelerate our efforts. The timing is good. The energy access industry is ready to grow. There now exist proven toolkits of electrification technologies (solar panels, batteries, cables, etc.), policies and business models.[2] However, to truly achieve scale, risks (especially customer and market risks) have to be better addressed and costs (capital costs, operating costs, financing costs) further reduced. This is where the digital solutions described in this report can make a real difference.

Our research shows that the large-scale and often real-time collection, analysis and use of all kinds of datasets, enabled by the rapid, global technology shift called "digitalization," is in the process of transforming the energy access industry. Companies across the energy access spectrum use digital solutions to enable their businesses and as the industry matures, there is a growing number of specialized digital solution providers.

- Digital planning tools are used to get perspective and gather market intelligence on remote regions. Data analytics is currently used for least-cost electrification planning at the country level, for selecting suitable sites for mini-grids and to predict customer characteristics in the off-grid solar (OGS) industry. The use of satellite imagery-based analytics has the potential to greatly increase the speed at which the energy access industry can scale and significantly reduce the costs of site and customer acquisition. Data, including satellite-based data, can be used to plan mini-grid systems and perform feasibility studies on these systems to predict their viability.

- Digital platforms seek to reduce transaction and financing costs in the industry. Such platforms come in mainly two forms. The first is the project aggregation

Image provided by Sam Duby, TFE Energy

1 – The World Bank, Tracking SDG 7: The Energy Progress Report, 2019 (link)
2 – TFE Energy, Kenya: The World's Microgrid Lab, 2017 (link)

platform (used mostly for mini-grids), which collects performance data on portfolios of projects and drives the industry towards quality and process standards, thereby de-risking investments. The second is the crowdfunding platform. These leverage a “crowd” of investors who are more accepting of the risks associated with the energy access market. Crowdfunding has outright funded a number of early energy access projects and has enabled companies to test new business models and collect data used to receive subsequent funding.

- Digital operations include solutions like remote monitoring, which enable companies to collect data on their deployed systems. Due to the remoteness and dispersion of the OGS and mini-grid markets, costs associated with traveling to customers to perform maintenance can greatly increase operating expenses. As a result, being able to remotely identify and troubleshoot problems has greatly reduced the operating expenses of energy access companies. Likewise, detailed information on user behavior allows companies to improve and customize their service offerings. Digital operations also include lockout technologies and devices that can be remotely controlled.

- Digital payments have been enabled by the high penetration of mobile phones, wide coverage of 2G cellular services and supportive policies for mobile money in some countries. Digital payments allow rural (often unbanked) customers to pay for services and products remotely and securely. This addresses the significant challenge of payment collection in rural, remote regions. In addition, energy access companies use digital payments data to leverage customer credit risk analytics to identify customers for upselling, encouraging them to move up the energy ladder.

Our report starts off with three introductory chapters explaining how the parallel growth of energy access products and services coincides and interacts with the evolution of digital solutions. Then, we describe the four above mentioned clusters of digital solutions in detail. Lastly, we look at how digital solutions can be financed and share ideas on what could be done next.

To conduct the research, we have, over the past 18 months, screened over 200 companies and more than 100 investors. We have conducted nearly 50 interviews and collected 12 in-depth case studies on digital solutions. We recognize and are thankful for the great spirit of cooperation in the energy access community. It has been a hugely insightful journey for us and we now look forward to sharing our findings and analysis with the community. We hope the report is useful and appreciate any feedback.

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>200
companies
&
>100
investors screened

50
interviews conducted

12
in-depth case studies

Figure 1 – Digital solutions across the energy access value chain

SOLUTIONS → / USERS ↓	Digital planning	Digital platforms	Digital operations	Digital payments
Governments and DFIs	Electrification planning Tender preparation	Tender management Quality assurance	Data on industry performance (indirectly)	Data on industry performance (indirectly)
Investors and banks	Due diligence Strategic financing	Aggregation Due diligence Results-based finance	Due diligence Results-based financing	Due diligence Results-based financing
Mini-grid companies	Site identification Project aggregation for investors Impact measurement	Standardized reporting Access to funding	Lower operating costs Input for future system design	Lower operating costs Less fraud
OGS companies	Expansion and logistics planning Customer due-diligence	Access to funding	Lower operating costs Input for future product design	PAYGO business model Lower operating costs Less fraud

Scalability   Cost reduction   Risk reduction

1 THE POWER OF DIGITAL SOLUTIONS

KEY POINTS

- Digital solutions have begun to fundamentally change many areas of development and frontier markets – from health to education to finance and infrastructure, including electrification.
- The large, young populations in developing countries are ideal catalysts for digital leapfrogging opportunities.
- Data technologies are becoming ever more powerful, continuously improving the value proposition of digital solutions.

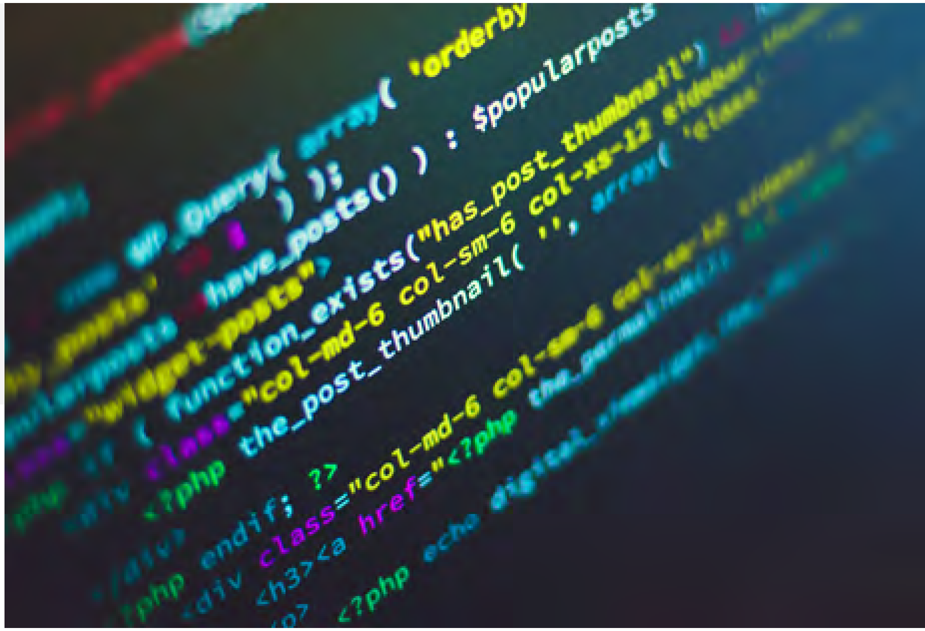

Photo by Shahadat Rahman on Unsplash

Digital technologies have given rise to digital solutions that impact many aspects of the delivery of products and services, including the opening up of new business models and markets, cost reductions or improved customer experiences. This is a fundamental, multi-faceted process of change.

1.1 DIGITAL SOLUTIONS FOR FRONTIER MARKETS

Investments into frontier market businesses, especially as they relate to the building of infrastructure or supply chains, are often characterized by substantial risks, high transaction costs, long lead times and a lack of reliable data for planning and impact measurement. Digital solutions can help address these challenges and deliver the Sustainable Development Goals (SDGs) faster and cheaper. They can also create more transparency, thereby attracting more (and more targeted) investment, and make results more measurable, helping the industry to learn more systematically from experience.

There are many new and promising digital solutions for frontier markets. Examples are e-health approaches that make better medical treatment available in remote locations, apps that assist farmers to increase yields on their fields or adapt to changes in climate or water resources, e-learning tools that offer widespread access to a modern education, or mobile money to offer banking services to the traditionally unbanked.

Digital solutions significantly increase transparency and reduce costs for frontier businesses.

Such solutions hold great promise. They enable the provision of essential services in places, where they have long been elusive. Developing countries might even leapfrog years, if not decades, of the development that today's industrialized nations underwent. A well-known example of leapfrogging is the rapid spread of mobile phones in countries that never built an extensive landline infrastructure. In some places, such as Kenya, mobile networks even helped leapfrog the banking sector with mobile money. Now, as this report outlines, digital solutions are key to enabling a large-scale, quality, distributed and solar-based energy infrastructure that in many places outcompetes traditional grid-expansion as the most effective electrification route.

However, there are challenges to the deployment of digital solutions. Even though internet access in the developing world is growing quickly, many people are still offline. Of the 4 billion-large global offline population, 90% live in developing countries.[3] The "digital divide" between on- an offline populations is most pronounced within developing countries themselves, especially between urban and rural areas. A second key challenge is to tailor digital solutions to low literacy levels, local languages and local cultures.

On the other hand, most developing countries have young populations. Wherever given half a chance, they are quick to pick up the opportunities of the digital age. Many of the urban centers of Africa, South and Southeast Asia have thriving digital technology communities.

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> 3.5 billion

people in developing countries are still off-line

A prime example of this incredible transformation is Myanmar, which, as a "least developed country", leapt straight from the pre-digital age to the smartphone and app era in just a few years, virtually skipping two whole generations of telephony, landlines and mobile phones. In 2015, around

66% *of mobile users in Myanmar owned a smartphone.*

– Toolkit- Digitalization in Development[4]

Photo by Suhyeon-Choi on Unsplash

1.2 DATA AND THE DIGITAL ECOSYSTEM

For the purpose of this report, we will look at digital solutions in the context of the digital ecosystem as described in Figure 2 below, where data is collected, analyzed for insights and used to make decisions. For the ecosystem to work well, data needs to be of a certain quantity and quality.

In a comprehensive digital ecosystem such as the "Internet of Things" (IoT), devices are connected over a local area network (LAN)[5]. The connected devices interact with the physical world and collect information about it, such as ambient temperature, movement, the flow of current, or images. This information is then communicated over the local network to a local platform such as a central computer and then, over a wide area

3 – German Ministry for Economic Cooperation (BMZ), Digitalisation in Development Cooperation and International Cooperation in Education, Culture and Media, (link)
4 – BMZ, Toolkit - Digitalisation in Development Cooperation and International Cooperation in Education, Culture and Media (link)
5 – A local area network is a network that usually spans a small geographic area and enables communication between connected devices.

network (WAN[6], the most common of which is the Internet), to a central platform such as a cloud server. The central platform receives the data and stores or processes it. Through the use of analytics, which can be as simple as comparing two values, or as complex as machine learning algorithms, insights can be extracted from the data. These insights usually require contextual knowledge. Finally, connected devices, potentially the devices that collected the information to begin with, but also other devices, again interact with the physical world. A simple example of such an ecosystem is temperature control. Sensors measure temperatures at different points in a building. This information is then sent over a LAN to a thermostat, where a computer compares the measured temperature to the desired temperature. Depending on the results, the thermostat will send a command to the air conditioning or heating system. A more complex, "smarter" system could, for example, make predictions on future temperature demand based on a wider dataset such as past usage patterns.

Importantly, digital ecosystems are rapidly growing in their capabilities. They are becoming ever more accurate and widely useful, and they now offer near-real time views on many important processes.[7] Also, they are becoming ever more integrated, weaving together different data streams such as electricity, finance, mobile usage, mobility, and many more.

This opens up important questions on data usage rights, data ownership, regulations and privacy that need to be addressed by all stakeholders. Overall, however, we argue that the opportunities presented by digital solutions in the field discussed in this report, namely achieving universal access to quality energy, are compelling and need to be much more systematically explored.

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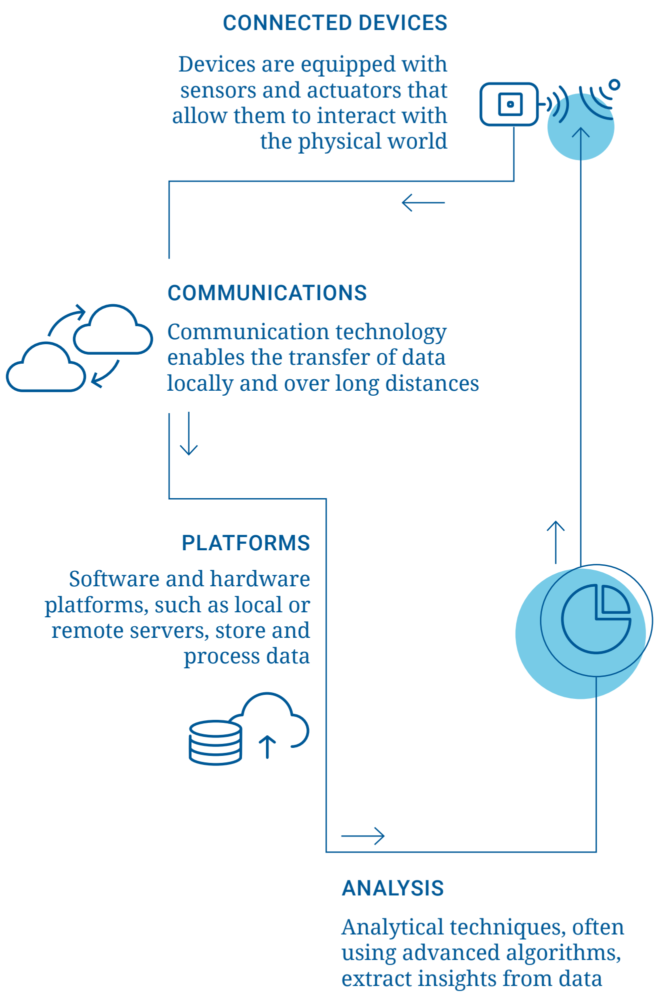
FURTHER READING

A German government report presents over 30 case studies of digitalization in development in the report, ***Toolkit – Digitalisation in Development Cooperation and International Cooperation in Education, Culture and Media***, 2016, (link). In addition to the case studies, the report provides a toolkit for working with information and communication technologies.

In the special report, The Leapfrog Model: ***What technology can do for Africa***, 2017, (link), The Economist explores how technology has underpinned progress in areas such as banking and education.

Figure 2 – The digital ecosystem



6 – A wide area network is a network that usually spans a large geographic area and connects thousands, millions and even billions of devices.
7 – Please refer to the Appendix for more information on the underlying drivers towards digital solutions.

2 THE GLOBAL ENERGY ACCESS CHALLENGE

KEY POINTS

- At the current rate, we will fail to reach universal access to energy (SDG 7). If we continue on the current trajectory, 680 million people will remain unelectrified by 2030, obstructing their path to prosperity, health and education.
- Distributed electrification options – OGS products and mini-grids – are becoming more prominent in electrification strategies vis-à-vis national grid extension.
- The three main challenges to their more rapid growth are: unlocking scale effects, reducing costs and reducing investment risks. These three challenges are interlinked.

680 million people still unelectrified, if we don't accelerate our efforts

2.1 THE STATUS OF ELECTRIFICATION

SDG 7 aims for universal access to affordable, reliable, sustainable and modern energy by 2030. The world is currently not on track to hit this target. The latest indicators show that as of 2017, 840 million people are still without electricity. Based on current projections and considering population growth, 680 million people will remain without access by 2030.[8]

In the past, electrification was primarily achieved by expanding centralized grid infrastructure. Now, however, as distributed generation technologies have become competitive in many situations, they are seen as a core and necessary aspect in many countries' electrification strategies. This is a function of falling technology costs (especially of solar modules and batteries), of the maturation of the distributed energy industry and its business models, and of the benefits of digitalization explained in this report.

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» Electrification is probably the single most important means of empowering people to leverage their own wits and talents for their own progress. Access to education and information, commercial and industrial enterprise, security and civic participation, sustainable farming practices and basic services are all enabled by electricity.«

JOSE IGNACIO BRIANO, Enzen

8 – The World Bank, Tracking SDG 7: The Energy Progress Report, 2019 (link)

Figure 3 – Projected electrification to 2030[9]

Under current projections, the world will miss the electrification target set by SDG 7 by around 680 million people.

The projected population in 2030 is 8.5 billion. The projected rate of electrification between 2017 and 2030 slows down because of the challenges of electrifying the last, most remote populations.

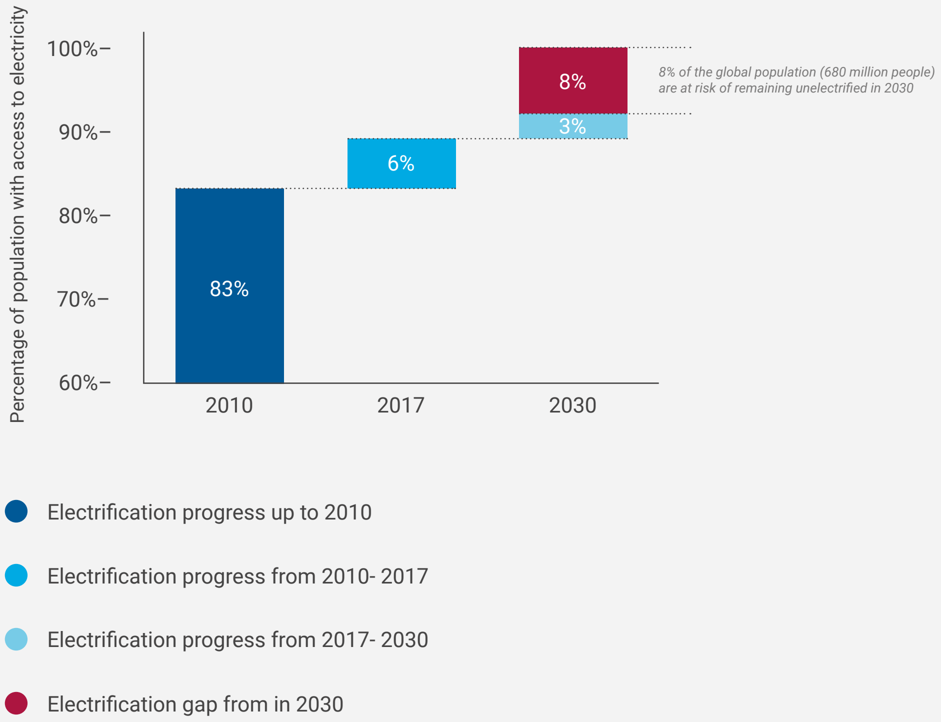
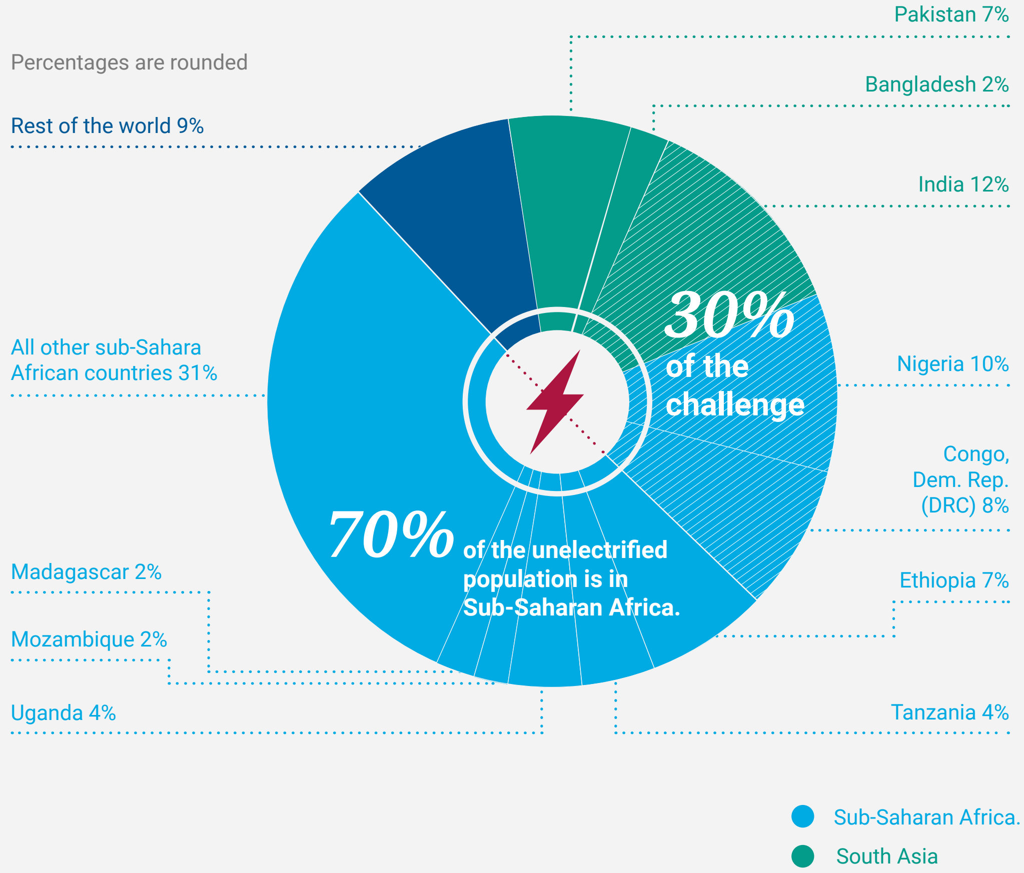


Figure 4 – Distribution of population without access to electricity



9 – The World Bank, Population Estimates and Projections, July 26th, 2019 (link); The World Bank, Tracking SDG7: The Energy Progress Report, 2019 (link)

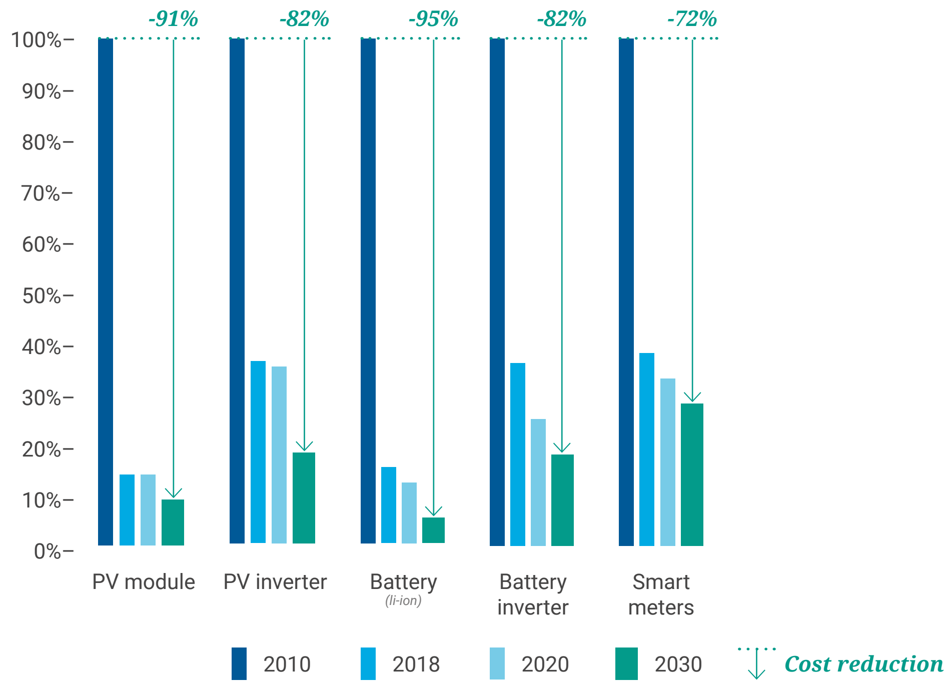
2.2 THE RISE OF DISTRIBUTED SOLUTIONS

Determining the most cost-effective electricity supply option depends on the size, density, and remoteness of settlements, on the required service level and on expected energy demand, as well as on terrain features and the condition of the main grid. Grid electricity is often the lowest cost option when settlements are large and dense, when the local economy and energy demand are strong, and when the terrain is easily accessible and contiguous. As communities become smaller and more sparsely populated, their local economies weaker and terrain more complex, the cost of extending the grid rises rapidly. The decentralized approach – mini-grids and OGS - is explicitly designed to avoid building costly infrastructure across large distances.

OGS and mini-grid industries are starting to reach scale.

Ideally, the provision of the least cost, robust service would be the yardstick for determining the best electrification approach, but the reality is often more complex. Importantly, while the fundamental capital expenditure (CAPEX) for main grid technology remains more or less constant, the CAPEX for distributed solutions – OGS and mini-grids – is continuously falling. This is driven by a number of factors: key components, such as solar panels and batteries are becoming cheaper, the OGS and mini-grid industries are starting to reach scale, the advantages of digital tools are more fully leveraged and business models are improved, as companies learn how to better deliver commercial energy services in frontier markets.

Figure 5 – Improved component economics of distributed energy access solutions[11]



The decreasing costs of solar PV components and digital technologies have improved the economics of OGS energy access solutions.

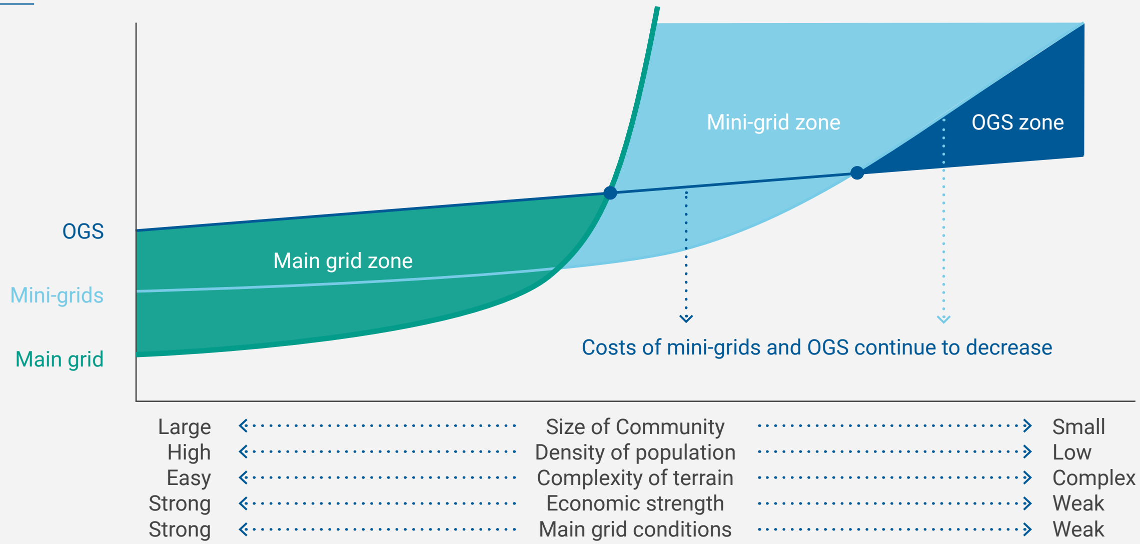
The energy access market benefits from cost reductions in other markets. For example, solar PV cost reduction is driven by solar PV deployment in utility scale and rooftop PV markets, while communications technology cost reductions are driven by the mobile phone and IoT markets.

11 – ESMAP, Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers, 2019 (link)

Figure 6 – Conceptual representation of least-cost electrification options[12]

A number of factors, including community size and density, terrain, income levels, and grid conditions, determine, how electricity can be supplied in the most cost-effective manner.

Arrows denote continuous cost reduction in mini-grids and OGS. As a result, the main grid zone shrinks and the mini-grid and OGS zones expand.



2.3 THE CHALLENGES TO FASTER GROWTH OF DISTRIBUTED ELECTRIFICATION

To succeed, mini-grid and OGS companies must overcome specific challenges tied to the fact that they operate in diverse and high-risk markets, across multiple geographies, and with many thousands of low-income and remote customers.

2.3.1 SCALE

Scaling distributed energy access solutions requires ongoing improvements in operations and business models. In addition, scale is inextricably linked to the cost of delivered power ($ per kWh) or the cost of energy-based products and services such as OGS as key drivers for demand. For instance, according to a recent study, a retail price reduction for solar lanterns from $9 to $4 increased household uptake by 40%.[13] The relationship between scale and risk is similarly interlinked. As the market scales and matures, and investment sizes grow, transaction costs fall, risk assessments become more sophisticated and risks are spread across larger portfolios. Also, perceived risk is a function of experience, so as the industry and finance community gain more experience with mini-grids and OGS, the perception of risk diminishes. At the same time, reducing investment risks drives down the cost of financing – a cost component that can make up

Price reduction for OGS from $9 to $4 increased household uptake by 40%.

12 – TFE analysis, based on EUEI PDF, Mini-Grid Policy Toolkit, 2014 (link)
13 – Rom, A., Günther, I. & Harrison, K., The Economic Impact of Solar Lighting: Results from a randomised field experiment in rural Kenya, 2017 (link)

30%-50% of the cost of energy.[14] This, again, pushes prices of energy products and services lower, thereby further scaling sales. As this report shows, all these linkages are crucially enabled and enhanced through the use of digital solutions.

Selling prices of OGS vary widely, based on size, product features, sale location and whether the sale is made on PAYGO or cash.

2.3.2 COST

With respect to OGS, average manufacturing costs were estimated to be $3.53/Wp for pico-solar products and $1.73/Wp for solar home systems (SHS) (including PV, LED, battery, labor, housing and circuitry costs) in 2018.[15] Extending distribution channels to the most isolated areas can increase end-user prices by as much as 20-50%.[16] Costs related to imports, the maintenance of a sales force in remote areas and customer education on the use of OGS also impact end-user prices. Selling prices, furthermore, vary based on system size, product features, sales location, use of subsidies and whether the sale is made on pay-as-you-go (PAYGO) or cash.[17] Pico solar products below 3Wp typically have selling prices of up to $35. Systems between 3Wp and 10Wp can exceed $70. Solar home systems (SHS) (>11Wp) range from around $260 for a 20Wp system, to more than $500 for systems larger than 100Wp.

CAPEX of mini-grids varies widely, depending on project size, generation technology, battery storage and length of distribution lines. According to the World Bank, the global median upfront CAPEX of solar-hybrid mini-grids is $3.91/Wp.[18] 100% solar mini-grids with full battery backup can exceed $5/Wp.[19] Operational expenses (OPEX) of mini-grids also vary, depending on fuel (if applicable), accessibility and maintenance, monitoring and local salaries. On average, mini-grid OPEX amounts to $80 per customer per year.[20] When CAPEX and future OPEX are discounted to present values and expected energy generation is taken into account, the levelized cost of electricity (LCOE) ranges between $0.55/kWh and $1/kWh.[21] The usually subsidized tariffs in national grids, by comparison, often range between $0.10/kWh and $0.30/kWh.[22] Mini-grids still often have a viability gap between the unsubsidized cost of electricity and the ability of customers to pay for electricity services. In 2016, this was around 30%.[23] International donors and foundations are attempting to fill this gap, but the sources of concessional financing are not yet sufficient to bring the sector to scale.

2.3.3 RISK

Many commercial equity investors and banks perceive the energy access market as high risk and struggle to see matching returns.

Annual investments in decentralized solutions grew from $107 million in 2014 to $512 million in 2018.[24] Yet, despite this impressive growth, investment is still not near the level required to achieve universal energy access by 2030. Many commercial equity investors and banks perceive the energy access market as high risk and struggle to see matching returns.

Risks can be classified into systematic, market-wide risks, on one side, and company and project-specific risks, on the other. OGS and mini-grid companies are faced with similar systematic risks. Political and regulatory instability can easily render business models unviable. For example, if a government changes policy on tariffs from cost-reflective to uniform national tariffs, sales revenues of a mini-grid may be instantly reduced. Similarly, if a government removes subsidies or raises import tariffs on OGS products, end-user prices increase and sales decrease. Macro-economic conditions also play a role. An unhedged mismatch between hard currency investment and domestic currency revenues can greatly affect the profitability of an energy access company.

14 – Example from TFE project work with OGS and mini-grid companies
15 – Derived from the World Bank and GOGLA, Off-Grid Solar Market Trends Report, 2018 (link)
16 – The World Bank and GOGLA, Off-Grid Solar Market Trends Report, 2018 (link)
17 – IFC and TFE Energy: Off-Grid Lighting Market Dynamics in Papua New Guinea, 2019 (link)
18 – The World Bank, Mini-grids for half a billion people, 2019 (link)
19 – TFE Energy: Analysis
20 – The World Bank, Mini-grids for half a billion people, 2019 (link)
21 – TFE Energy: Analysis
22 – Rocky Mountain Institute, Minigrids in the Money, 2018 (link); The World Bank, Mini-grids for half a billion people, 2019 (link)
23 – African Development Bank, Green Mini-Grids in Sub-Saharan Africa, 2016 (link)
24 – Wood Mackenzie, Strategic investments in off-grid energy access, 2019 (link)

In terms of company and project-specific risks, many operational processes still need to be streamlined. This includes the selection of populations to serve, quality assurance, and performance and impact monitoring. Mini-grid site selection and correct system sizing is particularly challenging due to the difficulty of estimating future energy demand for communities that either had no or only very inadequate energy access previously. If mini-grid projects are oversized or undersized, profitability is affected.

Mini-grid site selection and correct system sizing is particularly challenging.

For PAYGO OGS companies, there is always the risk that a customer will default on payments. Default rates in the industry vary widely, but remain, overall, one of the main reasons why many companies struggle to turn a profit. If a customer defaults on a recurring basis, OGS companies must repossess the system, which is costly and time-consuming (and therefore rarely done). Repossessed systems often cannot be resold.

The public sector can address risks by creating stable and favorable policy frameworks (such as financial compensation for a mini-grid operator in the case of grid encroachment), debt guarantees or investor financial incentives, such as proceeds from carbon offsets. The private sector can also address risks by building larger portfolios, by adjusting business models and diversifying income streams (through offering additional services alongside energy for example) and, as this report suggests, leveraging the advantages of digital solutions.

FURTHER READING

The World Bank in cooperation with GOGLA, publishes regular reports on the status of electrification and on off-grid solutions, such as the ***Off-Grid Solar Market Trends report,*** 2018 (link) and the report ***Mini-Grids for Half a Billion People***, 2019 (link).

GOGLA and Lighting Global publish reports on OGS, such as the ***PAYGO Market Attractiveness Index***, 2019 (link), the report ***Providing Energy Access through Off-Grid Solar: Guidance for Governments***, 2019 (link) and the ***Standardized Impact Metrics for the Off-Grid Solar Energy Sector***, 2018 (link).

The Alliance for Rural Electrification (ARE) publishes reports on the advancement of rural electrification, often with a focus on mini-grids. See, for example the report ***Private Sector Driven Business Models for Clean Energy Mini-Grids***, 2019 (link).

Photo by Clement Chai on Unsplash

3 DIGITAL SOLUTIONS FOR OFF-GRID ENERGY ACCESS

KEY POINTS

- The off-grid energy access market was started by vertically integrated companies who built the first digital solutions. Now, as it grows, it is disaggregating, and a number of digital specialists are emerging.
- While some digital solutions, such as digital payments, are mature and embedded in an ecosystem of solution providers and users, others are just breaking into the market and proving their value proposition.
- Geographically, digital solutions specialists tend to be headquartered in Europe or the US, where the majority of their engineering staff, innovators and investors are (still) located.

Digital solutions not only help overcome the challenges to faster growth of distributed energy access by supporting scalability, decreasing costs and reducing investment risk, but in many cases unlock entire business models. More than half of the companies surveyed for this report described how their core business as well as operations increasingly depend on the application of digital solutions.

Based on the industry practices and available technologies we observed in this study, we have clustered digital solutions for energy access into four categories: digital payments, digital planning, digital platforms and digital operations. The following chapters will look at each one in detail. All digital solutions are, in turn, enabled by a number of underlying digital technologies, as shown in Figure 7.

» There is no way to scale without technology.« — STEFAN ZELAZNY, Mobisol[25]

» We can't reach scale without technology.« — ALESSANDRO PIETROBON, ZOLA Electric[26]

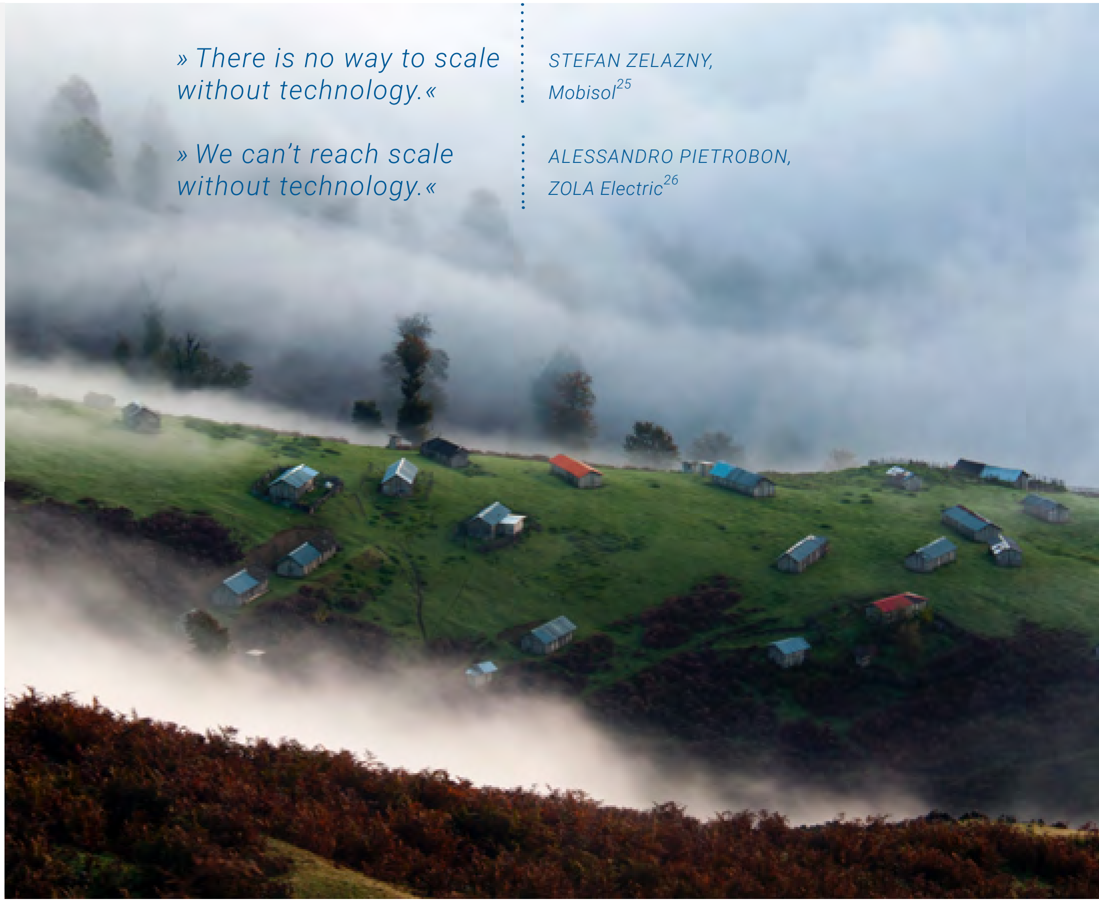


Photo by Pooyan Eshtiaghi on Unsplash

25 – TFE Energy, Case study interview, Stefan Zelazny, Engie Mobisol
26 –TFE Energy, Case study interview, Alessandro Pietrobon, ZOLA Electric

Figure 7 – Digital technologies and digital solutions for energy access (Examples)

Digital planning

- Geospatial portfolio planning
- Satellite imagery
- Drone imagery
- Remote sensing
- Feasibility planning tools
- Design tools
- Survey tools

Digital platforms

- Crowdfunding platforms
- Blockchain-based carbon credits
- Project aggregation platforms

Digital operations

- Cloud-based management platforms
- Remote monitoring and control
- Smart meters and IoT
- Forecasting algorithms
- Mesh WiFi and LWPAN for communications
- Operational analytics

Digital payments

- Mobile money
- Mobile phones
- Smart phones
- GSM mobile networks
- Cryptocurrency
- Credit analytics
- Keycodes
- Scratch cards

The list is not exhaustive. Some digital technologies are in regular use today, others are at the pilot stage. Some technologies are applicable to more than one category, such as machine learning or GSM mobile networks. A more detailed list is provided in the appendix.

Image provided by AMMP Technologies

3.1 TRENDS IN DIGITAL SOLUTIONS FOR ENERGY ACCESS

As data generation and storage get cheaper, processing capabilities improve and connectivity expands, many industries, including the energy access industry, are becoming ever more digital. Between 2008 and 2016 the global cost of sensors fell by over 90%, affordable low-power wide area network (LPWAN) technologies became commercially available and the mobile phone revolution pushed the costs of Global System for Mobile communication (GSM) modems ever further down. As a result, the entire cycle of off-grid data collection, system monitoring and generating user insights took off. In addition to improving existing energy access approaches, the growing digital ecosystem offers companies pathways to entirely new solutions and business models, for example those around mobile phones, digital payments and PAYGO.

» Recent technology innovations on metering and control processes... are enabling equipment to be downsized, thereby cutting the costs of providing small village-scale grids. New innovations are enabling pre-payment, mobile payments, load limits, and remote monitoring and control to improve mini-grid operations.«

THE WORLD BANK[27]

3.1.1 THE OGS MARKET HAS BEEN IN THE LEAD, BUT NOW MINI-GRIDS ARE CATCHING UP

The OGS market has already reached significant scale (see Appendix) and digital solutions – especially digital payments and digital operations, such as digitally-enabled customer relationship management (CRM) and customer data analytics – have been deployed for some time. The result is a robust and innovative ecosystem of digital solution providers and users (OGS companies).

The mini-grid market is at an earlier stage of maturity but is now driving the use of new digital solutions, especially those around digital planning, digital platforms and digital operations. These solutions address some of the mini-grid market's main pain points and barriers to scale, namely, managing the cost and risk of remotely located infrastructure, and developing and financing portfolios of new projects. In addition, digital technologies can improve the core service itself. Advanced system controllers, for example, balance the use of batteries, solar and diesel to maximize the lifespan and efficiency of a system, predicting failures and minimizing operating expenses.

Mini-grid companies have been quick to adopt PAYGO business models and digital payment solutions pioneered by OGS companies. As they diversify their offering, by, for example, extending lines of credit to customers or selling productive use machinery, there is much to learn from how OGS companies have analyzed data from digital payments to build detailed and sophisticated customer analytics. Inversely, OGS companies can now apply digital solutions pioneered by mini-grid companies. An example is digital planning. Mini-grid companies are beginning to use machine learning-based site identification and planning tools, such as Village Data Analytics. These can equally be applied by OGS companies to better target sales and marketing efforts, to improve the logistics of their supply chains, and to deepen credit risk analyses. The solutions are presented in detail in the following deep-dive chapters.

27 – The World Bank, State of Electricity Access Report, 2017 (link)

3.1.2 THE RISE OF DIGITAL SOLUTIONS SPECIALISTS

As component costs (mainly solar PV and batteries) started to reach economic viability around 2010, the OGS and solar mini-grid markets gained traction.[28] At this point, a number of first movers and current market leaders, such as Bboxx, Mobisol, Zola Electric, SteamaCo and PowerGen, began operations. They all were, and many still are, vertically integrated companies.

» Some early market entrants wanted to be platforms, but the market was not mature enough, so they also had to be operators.«

MICHAEL GOLDBACH, New Sun Road[29]

When the market was new, there were hardly any specialized companies offering products and services designed specifically for the off-grid space. For the first movers, this meant that they either had to develop all solutions in-house, use non-optimized technology transferred from other industries (like meters and sensors) or commission design companies to develop solutions at great expense. They became providers of end-to-end solutions, operating across the entire value chain, in some cases even designing and manufacturing the required technology in workshops located close to the rural end-user. Several OGS companies developed extensive in-house manufacturing capabilities to bring unit costs down and develop a supply chain for their business. During this process, first movers also developed proprietary digital solutions.

The advantage of being vertically integrated is the ability to design tools to exactly fit the company and market needs. However, this often comes at the price of high investment costs in the tools, low production runs, high unit costs and the requirement to add specialist technical staff to the team.

There are numerous examples of companies that moved from being fully integrated to a more specialized business model. In the mini-grid industry, SteamaCo was originally access:energy and the Sparkmeter team came from EarthSpark International. SteamaCo developed smart meter solutions initially for their own operations and then recognized the opportunity to sell their products and services to the wider market. SparkMeter was prototyped in EarthSpark and took a similar route. In the OGS market, Mobisol and Solaris Offgrid spun off digital solutions into new businesses. Bankable Frontier Associates (BFA) has analyzed the trend towards vertical disaggregation in the OGS market, calling it PAYGO 2.0.[31]

» Our collection app put daily payment collections that were due on to the agent's phone. The app then allowed the agent to send an SMS to the customer with the receipt. This was not a complicated app; however, a software company was charging 25,000 rupees per month per user for an app with identical services. There was no way we could be profitable with that additional operating expense, so we developed the app internally.«

NIKHIL JAISINGHANI, Co-founder and former executive director of Mera Gao Power[30]

Integrated companies are often as ready to sell their own digital solutions to others as they are to buying them from specialists vendors whenever appropriate. As an example, Bboxx is open to adopting third party solutions, if they are more capable and affordable than their own.[32]

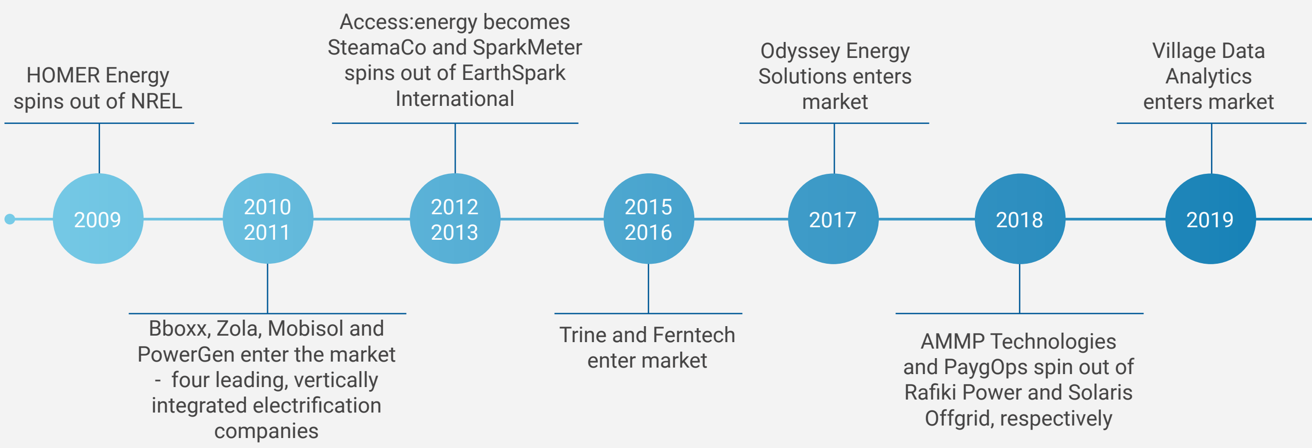
Our analysis of 270 companies in off-grid energy access showed that the number of digital specialists, whose core competency is to develop and distribute digital solutions, has increased from 15 in 2010 to 56 in 2019.

» Our philosophy is to build the best tech possible and give it to people who understand their markets and know how to access off-grid households in an effective way. We are mainly an R&D company.«

AFNAN HANNAN, Okra Solar[33]

28 – ESMAP, Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers, 2019 (link)
29 – TFE Energy, Market expert interview, Michael Goldbach, New Sun Road
30 – TFE Energy, Market expert interview, Nikhil Jaisinghani, Co-founder and former executive director of Mera Gao Power
31 – Bankable Frontier Associates, "The Promise of Unbundling to Reshape PAYGo solar", 2018, Medium (link)
32 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx
33 – TFE Energy, Market expert interview, Afnan Hannan, Okra Solar

Figure 8 – Digital solution specialists are entering the market



The energy access market is shifting from vertically integrated players to digital specialists

HOMER Energy was the first specialist to enter the market which was dominated by vertically integrated players in the years that followed. Starting in 2012, a new trend emerged; teams from vertically integrated players began to spin out specialized companies. Most recently, vertically integrated companies such as Solaris Offgrid and Mobisol have begun to license proprietary digital solutions to third parties.

3.1.3 MOST DIGITAL SOLUTIONS STILL COME FROM EUROPE AND THE USA

There are, of course, thriving digital hubs in cities across many of the developing markets where energy access companies operate. Examples are Hyderabad, Bangalore, Delhi and Mumbai in India, or Nairobi (Kenya), Lagos (Nigeria), and Cape Town (South Africa) in Africa. For many established digital technologies, such as mobile customer interaction solutions, including mobile money, they provide a rich ecosystem of local innovation and capabilities that energy access companies have been tapping into. For data analytics, too, there are specialist local service providers. Examples are Samasource, based in Nairobi (Kenya), or Getinnotized based in Accra (Ghana).[36]

» We are a vertically integrated business and started when there was nothing. That is why we have a bunch of custom-made solutions. Now, as the market turns, we are considering how to interface better with third party solutions and whether to make our resources available to others.«

KIERAN CAMPBELL, PowerGen[35]

» I think that we will see more disaggregation of the value chain over the next few years.«

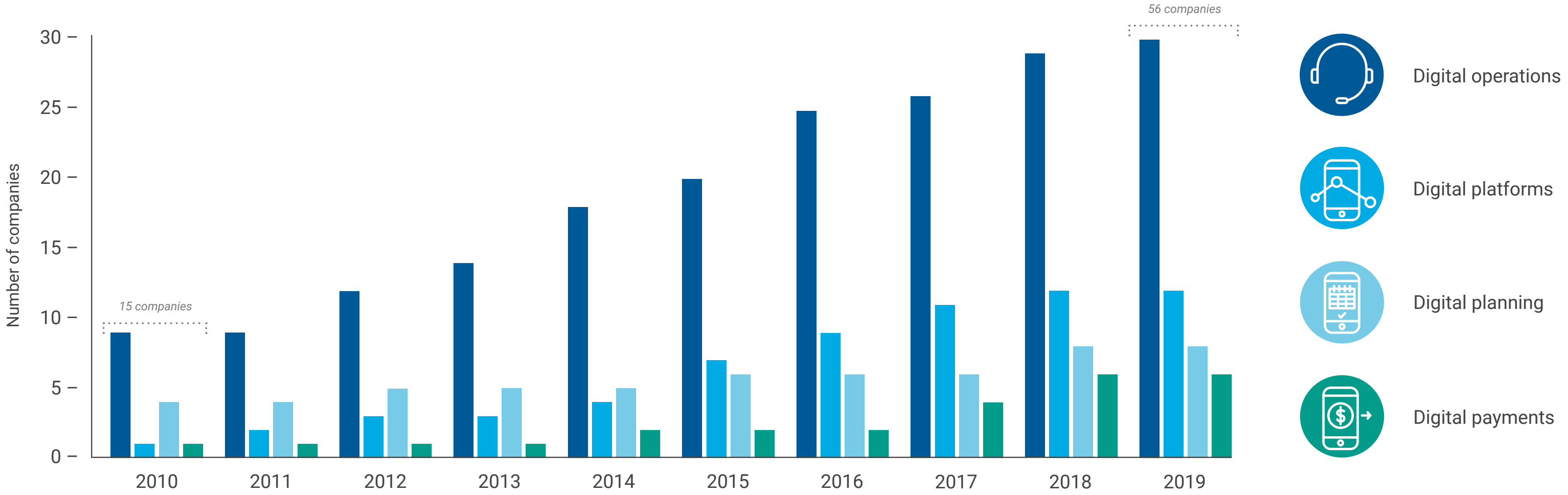
CHRISTOPHER BAKER-BRIAN, Bboxx[34]

When it comes to companies specializing in developing digital solutions for the energy access market, however, our database shows a heavy tilt towards Europe (30 companies) and the USA (15). Only a combined 7 are based in Asia, Africa and Oceania. This contrasts with the OGS and mini-grid companies they serve. Of those, almost half are headquartered in developing countries.

Feedback from case study interviews indicates that several digital solutions specialists are considering shifting certain technical operations, such as engineering and customer support, to the countries their customers operate in. In several cases, however, potential benefits,

34 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx
35 –TFE Energy, Case study interview, Kieran Campbell, PowerGen
36 – See: Samasource (link); Getinnotized (link)

Figure 9 – Number of digital solution specialists in the energy access market[37]



such as reduced wages, were negated by the difficulty of finding technical talent locally. The small group of candidates is often attracted to higher paying industries. In other cases, it works. D.light, for example, recently shut down its engineering team in the USA and shifted the development of software, including enterprise software, to Nairobi.

There is a larger debate about whether countries with off-grid populations are facing a new type of economic dominance from digital and other technology companies based outside of their borders. The concern is that data is transferred outside of the market to the locations where the technology teams work, that the ownership structures of these companies are not local, and that innovation is not generated locally.

Between 2010 and 2019 the number of digital companies operating in the energy access market has grown from 15 to 56. Digital operations companies make up over 50% of the total.

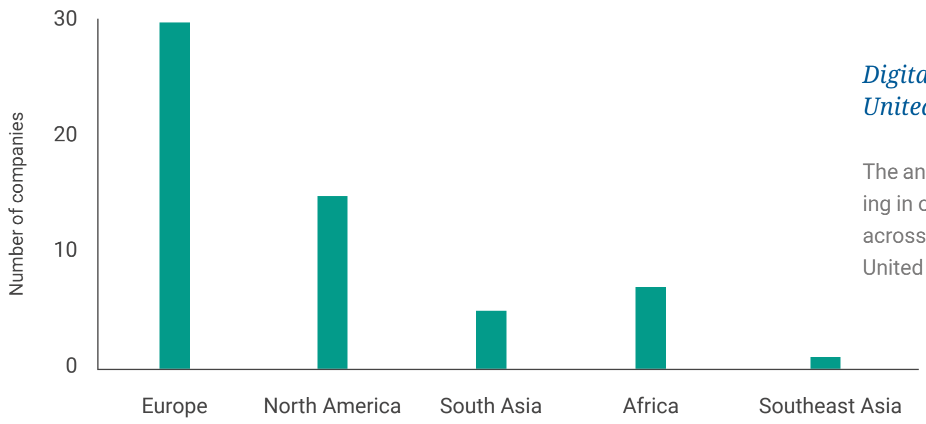
The analysis was derived from TFE Energy's energy access stakeholder database of 270 companies operating in off-grid energy access. Due to the difficultly of assessing when companies entered the market, the temporal analysis is a measure of their founding date.

» We still find it easier to find affordable technical talent in Europe. In our experience, in Africa, talent is often poached by banks or telecommunication companies. It is a real shame. Since we are a software company that provides services in the cloud, we are flexible.«

SVET BAJLEKOV,
AMMP Technologies[38]

37 – Analysis: TFE Energy
38 – TFE Energy, Case study interview, Svet Bajlekov, AMMP Technologies

Figure 10 – Geographic distribution of digital solution specialists for energy access[39]



Digital specialists often have their headquarters and engineering staff in Europe and the United States.

The analysis was derived from TFE Energy's energy access stakeholder database of 270 companies operating in off-grid energy access. Many companies in the market, especially OGS companies, have local offices across the globe. However, engineering staff is typically located at the headquarters, often in Europe or the United States.

3.2 DATA AND CYBER SECURITY RISKS

Data is the lifeblood of digital solutions. While using it yields great benefits, it also comes with risks that need to be addressed. Energy access companies are pioneers in linking off-grid populations to global markets. As such they have an outsized level of information about their customers, storing potentially sensitive data, such as credit performance and location history. Companies with offices in the European Union have to comply with certain data protection policies. Some case study companies indicated that they want to voluntarily comply or are already complying with policies similar to those applied in the European Union.

Voluntary data protection is not enough.

However, voluntary data protection is likely not enough. Regulations enforceable by a regulatory body, or at least clear national or industry-wide standards would help. To that end, the industry association GOGLA has established a consumer protection code for the energy access industry, including personal data privacy.[40] Having said that, it is important not to stifle the sharing of anonymized, higher-level data to allow the market to learn and improve.

While energy access companies are very conscious about protecting the data of their customers, they seem less concerned about cyber security threats. Only one in ten companies surveyed for this report mentioned it as a key concern.

FURTHER READING

IASS with support from the German Federal Ministry for Economic Cooperation and Development and the United Nations Industrial Development Organization published a report titled, ***Exploring the nexus of mini-grids and digital technologies: Potentials, challenges and options for sustainable energy access in Sub-Saharan Africa***, 2019, (link). It looks at the potential applications for digital technologies in mini-grids and analyzes them in the context of a number of African markets.

The article ***Are tech companies Africa's new colonists?***, 2019, in the Financial Times discusses the idea of "digital colonization" (link). It covers the recent growth of investment into technology that targets the African markets and asks why this is potentially controversial.

39 – Analysis: TFE Energy
40 – GOGLA Consumer Protection Code (link)

4 DIGITAL PAYMENTS

KEY POINTS

- Digital payments, and mobile money in particular, have had the largest single impact of all digital solutions on the energy access market and are directly associated with the rapid growth of the OGS sector.
- With supportive policy, adoption from mobile network operators (MNOs) and the business case proven in many markets, mobile money is spreading quickly.
- Historically, digital payment platforms have been proprietary solutions. Now, a number of third-party solutions are available, such as PaygOPS and Paygee. This lowers the market entry barrier for new OGS and mini-grid companies.
- The evolution of digital payments has not plateaued. There is ongoing and promising research and development in the core technology, as well as on the data analysis around it.

Digital payments are all non-cash payments, in which the payer initiates the payment electronically. One type of digital payment is mobile money. This disruptive technology has emerged as a leading payment platform in many developing countries with over 866 million registered accounts (143 million were added in 2018 alone) and transactions worth $1.3 billion conducted every day.[41] Energy access operators have rapidly integrated mobile money into their business models, because it dramatically reduces their operating costs and risks associated with handling cash. Often, it is the only payment method they offer to customers. In the countries where mobile money is not widely available (for instance, in much of francophone West Africa, in Nigeria or in Ethiopia), it severely hampers the growth of electrification businesses.

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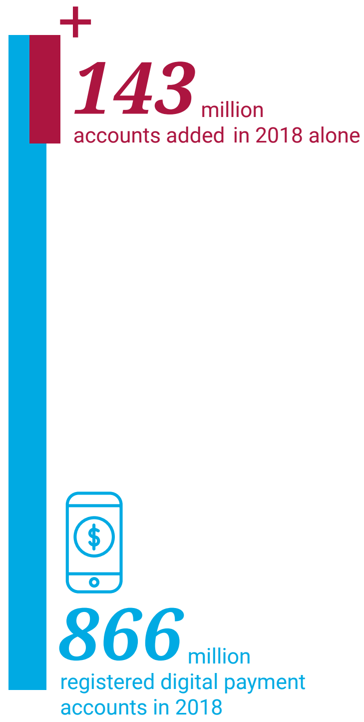
» We only accept payments through mobile money. PAYGO solar is a technology enabled business model.«

ALESSANDRO PIETROBON, ZOLA Electric[42]



41 – GSMA, 2017 State of the Industry Report on Mobile Money, 2018 (link) and 2019 (link)
42 – TFE Energy, Case study interview, Alessandro Pietrobon, ZOLA Electric

4.1 THE DEVELOPMENT OF DIGITAL PAYMENTS

Digital payments have been used by energy access companies – especially OGS companies – for more than a decade and have become ever more important, as the OGS market transitions towards selling larger, more expensive products that offer higher tier energy access.[43] Most energy access customers do not have enough money to buy a product outright. The PAYGO model, a payment in instalments, solves this problem but raises another one, albeit for the vendor: the need for regular payment collection. If cash is used as the payment method, the customer needs to regularly interact with a physical vendor agent. This would be straightforward in an urban setting, but OGS customers are typically scattered and located in remote, rural areas: enter digital payments. These have become the main payment method for PAYGO. The centrality of digital payments to the OGS business model is reflected in investment trends between 2012 and 2017, when PAYGO companies received 85% of the funding in the OGS market – a total of $773 million.[44]

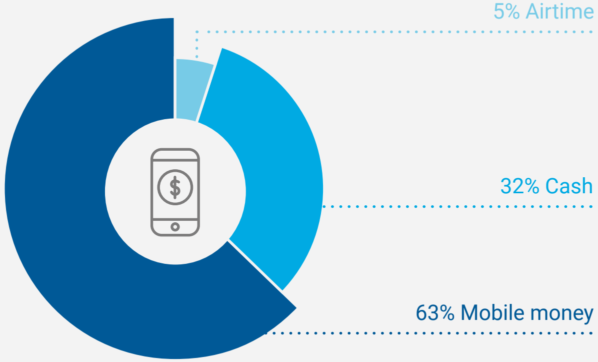
The combination of extensive mobile communication service coverage, high mobile device ownership rates and widespread mobile money adoption in Sub-Saharan Africa has meant that the region had become the ideal market for implementing mobile money based PAYGO technology. Kenya, in particular, is a pioneer since the establishment of the M-Pesa platform. Many of the current OGS and mini-grid market leaders use Kenya as a testbed for new innovations.[45]

In 2018, 68% of PAYGO companies were vertically integrated, with more than half developing their own digital payment platforms at costs of $1-10 million.[46] Today, digital specialists such as Solaris Offgrid, Mobisol (Paygee) and Angaza offer digital payment solutions off-the- shelf.

» Kenya has been a showcase market for us. I think that it has everything going for it: good connectivity, access to mobile money and a reasonable regulatory framework. It is a great testbed for the sector.«

CHRISTOPHER BAKER-BRIAN, Bboxx[47]

Figure 11 – The use of mobile money by OGS PAYGO companies[48]



Mobile money is the dominant form of payment for PAYGO operators.

The distribution of mobile money is not uniform across geographies. East Africa has a much larger share of mobile money payments than other geographies. As the market continues to mature, mobile money will likely grow its share globally. This is, however, contingent on major markets such as India and Nigeria adopting enabling policy.

43 – World Bank and GOGLA, Off-Grid Solar Market Trends Report 2018, 2018 (link)
44 – World Bank and GOGLA, Off-Grid Solar Market Trends Report 2018, 2018 (link)
45 – TFE Energy, Kenya: The World's Microgrid Lab, 2017 (link)
46 – World Bank and GOGLA, Off-Grid Solar Market Trends Report 2018, 2018 (link)
47 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx
48 – World Bank and GOGLA, Off-Grid Solar Market Trends Report 2018, 2018 (link)

Smart metering companies, such as SparkMeter and SteamaCo, have integrated mobile money payments into their systems to allow mini-grid operators to leverage digital payments. There are also partnerships emerging between off-grid energy access companies and mobile network operators (MNOs). The latter can offer the former a channel to reach customers, while the energy access companies can help MNOs grow their customer base and increase sales with existing customers. The mini-grid company Devergy and the mobile money provider Tigo have formed such a partnership in Tanzania.[50]

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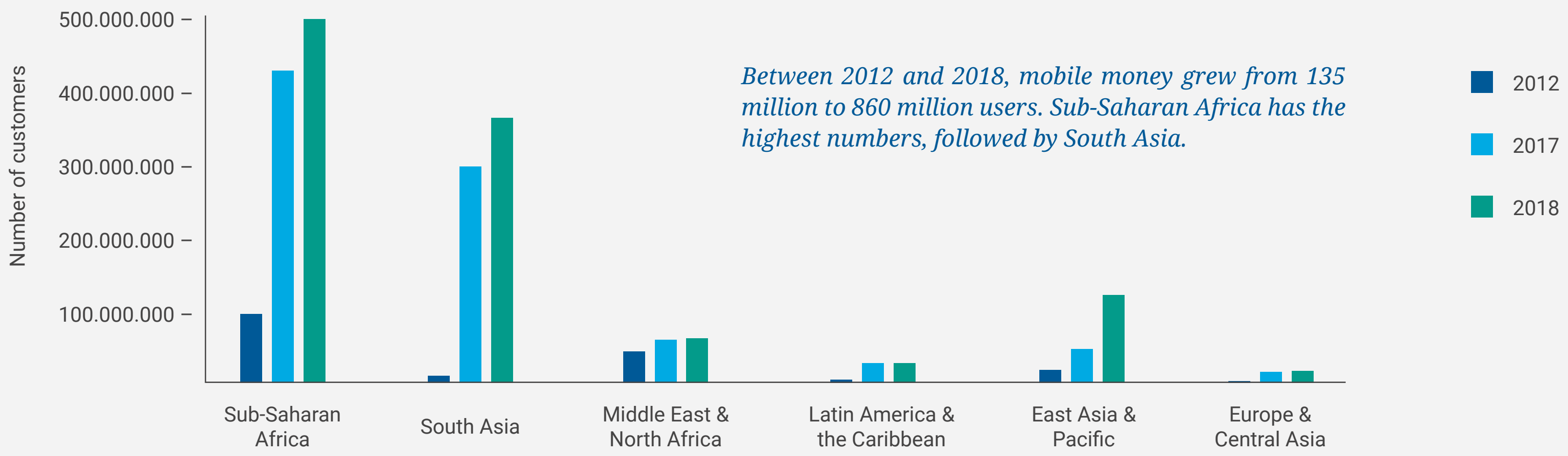
» An important part of our collection method was our physical presence in the village. We maintained regular face to face contact with our customers which helped ensure they came to payment meetings and paid on time.«

NIKHIL JAISINGHANI, former executive director and co-founder of Mera Gao Power[51]

» Mobisol would like to utilize small, "mom and pop" shops as distributors. This is currently not possible due to the high entry cost tied to mobile money integration. Reducing the cost of mobile money can change the way the market operates.«

STEFAN ZELAZNY, Mobisol[52]

Figure 12 – Mobile money users by region[49]



Between 2012 and 2018, mobile money grew from 135 million to 860 million users. Sub-Saharan Africa has the highest numbers, followed by South Asia.

49 – World Bank and GOGLA, Off-Grid Solar Market Trends Report 2018, 2018 (link)
50 – GSMA, Devergy: Leveraging a mobile services bonus to encourage the use of mobile money wallets for smart solar mini-grids in Mbeya, Tanzania, 2018 (link); another interesting example is the collaboration between Lumos and MTN in Nigeria (link)
51 – TFE Energy, Market expert interview, Nikhil Jaisinghani, former executive director and co-founder of Mera Gao Power
52 – TFE Energy, Case study interview, Stefan Zelazny, Engie Mobisol

4.2 HOW DIGITAL PAYMENTS WORK

PAYGO technologies use similar models. Often, the customer must initiate a payment to unlock an energy product or service. This is done remotely and automatically. In other instances, the device is unlocked by default, and only becomes locked when an account is in arrears. The unlocking or locking of the device is an example of combining digital payments and digital operations. The speed at which this happens depends on whether or not instant payment notifications are in place. Regardless of the payment method used, PAYGO business models all leverage a digital component. Even in the case of cash, an agent will accept the cash payment and then activate the OGS product digitally, through either a cable, Bluetooth or a manually entered SMS code.

In Africa, 90% of mobile money transactions are made over the Unstructured Supplementary Service Data (USSD) layer.[53] This fundamental protocol is available on the most basic mobile devices and is even more robust than SMS in areas with poor mobile coverage.

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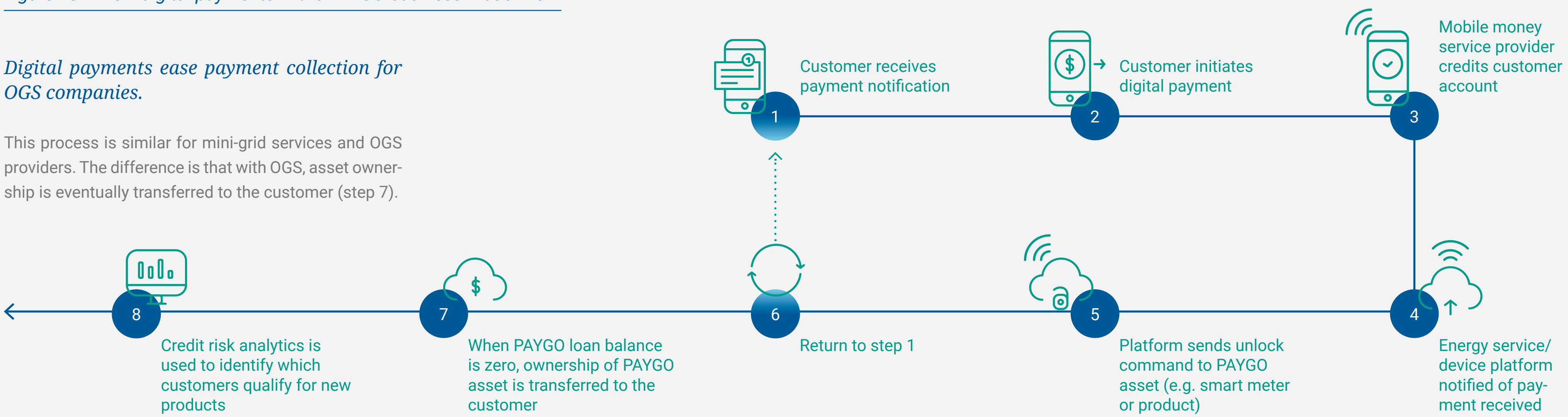
Figure 13 – How digital payments in the PAYGO business model work[54, 55]

Digital payments ease payment collection for OGS companies.

This process is similar for mini-grid services and OGS providers. The difference is that with OGS, asset ownership is eventually transferred to the customer (step 7).



53 – GSMA, 2018 State of the Industry Report on Mobile Money, 2019 (link)
54 – Adapted from Mastercard, Pay-As-You-Go and the Internet of Things: Driving a New Wave of Financial Inclusion in the Developing World, 2018 (link)
55 – GSMA, State of the Industry Report on Mobile Money, 2019 (link)

4.3 HOW DIGITAL PAYMENTS ADDRESS THE MAIN CHALLENGES OF ENERGY ACCESS

Digital payments have so far been the most impactful digital solution in the energy access market and are a key driver for the growth for many market leading companies.[56]

4.3.1 IMPACT ON SCALE

Digital payments enable scale directly, by significantly reducing the complexity of operating an energy access business. The effect can be seen in the growth of the OGS market as a whole. Moreover, energy access companies that use mobile money have been able to attract significantly more investment than those that use cash payments.[57]

Globally, the sales volume of PAYGO products grew by 30% last year with revenues growing even faster at 50% driven by customers upgrading to solar home systems beyond basic products like solar lanterns. According to the global off-grid solar market report, PAYGO companies represented just 24% of the sales volume in the last six months in 2018 but accounted for 62% of revenues.[58]

4.3.2 IMPACT ON COST

As digital payments reduce the need for agent networks and ease payment collection, they have the potential to significantly reduce operational costs. However, they also come at a cost: for building or buying the solution and for the hardware to enable it. In addition, MNOs charge transaction fees for their mobile money networks that can make up as much as 25% of the total cost of an OGS system over the course of the repayment period.[59]

Digital payments, therefore, only have a cost benefit beyond a minimum operational size and product value. According to case study companies interviewed for this report, the threshold value is around 100 OGS products sold per month. Strategically, however, any energy access company with growth aspirations that operates in regions with network coverage, should integrate digital payment solutions.

4.3.3 IMPACT ON RISK

Digital payments reduce risk in different ways. Firstly, a business based on cash transactions carries the risk of theft and straightforward fraud. By comparison, a digital payment involves an auditable third-party (in this case the MNO) and is thus more transparent and secure. This increases the confidence of the end-user buying the services, as well as of the investor investing into the service provider.

Secondly, digital payment information can be used to build a credit history and identify opportunities for low-risk customer up-selling. Customers who pay installments on time and repay loans on schedule can be targeted for upgrade products.

Thirdly, digital payments can be linked with digital operations to reduce operating risks. For example, Mobisol has

Image provided by Sam Duby, TFE Energy

56 – TFE Energy, Case study and market expert interviews
57 – World Bank and GOGLA, Off-Grid Solar Market Trends Report, 2018 (link), Wood Mackenzie, Strategic investments in energy access, 2019 (link)
58 – World Bank and GOGLA, Off-Grid Solar Market Trends Report, 2018 (link); see also: Quarz, Solar Power in Africa and the Mobile Money Advantage (link); IFC Lighting Global, PAYGO Market Attractiveness Index (link)
59 – Lighting Global, Off-grid Power and Connectivity: Pay-as-you-go Financing and Digital Supply Chains for Pico-Solar, 2015 (link); for an assessment of how MTN and Fenix worked to reduce the fees, see a GSMA case study (link)

determined that there is a strong correlation between late payments and default rate. The quicker they are able to address the reasons why a customer is late in paying their monthly installment, for instance a faulty battery (which is easy to detect via digital operations) causing a loss in service, the less likely the customer will default.

Real-time, transactional data can also be used to detect and counter fraudulent payment behavior. Fraud detection is enabled by a combination of data analytics and manual verification. Data analytics can flag potentially fraudulent behavior. Then, a trained person must verify whether fraud has actually occurred. As an example, Mobisol is able to detect collusion between customers and agents.

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» The later the interaction with a customer who is late on a payment, the higher the chance that they will default. Time is of the essence here and the digital platform gives us the opportunity to react almost in real-time.«

STEFAN ZELAZNY, Mobisol[60]

4.4 CHALLENGES TO DEPLOYMENT

The main barrier to increased use of digital payments is regulations. Some countries, such as Ethiopia, do not currently allow mobile money transactions. This deters PAYGO companies who use mobile money from entering the market. More often, however, the question of how conducive regulations are is a matter of detail, touching on issues of taxation, know-your-customer (KYC) requirements, cross-border payments (especially remittances), national financial inclusion strategies and data protection.[61]

Another challenge to deployment is the reach of fundamental enabling factors like GSM network coverage. Energy access companies naturally operate in off-grid and remote areas, where networks are often weak. One reason for weak networks is the challenge of supplying mobile network masts with stable energy. This can, of course, also turn into a symbiotic relationship with mini-grid companies looking for anchor loads.

Entering a new market can be slow for PAYGO operators, as integration with mobile money networks can take up to six months to complete.[63] The largest PAYGO operators are often integrated with more than a dozen MNOs to cover different geographies. Often, each of these integrations uses a different method.

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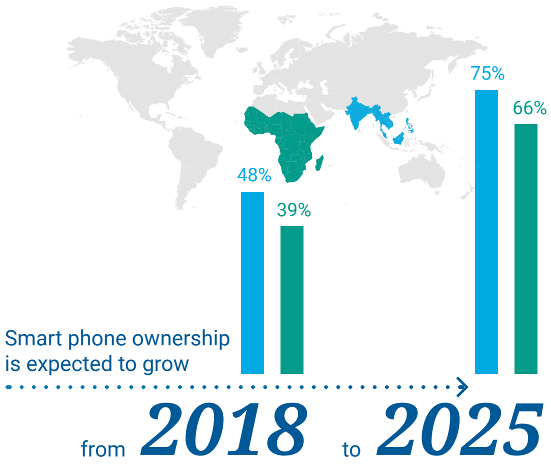
» We cannot operate in markets where there is no cellphone signal.«

ALESSANDRO PIETROBON, Zola Electric[62]

60 – TFE Energy, Case study interview, Stefan Zelazny, Engie Mobisol
61 – GSMA, 2018 State of the Industry Report on Mobile Money, 2019 (link)
62 – TFE Energy, Case study interview, Zola Electric
63 – GSMA, Mobile for Development Utilities Annual Report: Intelligent Utilities for All, 2019 (link)

4.5 LOOKING AHEAD

There are a number of key developments in digital payments that are highly relevant for the energy access market. These include innovations in telecom technology, such as the rise of new application programming interface (API) standards, the adoption of 4G, the increased availability of digital payments, as well as the application of data analysis to analyze customer data for commercial insights.



4.5.1 MAKING DIGITAL PAYMENTS MORE WIDELY AVAILABLE

One approach to making digital payments more widely available is by improving the integration of PAYGO operators with MNOs. The Instant Payment Notification (IPN) Hub, developed by the Global System Mobile Association (GSMA), addresses this by providing a single point of connection between provider of mobile money and those of PAYGO utility services. This minimizes the integration bottleneck and allows companies to more easily scale in new geographies. Specialist digital payment companies, such as PaygOPS or Paygee, will likely benefit the most, because they are designed to scale internationally. Our case study companies, and market experts flagged the potential importance of the IPN Hub, although membership is currently still limited. As of February 2019, seven mobile providers were integrated. The Hub's success depends on higher levels of adoption from both OGS companies and mobile money providers.

There are also first attempts at using blockchain technology. Okra Solar, for example, works with Bitspark to pilot a blockchain-based payment system in South East Asia. In Africa, there are also encouraging use cases, such that by the South African startup Wala, operating in East Africa.

However, many interviewees, both market experts and case study companies, still expressed skepticism about blockchain, wondering if and when the technology will be able to replace other, more established means of enabling payments.

» Our team headed to Palawan, a remote island west of the Philippines. Until now, there wasn't an easy way for these communities to pay for commercial services such as power. By simply giving them a way to pay cash for their power bill, communities in Palawan can now pay for their Okra electricity bill remotely using Bitspark.«

Bitspark[64]

All the more sophisticated payment functionalities, including blockchain, rely on better mobile network service (3G rather than GSM 2G) and more advanced mobile devices, like smart phones. In South Asia, smart phone ownership is expected to grow from 48% penetration in 2018 to 75% by 2025. In Sub-Saharan Africa, penetration could rise from 39% in 2018 to 66% by 2025.[65] There will likely be a lag until this development reaches the off-grid energy access customer base. Until then, most payment services will continue to rely on more basic protocols like USSD.

» USSD is not a great mechanism for making payments. It is time sensitive; you can get timed out of a session easily. It requires a degree of literacy; the user has to memorize long strings of numbers and multiple numbers. The buttons and text are small; many older people do not want to engage with it. There are a lot of ways that it can go wrong, but it is still better than the alternative, which for non-smartphone users is cash.«

DANIEL WALDRON, CGAP[66]

64 – Bitspark, Bitspark Roadmap Update - The Month of Milestones, 2019 (link)
65 – GSMA, State of the Industry Report on Mobile Money, 2019 (link)
66 – TFE Energy, Market expert interview, Daniel Waldron, CGAP

4.5.2 USING DIGITAL PAYMENTS FOR CREDIT SCORING

Many rural off-grid energy customers are unbanked. This means that customer data collected by mini-grid operators or OGS suppliers is often their first digital trail. Data on payment patterns and product usage can help create simple creditworthiness profiles. As an example, Bboxx uses this kind of data to identify customer trends, perform credit checks and determine which customers may have the capacity for an upgrade.[67]

» The credit side gets much easier as you get to a higher-margin item because you can afford to do more thorough assessments, you can call references, you can actually visit the borrower's home if you are talking about something in the $800 or above range.«

DANIEL WALDRON, CGAP[68]

4.5.3 ADVANCED DATA ANALYSIS

Companies are investing into advanced data analysis and are applying new technologies such as machine learning. Some have integrated credit risk assessments and default forecasts into their workflows. There are still some questions around the effectiveness of credit scoring, especially for new markets, and it is important to keep in mind that many insights and quick wins can be obtained through simpler, big data-based models.[69] Nevertheless, companies are gaining first insights and experiences that they can then test and improve upon. For example, Fenix has found a correlation between customers who are late on

» We do not currently understand customer behavior well enough to predict who is going to be a good or bad customer or what the payment patterns are going to look like. That is a big challenge in the sector.«

NICHOLAI LIDOW, LIB Solar[71]

their first digital payment and loan defaults. Building on this insight, they have applied advanced analytics to predict which groups are most likely to miss their first payment and are now testing whether a call from the call center can increase the likelihood that this at-risk group will make their payments.[70]

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» Credit risk assessments for PAYGO solar home systems (SHS) are really hard, because off-grid, unbanked customers have no history repaying a loan of this size. There were a couple of data firms working with PAYGO firms, trying to create credit scores based on all of the mobile data that they could get through linkups with MNOs such as data records, airtime, mobile money transactions. But it's a different size, term, and type of lending, and those experiments either have not worked or have not worked well enough to justify the cost, yet.«

DANIEL WALDRON, CGAP[72]

67 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx
68 – TFE Energy, Market expert interview, Daniel Waldron, CGAP
69 – Guilhem Dupuy and Thibault Lesueur, Big Data, Big Opportunity: Is Data Science the Key to Universal Energy Access?, 2019 (link)
70 – Brianna Schuyler, The Interplay of Experimentation and ML to Aid in Repayment of Micro-Loans in Sub-Saharan Africa, 2019 (link)
71 – TFE Energy, Market expert interview, Nicholai Lidow, LIB Solar
72 – TFE Energy, Market expert interview, Daniel Waldron, CGAP

FURTHER READING

GSMA conducts research on mobile money technology and funds pilot projects and studies. GSMA's annual report, ***State of the Industry Report on Mobile Money*** (link) provides an up-to-date overview of the mobile money industry. While it does not specifically address the relationship between mobile money and energy access, the annual report, ***Mobile for Development Utilities*** (link), describes the linkages between the telecommunications industry as a whole and the energy access industry. Finally, GSMA, through their Mobile for Development Utilities Fund, has produced a number of case studies, highlighting the mobile-related work of several energy access companies, such as ***Mobisol, Devergy, Village Infrastructure Angels and ME SOLshare***. A complete list of case studies can be found here (link).

The Consultative Group to Assist the Poor (CGAP) is a global partnership of development organizations and publishes on PAYGO and mobile money. The primer, ***Open APIs – From integration to Innovation: Implementing an Evolving API Strategy***, 2018, (link), provides a brief overview of how APIs are changing. In a 2015 article titled, ***What is USSD & Why Does it Matter for Mobile Financial Services?***, 2015, (link), CGAP describes USSD in detail.

Bankable Frontier Associates (BFA), has written a report called ***Payment APIs***: ***What, Why, and for Whom? An Introduction to Payment Interfaces & the Kenyan Market***, 2016, (link). It is one of the best resources for gaining a deeper understanding of the role of APIs in digital finance.

Lighting Global is the World Bank Group's initiative for increasing energy access through OGS. It is a market authority on OGS and publishes many reports on quality standards, policies, technology and markets. The report, ***Off-grid Power and Connectivity: Pay-as-you-go Financing and Digital Supply Chains for Pico-Solar***, 2015, (link), was one of the first to explore the impact of digital solutions on off-grid energy access.

Companies, such as Solaris Offgrid and Angaza, publish ***technical articles*** on solutions, impact and technology development. Solaris Offgrid's material can be found here (link) and Angaza's here (link).

The Future Energy Program, has written a report ***Digitalization for Energy Access in Sub-Saharan Africa: Challenges, Opportunities and Potential Business Models***, 2019, (link). The report provides an in-depth view on the status of the role that PAYGO technology plays in OGS solutions.

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Image provided by Sam Duby, TFE Energy

5 DIGITAL PLANNING

KEY POINTS

- Digital planning tools significantly de-risk and accelerate electrification efforts.
- More established tools, such as those for technical system design and least-cost electrification planning, are now complemented by decision-making tools for site selection. The tools have the – as yet untapped – potential to work in an integrated manner, where they build on each other to span from the regional or country perspective to specific village level risks and costs.
- The development of underlying technologies (like satellites), increasingly large and qualitatively good available datasets and machine-learning algorithms push planning tools towards ever more precision and predictive power.

Image provided by Sam Duby, TFE Energy

Digital planning tools can support electrification strategies and operations accelerating them, improve their accuracy and reducing uncertainties and, ultimately, risks. Governments and development finance organizations in the energy access sector already start using digital planning to identify least-cost electrification strategies and develop attractive tenders. Mini-grid developers can find suitable sites more quickly and reliably, and they can create initial system layouts and cost estimates. OGS product companies can identify attractive sales regions, cross-check customer information and better plan distribution channels. Planning tools are rapidly gaining in relevance as the market seeks to scale and many stakeholders are shifting from anecdotal or opportunistic approaches to data-driven and strategic decision-making.

Planning tools are rapidly gaining in relevance as the market seeks to scale.

5.1 THE DEVELOPMENT OF DIGITAL PLANNING TOOLS

The digital planning tool chain, shown in Figure 14 below, emerged from the mini-grid (and grid-extension) sector, where the significant investments made into stationary infrastructure demand a certain amount of planning. Finding the least cost electrification option, the right site for a mini-grid or designing the most cost-effective system configuration crucially impacts the financial viability of the investment.

Currently, the tool chain is applied intermittently and by different stakeholders. Governments and development finance institutions (DFIs) use more and more least-cost maps for planning electrification, but they are not yet available for every country with low energy access rates at sufficient quality. Site identification tools for tendering support are only beginning to be applied. Similarly, mini-grid developers and OGS companies are not yet making full use of the toolchain. Most established is the use of technical design software for mini-grids. These are either in-house or third-party solutions, such as HOMER. For site identification, most still work manually with Google Earth. Some use more sophisticated geographic information system (GIS) tools (e.g. QGIS[73]) and freely available information layers. The work is almost always done by electrification companies in-house. Advanced site assessment tools, such as Village Data Analytics, are only now available in the market. However, as the OGS and mini-grid markets grow and actors are looking to accelerate project development or sales, or venture into new areas, site assessment tools that offer an analysis of target areas become increasingly important. They help mini-grid companies better locate suitable sites and OGS companies identify prospective customers and formulate optimized sales and supply strategies. One advantage of the OGS market, as compared to the mini-grid market, is that companies often have a large amount of existing customer data (e.g. point-of-sale information) that can be used to validate and strengthen GIS-based analyses.

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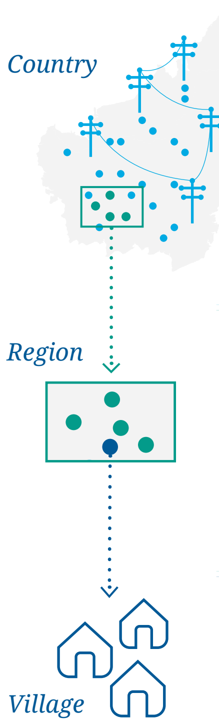
Photo by Văn Ngọc Tăng on Unsplash

73 – QGIS is an open-source GIS software (link)

TFE Energy

Figure 14 – The digital planning tool chain[74]

The digital planning toolchain helps electrification planners identify the most cost-effective approach, locate suitable areas and settlements for business and estimate system cost.



	Users	Solution	Output	Input	Tools	Providers	Age
LEVEL 1 National electrification planning	DFIs/governments	Policy planning tool	Online map and report of a country or region, outlining areas for grid extension and off-grid electrification, based on cost of power provided	Public information on, e.g. population, power grid, electrification policy and goals, topography, designated infrastructure (e.g. schools)	• GIS software • Least-cost models	• Research institutes (KTH, MIT, Columbia) • Energy/GIS consultants	Ca. 10 years
LEVEL 2 Off-grid area analysis	• OGS companies • Mini-grid developers • DFIs /governments	Decision-making tool	Interactive map and report identifying and ranking suitable mini-grid sites or OGS sales regions, based on estimated demand and ability to pay	• Satellite data on, e.g., settlements, grid/road infrastructure, agriculture • Survey data on, e.g. asset ownership, type of agriculture • Public information (as for national maps)	• Automated image recognition • Advanced data analytics • Energy modelling	Energy access/tech specialists (TFE Energy /Village Data Analytics, Fraym, AtlasAI)	Ca. 2 years
LEVEL 3 Mini-grid design	Mini-grid developers	Technical design tool	Preliminary mini-grid system design and bill of materials (BoM), based on load estimates, grid layout, system costing and (in future) on digital village layout	• Local information on, e.g. number/type of loads, energy resources • User inputs on, e.g. system type/size, component costs • In future: Very high resolution satellite or drone images	• Design software • In future: automated image recognition	• Energy access/tech specialists (Homer, VIA, Taos.ai, MIT) • In-house solutions	Ca. 20 years

74 – TFE Energy analysis

5.2 NATIONAL ELECTRIFICATION PLANNING

Geospatial, least cost electrification planning was pioneered by a group of universities, including the KTH Institute of Technology in Sweden, the Massachusetts Institute of Technology (MIT) and Columbia University, both in the USA. Today, DFIs and governments routinely tender such studies to provide a planning framework for national electrification efforts.

The analyses typically encompass a high-level comparison of the relative benefits of central grid expansion, construction of mini-grids and the provision of OGS solutions. Many of the methodologies are open source as part of academic publications. The most widely used open source tool is the OnSSET model developed by KTH.[75] Other players, such as the Reiner Lemoine Institute (RLI)[76] or the World Resources Institute (WRI),[77] apply these or similar methodologies. The platform Energydata.info, initiated by the World Bank Group, collects and presents a number of these maps.[78] In September 2019, the Global Electrification Platform was launched by a number of partners, including the World Bank and Google. It hosts different datasets related to electrification for around 40 countries.[79]

Image provided by Sam Duby, TFE Energy

5.2.1 DATA COLLECTION

Least cost mapping typically takes into account information layers from two domains:

- **Physical factors:** e.g. solar irradiance, topography (elevations, islands), water surfaces
- **Demography and infrastructure:** e.g. population maps, grid extension and reliability, road networks, schools, medical centers

The number and types of information layers depend on the model used and, on the availability and quality of country-specific data. Typically, datasets are collected from local government offices. These are then cleaned and quality-checked before being fed into the model. In addition, datasets and maps from satellite imagery are increasingly available in the public domain. These can be used to complement and cross-check the other datasets. A third dataset is open source information from e.g. the Humanitarian Open Street Map (HOT) or Humanitarian Data Exchange (HDX).[80]

5.2.2 MODELING

By combining the geospatial layers collected in the first step, a LCOE is calculated for different regions on a map and for different electrification technology choices.[81] These include grid extension and various mini-grid gener-

75 – OnSSET, GIS based electrification platform developed at KTH (link)
76 – Nigeria Rural Electrification Plans platform, created by Integration and Reiner Lemoine Institute (link)
77 – Energy Access Explorer, with data for Uganda, Kenya and Tanzania, created by World Resource Institute (link); The World Resource Institute in turn supports KTH in their ongoing development of the OnSSET tool.
78 – Energydata.info, open access collection of renewable energy related platforms and tools (link)
79 – Global Electrification platform (link)
80 – Humanitarian Open Street Map (link); Humanitarian Data Exchange (link)
81 – The levelized cost of energy refers the average cost per kWh produced over the lifetime of a system, thus making high CAPEX / low OPEX technologies like solar more comparable with low CAPEX / high OPEX technologies like diesel generators.

ation technologies, such as small-hydro, solar or biomass, as well as OGS products. Simpler models are based on broad assumptions around population, distance to grid and topography. More advanced models use an algorithm that iterates through scenarios and picks the one with the lowest overall LCOE. Parameters can be set regarding estimated population growth, energy demand (and growth) and political priorities. The costs and benefits of investment options can be calibrated.

5.2.3 ACTIONABLE INSIGHTS

The output of these least-cost electrification maps is a rough area plan, primarily used by governments to inform their grid extension and rural electrification strategies. The maps indicate which regions should be electrified by extending the grid, which should be served by mini-grids and which are markets for OGS. Mini-grid developers and OGS companies can use these maps to identify regions for potential business activity that merit further investigation. Typically, these maps are not granular enough to provide actionable business intelligence.

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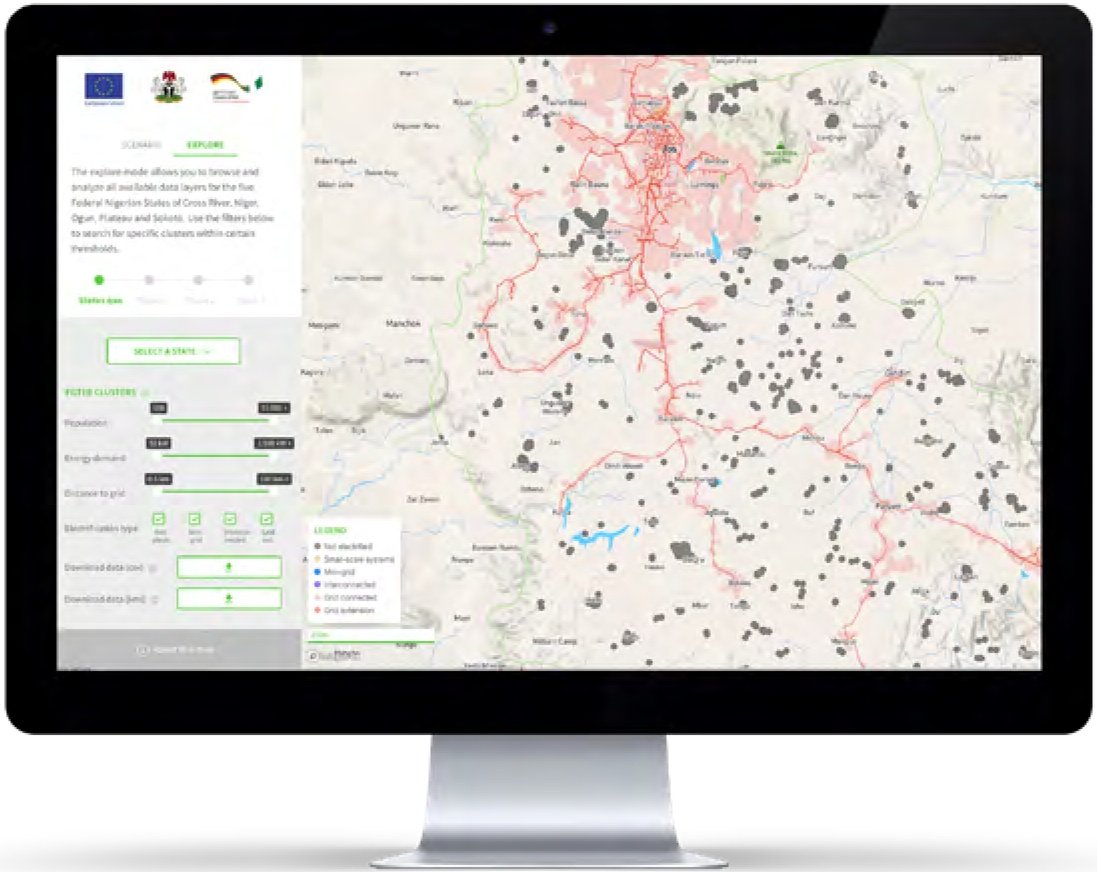
Figure 15 – Example least-cost electrification map (Nigeria)[82]



Rural electrification scenarios and least-cost maps help estimate potential demand and best supply options for energy access.

82 – Image taken from the Nigeria Rural Electrification Plans platform, created by Integration and Reiner Lemoine Institute (link)

5.3 OFF-GRID AREA ANALYSIS

A key challenge in the off-grid sector is the lack of timely, available, actionable information about markets. This often means that business decisions are based on reacting to opportunities, on anecdotal insights in a region or on expensive, time-consuming and often inaccurate customer surveys. As a result, business development timelines are long and unreliable, and decisions are inaccurate, driving up costs, uncertainty and, ultimately, the risk associated with working in conditions of uncertainty.

» There seem to be two camps in terms of demand prediction. One camp says that we will collect a lot of detailed data on our customers and apply sophisticated quantitative models. Another camp says that it is hopeless and there is no way you can predict people's demand so let's have modular systems and install minimum capacity when we get there, observe what the demand is, control people's consumption and then we can scale up from there.«

NATHAN WILLIAMS, CMU[87]

New digital planning tools address this market challenge. They usually combine several data layers. In some cases, advanced machine learning tools are applied to give more depth, texture and precision to the information maps. Site identification tools are gaining momentum as the electrification market matures. They empower governments to run much better large-scale mini-grid tender processes, help growing mini-grid developers identify suitable new sites quickly and at scale, and enable OGS companies to scale faster and reduce customer repayment risk.

5.3.1 DATA COLLECTION

An important data-stream for initial site identification and analysis is satellite imagery or earth observation (EO) data. Satellite imagery is becoming more widely available through both publicly funded satellites from the European Space Agency (ESA) and the US National Aeronautics and Space Administration (NASA), as well as a growing number of satellite constellations operated by private companies, such as Planet Labs or DigitalGlobe.[83] At the same time, the cloud-based computing and data storage services required for work with large amounts of image data, have become more affordable, accessible and faster. Various teams – both academic and from the private sector – have published freely available datasets derived from satellite imagery. Facebook has recently released a population map of most of Africa as well as an electricity grid network map, based on nightlight imagery.[84] We expect more of these satellite-derived products to be published in the future.

Large-scale household surveys, in many cases publicly available, are another important data source. The two most widely used ones are the Living Standards Measurement Study (LSMS) from the World Bank and the Demographic and Health Surveys (DHS) from USAID.[85] These extensive datasets provide socio-economic information on factors including primary income sources or quantity and type of agricultural produce. However, the datasets are "geo-shaked", i.e. the geolocations of the households have a random offset in order to ensure anonymity. Some companies have a slightly different approach and value proposition. Nithio, for instance, combines socio-economic layers with point-of-sale data to predict the creditworthiness of OGS customers.[86]

© Contains modified Copernicus Sentinel data, processed by ESA

83 – ESA, Copernicus fleet providing free imagery of the planet (link); NASA, Landsat mission overview (link); Planet, commercial provider of satellite imagery (link); DigitalGlobe/Maxar, commercial provider of satellite imagery (link)
84 – Facebook, Data for Good program repository on The Humanitarian Data Exchange (link); NASA, VIIRS satellite providing nightlight imagery (link)
85 – USAID, Demographic and health surveys (DHS) (link); World Bank Group, Living standards measurement studies (link)
86 – Nithio, rural customer credit intelligence (link); Fraym, geospatial market intelligence (link)
87 – TFE Energy, market expert interview, Nathan Williams, Carnegie-Mellon University (CMU)

The survey process itself, is becoming digitally enabled, too, which improves the data quality. Site identification tools based on granular village analysis, such as Village Data Analytics, allow a user to create shortlists of relevant survey locations and contextual information about them. For dedicated on-ground household surveys, smartphone based survey tools are replacing the traditional pen-and-paper approach. This has many advantages, including increasing the speed of data entry, making surveys dynamic (e.g. answers can change follow-up questions), automatically linking to GPS coordinates, real-time outlier detection and reduced error rates at the point of data entry.

The most widely used example of smart phone-based surveys is the open-source Open Data Kit (ODK), from which various tools, such as KoBoToolbox have been developed.[88] The tools allow users to generate and run survey campaigns. Once gathered by on-site enumerators, data is automatically sent to a central server. The apps were initially developed for quick disaster response, e.g. in refugee camps. Challenges to using electronic surveys include acceptance by local staff and survey participants, as well as technical challenges, such as the need to recharge devices in the field. One innovative way of addressing these survey challenges is offered by the German startup Groots. It has developed a technology-enabled process, by which village data is collected through local mom-and-pop-shops in an ongoing manner, and where questions can be adjusted over time.[89]

» Village Data Analytics helps donors, governments, companies and investors make data-driven electrification decisions based on their customized set of criteria.«

NABIN RAJ GAIHRE,

Village Data Analytics

Further interesting datasets are mobile coverage information, GPS data from mobile subscribers, data from machines located in villages, such as water pumps, food processing machines or diesel generator sets.[91]

5.3.2 MODELLING

Site identification planning tools ingest satellite imagery, freely available geospatial layers as well as socio-economic data streams to estimate the most promising sites for mini-grids or areas for OGS sales. Physical factors (populations, distances, terrain) are combined with socio-economic factors (economic activity, willingness and ability to pay for electricity, potential energy demand). Algorithms can help overcome data gaps and automate analyses. The parameters are then fed into specific energy access models to compare and rank regions or sites and provide decision-making guidance. The more data is available, the more accurate statistical forecasts can be, and the less on-ground surveys are needed.

After acquiring household survey data on shortlisted villages, a village energy demand profile is calculated. Here, the survey data and predictive data from the site selection tool are cross-checking each other. Often, the distinction between residential and productive use of power is useful. Different customer groups are defined, and their demands are specified.

5.3.3 ACTIONABLE INSIGHTS

Site identification based on remote analysis (i.e. via socio-economic survey data and satellite imagery) provides mini-grid developers with a shortlist of ranked settlements and OGS companies with interesting sales

» Detailed energy consumption and socioeconomic data are often scarce in remote or low-income areas. Today, the expansion of information and communication technologies (like satellite imagery, mobile phones, and mobile payment systems), has made available an increasing amount of interrelated data that can be integrated in energy planning models «

ESMAP
ENERGY ANALYTICS FOR DEVELOPMENT:
Big Data for Energy Access, Energy Efficiency, and Renewable Energy[90]

88 – Open Data Kit, toolkit for digital field surveys (link); KoboToolbox, an ODK-based digital field survey software suite (link)
89 – Groots (link)
90 – ESMAP, Energy Analytics for Development: Big data for Energy Access, Energy Efficiency, and Renewable Energy, 2017 (link)
91 – The Access 2 Energy Institute has started integrating smart meters in diesel pumps in Nigeria to measure current electricity demand and understand the market potential for alternative solar plus storage options (link).

regions. Additional data layers can include statistics about, for example, the total area, number of villages, road network and accessibility. Governments and DFIs can have a shortlist of sites to plan grid extension or to feed into tender process for large-scale mini-grid development. Investors can use the analysis to support due-diligence processes and to measure impact.

5.4 MINI-GRID DESIGN SOFTWARE

For mini-grids, a design software can create initial technical layouts once a suitable village has been identified. Design software has been among the first digital tools to emerge in the energy access market and is widely used today. The best-known one is from HOMER Energy.[93] It was initially developed by the US National Renewable Energy Laboratory (NREL) under the Village Power program in the 1990s. There are now more than 2,000 active users and a total of 2.7 million HOMER files have been created over the last 5 years.[94] These files offer initial cost and generation estimates. Later in the mini-grid planning process and with more on-ground data, a final layout is created manually and optimized.

Advances in processing power and architectures, such as parallel computing, have made design software ever more sophisticated and faster.

5.4.1 DATA COLLECTION

Energy system design software requires data about sites and consumers, i.e. potential consumption, customer groups, productive loads, number and location of households. This information might have already been gathered during the site selection process (site identification tools, socio-economic modelling, identification of productive loads) and can be reinforced by additional, specific on-site surveys. These can also reveal constraints on the location of the generation asset as well as the distribution grid. Building footprints can be extracted from satellite or drone imagery, either manually or aided by machine learning algorithms.

Another source of information for building footprints and type is the Humanitarian OpenStreetMap project, which has digitally mapped large areas in East Africa and beyond.[95] In addition, companies such as Development Maps offer a digitalization service of households based

Figure 16 – Site selection using Village Data Analytics for a mini-grid developer in Nigeria[92]

Site selection based on data analytics and satellite imagery can create a ranked shortlist of promising villages within an area of interest and reduce the number of on-ground surveys needed.

92 – Image provided by TFE Energy / Village Data Analytics
93 – HOMER Energy Platform (link)
94 – TFE Energy, case study interviews, HOMER Energy
95 – Humanitarian OpenStreetMap, crowdsourced mapping for development (link)

on Google Earth imagery.[96] Taos.ai, an Engie spin-off, used drone imagery of rural villages to generate mini-grid distribution layouts.[97]

Cost relevant information, such as equipment choices and datasheets, as well as prices have to be gathered from vendors.

5.4.2 MODELLING

The design of a mini-grid power system is very sensitive not just to the total consumption and peak load, but also to the daily and seasonal load profile. For this reason, software packages like HOMER PRO use a yearly load profile. In case the data is not available, assumptions based on prior customer profiles and existing databases are used to create the load profile.

The user then selects a set of generation and storage assets (diesel gensets, PV, wind, batteries, converters, loads) for the software to consider. For PV and wind, irradiance and wind speed information can be added from public repositories. It is important for the user to stipulate the variability of parameters, such as wind speeds over the year, fuel prices, customer demand or maintenance down-time. The software then goes on to simulate all possible system layouts for these scenarios and calculates financial indicators (e.g. upfront CAPEX, revenue, LCOE, excess energy generated, payback times, performance when compared to a pure diesel mini-grid). A set of filters and additional, user-defined constraints helps to identify the optimal mini-grid layout.[98]

Figure 17 – Example mini-grid design software user interface[99]

Mini-grid design software, such as Homer Pro generates optimized layouts for a given demand profile. The process is typically automated and compares many different designs.

Homer is the most mature design software. It allows for simulations and optimization of mini-grid layouts, as well as sensitivity analyses for the user to learn how external factors (e.g. fuel cost) impact the financial performance of the mini-grid. Homer has an API to integrate with other software (e.g. Odyssey Energy Solutions), as well as add-on modules for different generation technologies.

96 – Development Maps, on-demand mapping of settlements for development (link)
97 – Taos.ai, self-learning tool for optimal mini-grid design (link); the company may no longer be operational
98 – TFE Energy, case study interviews, HOMER Energy
99 – Image provided by HOMER Energy

Another key cost driver of the mini-grid is the length of low-voltage distribution lines required to connect the households. Given the digitized locations of the buildings, there are algorithms, such as the minimum spanning tree, to draw the shortest grid network which connects the targeted number of households. While on-ground constraints might significantly change the final design, automatically generated grid layouts provide valuable cost estimates during a feasibility study.[100]

5.4.3 ACTIONABLE INSIGHTS

The design software described in this section structures a feasibility study of a mini-grid. It includes optimal layout of generation and distribution assets for a specific site given a user-defined list of parameters, hardware specifications and demand estimates collected during surveys. The output includes yearly system performance estimates, key financial indicators (e.g. CAPEX, LCOE) as well as the overall financial viability of a mini-grid. The optimized design as well as distribution layout are key elements of the business plan and investor discussions. In addition, the refined design can be handed over to an engineering, procurement and construction (EPC) company to create engineering drawings and plan the logistics for the construction.

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Image provided by Nabin Raj Gaihre, Village Data Analytics

100 – See, for example, Village Infrastructure Angels (link)

5.5 HOW DIGITAL PLANNING ADDRESSES THE MAIN CHALLENGES OF ENERGY ACCESS

As a whole, digital planning accelerates the growth trajectory of the electrification industry. It is a key driver helping the industry reach global targets (SDG7) and become profitable through scale. Digital planning solutions also reduce the error margin in planning and business development for mini-grid developers and OGS companies.

5.5.1 IMPACT ON SCALE

The data void in off-grid communities and the difficulty of estimating energy demand and customers' ability to pay have led to an anecdotal and slow approach to selecting sites and sales regions, making the scaling of energy access solutions challenging. The emerging digital planning toolchain addresses this challenge.

Least cost electrification planning provides a crucial framework to help utilities, mini-grid and OGS companies identify focus regions. Site assessment tools allow both governments and companies to move quickly from a region to a shortlist of viable villages, and technical design software enables fast cost estimates.

5.5.2 IMPACT ON COST

According to a recent World Bank report, least cost electrification maps and site identification tools have decreased the cost of pre-selecting a mini-grid site, ready for detailed on-ground assessment and community engagement, from $30,000 to about $2,300.[101] Cost reductions will be most visible for companies who work on large numbers of sites or sales regions and take a strategic approach. Digitized building footprints and connection cost estimates reduce the amount of in-house engineering man-hours. It is currently difficult to quantify the reduction in financing costs derived from data-based investment decisions and operational risk reductions.

5.5.3 IMPACT ON RISK

Digital planning tools significantly reduce uncertainty for electrification policymakers and businesses by introducing new and independent information layers to the analysis that allow them to quantify risks and make data-based decisions. The analyses can be continually improved upon as they are deployed, and they can be cross-referenced with existing site identification approaches to improve the accuracy of both. The tools can also help monitor impact and support due diligences in an emerging secondary market. Finally, the toolchain offers the opportunity to establish best practices and more transparency in the sector, which decreases the overall, actual and perceived industry risk.

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» To reduce mini-grid cost, don't look to panels and batteries, that's going to be cheap. Look to distribution, maintenance and payment collection.«

AFNAN HANNAN,
Okra Solar[102]

Image provided by Sam Duby, TFE Energy

101 – ESMAP, Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers, 2019 (link)
102 – TFE Energy, Market expert interview, Afnan Hannan, Okra Solar

5.6 CHALLENGES TO DEPLOYMENT

Least-cost electrification tools are typically financed by DFIs such as the World Bank and deployed by governments and state-owned utilities. The quality of their results is strongly linked to the availability and quality of information. One particular challenge is to detect the electricity grid. Part of the solution can be ground-truthing the analysis. An example of this is the work of the GIZ team in Nigeria to map the grid infrastructure through photography and geotagging from cars.

Technical design software, on the other end of the spectrum, is bought by mini-grid companies. The challenge there is mainly the cost. The off-grid energy access market is still maturing and has slim margins and thus reduced acceptance of external, commercial software tools that do not reduce current investment or operational costs.[103] Sometimes technical assistance grants step in. In other cases, the technical design is still regarded as a core-competency of developers and therefore developed in-house.

Off-grid area analytical tools can be used by the public sector (DFIs and governments) and by companies (mini-grid and OGS companies, investors and banks). The challenge with the former group is that it takes time to implement innovation into established procurement processes and program designs.

Overall, companies who develop digital planning tools, often struggle to find a pricing model that can cater to the market but still provide reasonable returns. They are fundamentally built for a scale that the market is only beginning to grow towards. The most important push for their more widespread use could come from investors and banks, looking for ways to reduce risks and transaction costs through improved due diligences and more standardized processes.

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5.7 LOOKING AHEAD

Least-cost electrification plans at the country level are applied to more and more countries. In the process, they will improve in granularity and precision. This can partially be achieved by integrating them with site identification tools. As distributed energy solutions, especially mini-grids, become more prevalent, the models might need to be readjusted to reflect their growing commercial attractiveness. Technical design software is quite established. In the future, it can also integrate more fully with other digital planning solutions. The most dynamic developments can be seen in site identification, where actual decision-making tools, such as Village Data Analytics, have emerged. By adding new data layers and more sophisticated data analytics, they have the potential to become central platforms for planning, customer acquisition and impact measurement. Site identification tools can, in the future, also be integrated with the digital operations tools discussed in the next chapter.

Actual decision-making tools for site identification have emerged.

103 – TFE Energy, Market expert interview, Nikhil Jaisinghani, formerly Mera Gao Power

In addition, digital planning tools can expand their analytical breadth to increasingly take into consideration agricultural value chains and opportunities for productive use of energy[104] that can shift value chains towards village economies. This would be closely linked to questions of water resource availability and the effects of agriculture and climate change on them. In addition, digital planning for electrification could be more systematically integrated with mobile network and internet connectivity planning.

The underlying technologies and datasets that empower decision-making tools are developing rapidly (see Appendix for details). For example, satellites are capturing ever more images and the images capture a wider information spectrum. There is a growing number of satellite operators, both public and private. An increasing number of companies provide platforms for easier access and processing of satellite imagery, such as IBM, Google, Planet, Descartes Labs, Astraea.EarthAI or Up42.[105] In addition, processing power is no longer a major limiting factor and there is continued growth in the number of potent algorithms. Growing datasets mean that machine learning algorithms can be better trained and tested, leading to better predictions. Publicly available datasets on population and grid extension published by Facebook have set an example for how institutions can provide stakeholders with high-quality data.[106]

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FURTHER READING

CGAP's report, ***Using satellite data in financial inclusion: How financial services providers can use satellite data and advanced analytics techniques to reach remote customers***, 2019, (link), provides an overview of currently available satellite imagery and key characteristics, such as temporal and spatial resolution. It also offers an introduction to machine-learning-based analysis and suggestions on how insights on remote customers can be generated.

A USAID-NREL Partnership report, by Nathan Williams et al., ***Survey use in mini-grid load prediction, project development, and operations: Review and Best Practices***, 2019, (link), describes the current site selection and survey practices of some well-known mini-grid developers in Africa. It shows how mini-grid developers approach the difficult task of collecting quality data in rural villages, survey strategies, types of questions asked and their stance on digital survey tools.

Image provided by Sam Duby, TFE Energy

104 – An interesting recent case study on productive uses of energy was published by CrossBoundary (link)
105 – IBM, Pairs platform for geospatial analysis (link); Google, Google Earth Engine for earth science data and analysis (link); Planet, Platform for automated & scalable access to Planet imagery (link); Descartes Labs, Cleaned and analysis ready catalog of earth observation data (link); Astraea.EarthAI, AI platform for big geospatial data (link); Up42 (Airbus), open platform and marketplace for Earth data and analytics (link)
106 – Facebook, Data for Good program repository on The Humanitarian Data Exchange (link)

The chapter “Creating the environment for take-off of mini-grid portfolios” in the World Bank Energy Sector Management Assistance Program’s (ESMAP) report, ***Mini-grids for half a billion people: Market outlook and handbook for decision makers***, 2019, (link), provides an overview of current geospatial tools for site identification.

The Joint Research Center of the European Commission has, in 2018, published an analysis of then available least-cost electrification tools, called ***Next generation interactive tools as a backbone for universal access to energy*** (link). Slightly older, from 2017, is a comparison of these tools from Oxfam called ***Achieving Universal Energy Access at the Lowest Cost*** (link).

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Image provided by PowerGen Renewable Energy

6 DIGITAL OPERATIONS

KEY POINTS

- Remote monitoring gives the energy access industry the data to transform their businesses from the provision of energy services to offering a broader set of customer solutions.
- The combination of digital payments with digital operations, particularly remote lockout technology, has led to the success of PAYGO.
- Without digitalizing operations, it will be very difficult to scale mini-grids beyond 10-20 sites.

Image provided by senivpetro

There are very few industries in the world today that do not use digital tools to streamline their operations in some way. Examples range from widely used accounting, inventory and CRM tools, to more specialized ones, such as call center and sales force management apps, and to highly sophisticated analysis of user data to accurately target advertising, products and services. While the energy access industry has benefited from many of these, there are operational challenges unique to this industry that required the development of specialized digital solutions. These challenges fall loosely into two categories: the operation and optimization of technology in remote areas and the management of a widely dispersed, often poor customer base.

The first challenge has been met using remote monitoring tools. These allow companies to monitor the state and usage of their assets and enable remote control of these assets. The second challenge, dealing with remote and often unbanked customers, has been met with the development of GSM- and internet-enabled smart meters (in the case of mini-grids) and PAYGO switches (in the case of OGS). Both of these tools unlock two fundamental functionalities: the ability for customers to incrementally pay for services remotely using mobile money and the ability for a company to remotely lock an asset or disconnect a customer when appropriate.

6.1 THE DEVELOPMENT OF DIGITAL OPERATIONS

The development of digital operations tools has evolved through three phases. Starting in 2010, first movers into the rural electrification market, such as Bboxx, EarthSpark International, access:energy and Devergy, were forced to develop their own proprietary digital operations solutions because there simply was nothing available on the market to meet their specific requirements. As the industry grew, companies began to specialize and offer these digital tools to others. This first took place in the mini-grid sector with access:energy and EarthSpark International evolving out of smart meter specialists SteamaCo and SparkMeter, respectively. More recently, digital operations specialists, such as AMMP Technologies and FernTech entered the market. The value-add of these companies is their ability to aggregate multiple data sources across vendors of both smart meters and energy generation technology. With these solutions, customers can see valuable operational and customer insights from a large portfolio of projects. This enabled significant cost and efficiency gains and provided the mechanism for their operations to scale.

» AMMP is a crucial tool in operating our power systems across West Africa. It allows us to monitor all critical aspects in real time, enabling us to intervene immediately.«

JASPER GRAF VON HARDENBERG, Daystar Power Group[107]

Photo by Christopher Gower on Unsplash

In the OGS sector, leading companies like Bboxx and Mobisol continue to use their own end-to-end digital operations and customer management tools. This is now changing. A number of companies offer generic PAYGO tools to the sector.

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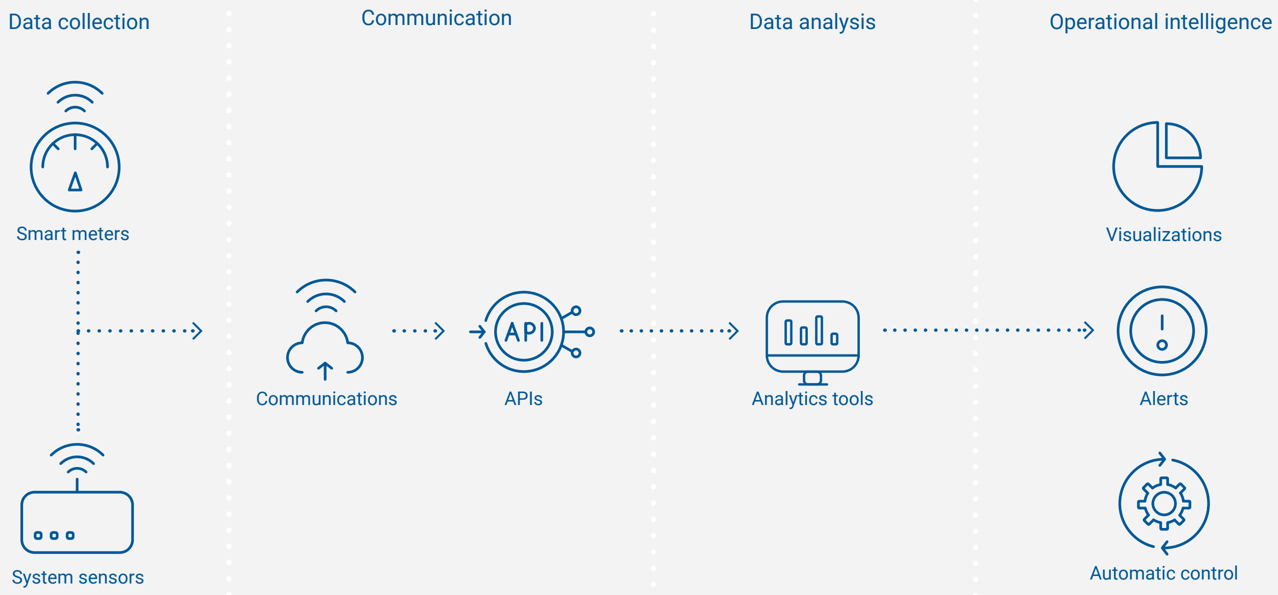
CHRISTOPHER BAKER-BRIAN, Bbox[108]

» Our IoT monitoring gives us the ability to see how our 200,000 solar home systems (SHS) around the world are performing, switch them on or off, and anticipate any issues before they arise. Moreover, it gives us access to data on how the customer is using our product, which can then be used to perform credit checks and identify customers with a high potential to upgrade or to move on to new systems.«

107 – Customer testimonial provided by AMMP Technologies
108 – TFE Energy, Case study interviews, Christopher Baker-Brian, Bboxx

Figure 18 – Illustrative setup of remote monitoring

Remote monitoring consists of four key steps: Data collection, communication, data analysis and operational intelligence.



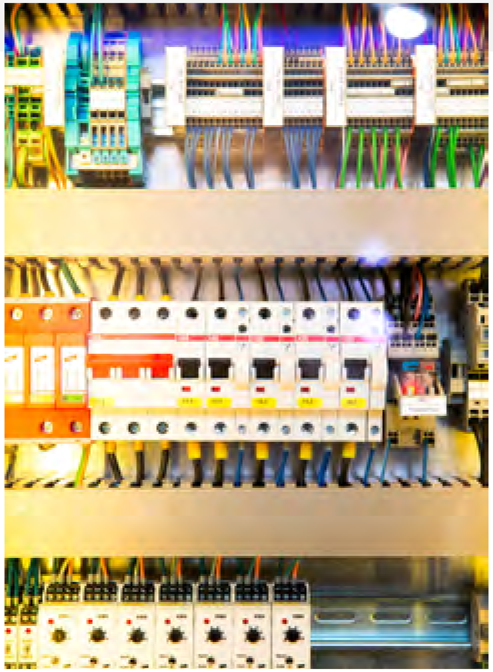


Photo by Markus Spiske on Unsplash

6.1.1 DATA COLLECTION

The data collection process to enable remote operations begins with hardware located in the field.[109] OGS products and mini-grids, whilst different in scale, both use sensors to collect data on, for example, customer energy use, battery state of charge, power quality and numerous other technical indicators. The data then needs to be transferred to a centralized platform, often hosted on cloud services, such as Amazon Web Services. This can be done using USSD, SMS or internet protocol over the mobile phone networks, and even by satellite communications, if GSM or other types of phone coverage is not available.

The mobile phone revolution reduced the cost of GSM modem modules (for SIM cards) to approximately $6-$8. Also, competition in the telecoms sector has substantially cut the cost of data packets. Yet, when aggregated across tens or hundreds of thousands of units, these costs become significant. As such, there is considerable pressure on remote asset operators to make any small savings they can. The most accessible point of leverage is optimizing and streamlining the way data is transferred. This can take multiple forms: either cleverly encoding each message to pack as much information in as few bytes as possible or being flexible with how often messages need to be sent. For example, a product can be set to send a bare minimum of summarized messages when operating

109 – Hardware here refers to components with the ability to collect and transmit data.

normally, but to boost the amount of data sent, if there is a problem that might benefit from remote diagnostics.

Another way to optimize communication is to leverage edge processing. This concept relies on the increasing processing power of cheap processor chips to enable "smart" remote devices to make more decisions, autonomously reducing the need for remote diagnostics via a central service. OGS products and mini-grid smart meters can equally benefit from these developments in global microprocessor technology (see Appendix for details).

» It depends on the operator's system layouts and portfolio but really as they move past 10 to 15 mini-grids, the operator will start to feel some pain points around being able to operate their assets in a sustainable manner.«

SVET BAJLEKOV, AMMP Technologies[111]

Unlike OGS products, mini-grid data collection can benefit from having large numbers of smart meters operating in relative proximity (in the houses or businesses of all connected mini-grid users in a village). This allows smart metering providers to use low-power, low-bandwidth local communication technology, which allow many devices to communicate (over a distance of a few kilometers depending on technology used) with a central unit (often located in the power hub). This central unit can then aggregate and summarize the data from the numerous smart meters into a single communication with the cloud platform, reducing the communications burden of remote smart meter operations. Smart metering companies have various approaches to local communications, from using RF mesh technology developed specifically for the sector to adopting off-the-shelf technology pioneered in the IoT industry such as LoRa.[110]

» At 10 grids you do not need [system] data to operate, but as soon as you want to go bigger, you need data.«

NIKHIL JAISINGHANI, Co-founder and former executive director of Mera Gao Power[112]

There are two main categories of useful data that mini-grid operators gather. The first is operational data on how well the system is performing, usually from a smart inverter. The second is commercial data on energy sales, originating from smart meters. The usual communication channel for this data is an internet connection through the mobile phone cellular networks.

The share of global inverter sales that go into rural mini-grids is low. Thus, traditional manufacturers had little reason to customize their technologies for these bandwidth-challenged sites, which often have poor cellular signal. Smart meter companies like SteamaCo and SparkMeter, on the other hand, almost exclusively operate in these markets. Their products are usually built with back-up communication channels, switching to lower bandwidth SMS channels, a different SIM from a different cellular service provider or high reliability, high cost satellite-based channels, if the need arises.

The data costs for mini-grid operation can be high. To minimize these costs, many smart meter systems can also read the data being generated by an inverter and combine this with their own data into a single, data-optimized outgoing data stream.

As the energy access market matures, and companies increasingly source data-enabled hardware from a number of different manufacturers, synchronized data collection becomes more complex. This can already be seen with some of the larger mini-grid developers who use, for example, meters from both SparkMeter and Stea-

110 – LoRa, NB-IOT (Narrowband IOT) and Sigfox are all long-range, radio frequency wide-area network (LPWAN) technologies increasingly used in IoT applications worldwide. LinkLabs estimate that the number of interconnected devices using these technologies will reach 125 billion by 2030 (link).
111 – TFE Energy, Case study interview, Svet Bajlekov, AMMP Technologies
112 – TFE Energy, Market expert interview, Nikhil Jaisinghani, Co-founder and former executive director of Mera Gao Power

maCo, and inverters from both Victron and SMA. All four manufacturers provide independent data platforms. A data aggregator, like AMMP Technologies, can monitor and integrate data from different sources.

6.1.2 DATA ANALYSIS AND OPERATIONAL INTELLIGENCE

Data analysis can be as simple as checking to see if values (such as battery voltage readings) are within a normal operating range, basic queries such as searching large data bases for anomalies or complex algorithms to uncover deeper patterns in the data.

Operational intelligence is the creation of actionable insights from data analysis. Figure 19 shows a snapshot of the AMMP Technologies platform with graphs and live information. As the number of customers in a portfolio grows, operators often do not have the bandwidth to actively and consistently monitor multiple data streams. Feedback from mini-grid operators shows that a particularly useful section is the box in the bottom right, labeled "Alerts history". It shows pressing issues that require immediate attention, allowing operators to focus on anomalies in the data or specific issues that require human input. As automated analysis techniques become ever more sophisticated, a single operator is able to monitor an ever-larger number of sites and customers.

Data analysis can be used to guide a variety of interventions. For example, if there are consumers on a mini-grid with significant inductive loads (such as an electric motor driving a grain mill) and their power factor shifts from an ideal 1, the mini-grid operator will have to provide more actual energy to that connection than they are being paid for. This can put a burden on equipment and weakens the business case. An analysis of the power factors of large consumers can guide the development of compensating mechanisms such as the installation of power factor compensators near the specific loads or the design of special tariffs for customers of this kind.

More advanced monitoring platforms enable automated load limiting to balance systems or dynamic tariffs to reactively influence user behavior and "nudge" them towards consumption patterns better matched with environmental conditions such as poorer than average sunshine.

Figure 19 – Example of a remote monitoring user interface by AMMP[113]

The type and manner in which data is displayed, depends on the platform. Interfaces are often accessible via web apps, which can be viewed on a computer with internet access or a mobile phone.

113 – Image provided by AMMP Technologies

Some platforms, such as those developed by Mobisol and Bboxx, can automatically detect and characterize technical issues with products, generate repair tickets and then dispatch a technician to address the issue. Mobisol's system has similarities with Uber: Through the mobile app, a local, licensed technician can accept or deny a maintenance or repair task. Using geolocation technology, the app shows the location of a faulty product. Then, when the technician sets off, the physical route is tracked via GPS so that she can be reimbursed for travel costs. Once the technician has arrived, she takes an image of the system, repairs it and scans any replaced parts. Finally, she takes another image of the system once the repair is complete. This level of tracking increases quality of the work performed, and images can be used to manage warranty claims.

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» Mobisol leverages machine learning to predict, before the customer even realizes it, which batteries are about to fail or have already failed. This way we can sell them a refurbished or new battery for their system.«

STEFAN ZELAZNY,
Mobisol [116]

» Features such as time of use load-limiting and designing our own tariff system within the SteamaCo platform have been an invaluable asset.«

JESSE PIELKE,
Africa GreenTec [115]

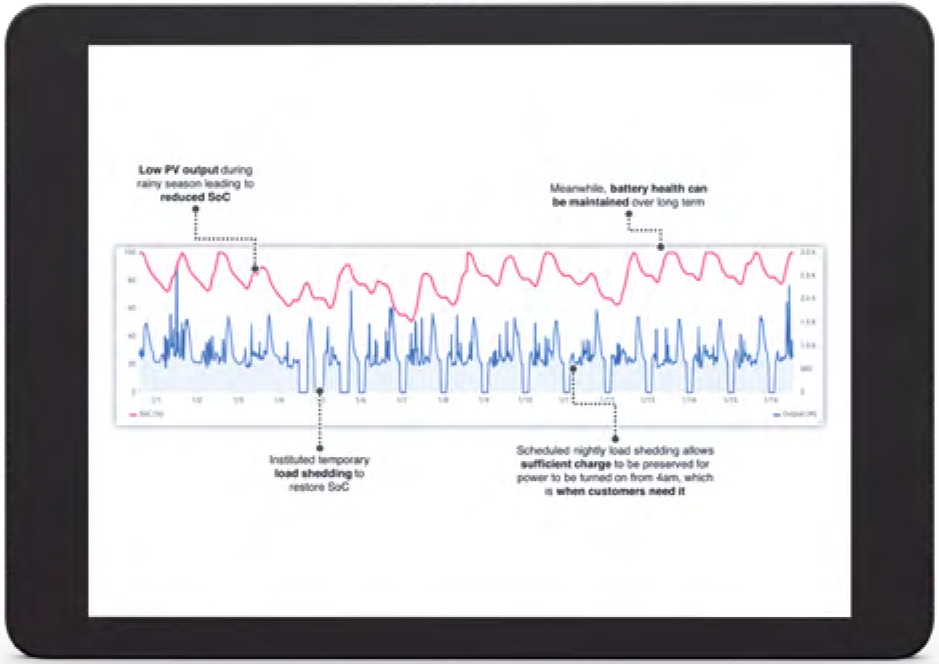

Figure 20 – Example of a system monitoring interface by AMMP[114]

Tracking data on battery state of charge (SOC) is crucial to understanding operational behavior and identifying measures to improve battery performance.

114 – Image provided by AMMP Technologies
115 – Customer testimonial for SteamaCo (link)
116 – TFE Energy, Case study interview, Stefan Zelazny, Engie Mobisol

6.2 HOW DIGITAL OPERATIONS ADDRESS THE MAIN CHALLENGES OF ENERGY ACCESS

In the energy access market, the harsh operating conditions, remoteness and wide dispersion of assets, poor infrastructure and low-income customer base, make digital operations particularly relevant and provide a good driver for innovation that can spread into the wider energy industry. A number of digital operations specialist solution providers are exploring services for on-grid and developed country markets.

6.2.1 IMPACT ON SCALE

The need for coordinated, digital operations grows with portfolio sizes and geographic dispersion of electrification companies. This is especially true for mini-grid operators. Remote monitoring allows operators to manage large numbers of assets and PAYGO services provide a scalable mechanism for monetizing them. As the volume of available data increases, data analysis will become ever more useful to tease out patterns and make predictions on what potential new mini-grid sites or new OGS markets and customers are viable.

6.2.2 IMPACT ON COST

Digital operations can reduce operating costs of mini-grids, which account for approximately 13% of the LCOE,[119] by an estimated 15% with basic monitoring, and up to 30% with advanced monitoring.[120] At the component level, solution providers have driven down the cost of smart meters, which in turn reduces the overall CAPEX of a mini-grid. Five years ago, a smart meter would cost hundreds of US dollars. Today SparkMeter offers it for approximately $50. The OGS market has so far not published data on the impact of digital operations on their bottom line.

» It is valuable to be able to diagnose remotely and have a local technician solve the issue without someone from the team having to go there.«

JOHN KIKENDA, PowerGen[118]

Digital operations also reduce the cost of energy services for customers. For example, data gathered by ZOLA Electric indicated that the 100W solar panel on their unit was larger than it needed to be. By using a smaller panel, the company reduced overall system cost, without affecting user experience.[121] Mobisol, ZOLA Electric and Bboxx all take advantage of their ability to update their firmware remotely, which enables them to remotely improve the performance of their systems, in some cases significantly. Mobisol was able to increase the lifespan of batteries from 3 to 8-10 years with a remote battery management software update.

» When we started in 2011, we had an average battery life of three years, which was not the best, and a lot of batteries broke before the end of their warranty. Right now, we expect a lifetime of eight to ten years for a battery of the same size, technology and price. We have made huge improvements just by working with the data, improving our algorithms and having access to feedback from the broken batteries.«

STEFAN ZELAZNY, Engie Mobisol[122]

118 - TFE Energy, Case study interview, John Kikenda, PowerGen
119 – Rocky Mountain Institute, Minigrids in the money, 2018, (link)
120 – AMMP Technologies, Reducing the cost of operations and maintenance for remote off-grid energy systems, 2018 (link)
121 – TFE Energy, Case study interview, Alessandro Pietrobon, ZOLA Electric
122 – TFE Energy, Case study inteview, Stefan Zelazny, Engie Mobisol

6.2.3 IMPACT ON RISK

Digital operations reduce investment risk by creating operational transparency, tracking key financial and technical metrics, and by building a basis of operational data for future investment or sales decisions. Bboxx, for example, found that operational data helped them secure follow-up funding for expansion within a geographic area – but not really beyond it.[123]

Operational data is also used to develop trust between operators and investors. For example, Mobisol and Bboxx have created investor portals on their platforms to provide a real-time view into the performance of portfolios of systems an investor has invested in. Such portals only make sense beyond a threshold investment value and the OGS market has seen several deals larger than $10 million. From this size, investors have the incentive to actively monitor portfolios, track performance and flag issues before they become a problem. The mini-grid market currently has less stringent reporting requirements, but as deal sizes grow, so too will the need for transparent reporting.

Digital operations data also help make impact and customer service quality measurable. This is important for impact investors. Furthermore, companies that leverage predicative maintenance can identify and mitigate operational risks earlier. Finally, remote lockout technology is a key component of the PAYGO business model and is a key mechanism to reduce investor perceptions of default risk. Recent research by CGAP shows, however, that while creditors are reassured by the use of lockout technology, it may not actually prevent defaults.[125]

CHRISTOPHER BAKER-BRIAN, Bboxx[126]

» In Togo and other markets, we have secured follow on finance through the use of customer data. By illustrating customers' repayment and usage profiles, this data gives local banks confidence to help fuel our expansion. It is more difficult to raise funding in markets that lack historic data.«

STEFAN ZELAZNY, Engie Mobisol[124]

» Once you move beyond a certain level of investment, really beyond venture capital or impact driven money, you have to be transparent because people are extremely careful when investing in these markets. The only way you can build trust is through transparency and the best way to provide transparency is by opening up a technical channel, which gives a real-time view into the performance of their investment. «

Screenshot provided by Odyssey Energy Solutions

123 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx
124 – TFE Energy, Case study interview, Stefan Zelazny, Engie Mobisol
125 – CGAP, Remote Locations: The Dark Side of Pay-as-You-Go Solar, 2018 (link)
126 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx

6.3 CHALLENGES TO DEPLOYMENT

The limited size of the energy access market today is a barrier for all digital solutions, but particularly so for digital operations. The pain of not having digital operations is often only felt once companies start to scale beyond their initial pilot systems and since few companies have reached this point, it is difficult for digital specialists to prove both the value of their solution and their business model. In addition, the few electrification companies that have reached scale, will not try out every single digital operations solution on the market, but rather select one or two to pilot, and then pick one and stick with it. Changing the solution later might be costly and add overall complexity. This creates a path dependency and a significant barrier to entry for new digital operations solutions.

6.4 LOOKING AHEAD

Digital operations solutions are firmly embedded in the business processes of leading mini-grid and OGS companies. In the future, they need to become more accessible to smaller, newer market players. Also, there is a strong case for aggregating operational data and insights for the benefit of the industry as a whole.

6.4.1 STANDARDIZATION AND DATA POOLING

Efforts are underway, for example by the Africa Mini-Grid Developers Association (AMDA) and the African Development Bank (AfDB),[127] to develop a mechanism through which electrification companies can report aggregated, anonymized data on costs, revenues and operational performance of their projects to demonstrate the efficacy and value of mini-grids and OGS as an energy access route. This should improve investor confidence in the sector. It should also be an incentive for governments to place more trust in off-grid electrification and develop supportive legislation.

Comparing data on, for example, mini-grid service level between operators or across geographies can only be done if standard methodologies to measure, record and report this data are implemented. Initiatives, such as NREL's Quality Assurance Framework (QAF)[128] work towards this. They borrow heavily from quality assurance protocols developed for the traditional grid, but obviously need to be adapted for the rural mini-grid context.

6.4.2 THE CASE FOR BIG DATA ANALYSIS

The large amounts of operational data gathered by OGS and mini-grid companies can be still much better lever-

127 – TFE Energy's work with these organizations shows the need for a tailored quality assurance framework.
128 – With support from Sustainable Energy Fund for Africa (SEFA) the NREL QAF (link) has been adapted by TFE Energy into a QAF for the rural green mini-grid (GMG) context. This has resulted in the GMG QAF (link).

aged to improve their business case, customer service and investment readiness. The growth of the larger digital ecosystem (from processing power to machine learning algorithms, as described in the Appendix) will offer more and more tools to do so. Some of them can be deployed by the companies themselves, some will be offered by specialists. Some will be open source and standardized, others will be customized to the industry or individual companies. To unlock the potential of operational data analysis, there could be more cooperation between digital specialists, energy access companies and researchers.

KIERAN CAMPBELL, PowerGen[129]

» There is not much recognition or acknowledgement of the backend processes that enable mini-grids. People often only consider the hardware or systems themselves and do not have visibility into the software infrastructure that is required for it to function.«

» Currently, we use machine learning for anomaly detection. However, as with any tool, you have to figure out the best way to apply it. We do not want machine learning to be one of those solutions where we have a hammer, and everything looks like a nail.«

SVET BAJLEKOV, AMMP Technologies[130]

Today, many companies are still able to gain significant insight through aggregating data and implementing simple rules, which trigger alarms or automated control outputs. Machine learning may grow to have a larger impact in time, but currently, more basic techniques that are cheaper and quicker to develop seem to be sufficient.

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FURTHER READING

AMMP Technology's white paper, ***Reducing the cost of operations and maintenance for remote off-grid energy system: The impact of remote monitoring***, 2018, (link), provides a deep look into the impact of remote monitoring on mini-grid operations. The report is unique in that the team tracks current and potential impact through their history with the former mini-grid company, Rafiki Power.

GMSA's report, ***The IoT development journey for utility enterprises in emerging markets***, 2017, (link), discusses the development of individual IoT solutions. GSMA has partnered with a number of energy access companies, such as SteamaCo and Kramworks, to provide anecdotal evidence of the process of developing IoT solutions with a strong focus on GSM enabled IoT.

SparkMeter's presentation, ***Unlocking the Economics for Emerging Market Electric Utilities*** (link), explains the use cases and features of different smart meters available in the market. (SparkMeter itself sells smart meters.)

TFE Energy's article, ***Standardisation in the Microgrid Industry – Together We Are Stronger***, 2019, (link), discusses how quality assurance frameworks can be used to standardize energy access data collection. This work brings together many industry stakeholders including the AfDB, AMDA and Odyssey Energy Solutions.

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129 – TFE Energy, Market expert interview, Kieran Campbell, PowerGen
130 – TFE Energy, Case study interview, Svet Bajlekov, AMMP Technologies

7 DIGITAL AGGREGATION PLATFORMS

KEY POINTS

- Aggregation of projects helps the electrification sector transition from softer to more commercial financing by meeting minimum transaction requirements of commercial investors.
- Project aggregation platforms can offer a sufficient level of transparency and standardization of reporting without creating undue reporting burdens on operators.
- Crowdfunding is a growing funding stream, offering mostly debt solutions to OGS companies.

Photo by Ruthson Zimmerman on Unsplash

The primary purpose of digital aggregation platforms is to facilitate investment into the off-grid space. In order to achieve this, projects are standardized, aggregated and made accessible to different stakeholders. This can significantly reduce transaction and operating costs and unlock new investment sources. Digital aggregation platforms come in two main forms. The first are platforms that aggregate projects and link them to professional investors, regulators or subsidy providers (project aggregation platforms). The second are platforms that aggregate private investors and link them to companies or projects (crowdfunding platforms). The former are used mainly by mini-grid companies. For them, reducing transaction costs for infrastructure investors is key to scaling. The second kind are sometimes used by mini-grid developers for project financing. More often, they are used by OGS companies to access debt.

7.1 THE DEVELOPMENT OF PROJECT AGGREGATION PLATFORMS

Project aggregation platforms make the management of a portfolio of mini-grid projects easier. They help users make informed decisions based on standardized, comparable project data. This is relevant and valuable at a number of stages in the development, operation and financing of a mini-grid. Standardization of technical designs and documentation, for example, can assist first-time developers and reassure potential investors. Standardization of technical and financial performance reporting[131] of operating projects allows easy comparison between projects, reducing due diligence costs and creating portfolios large enough to meet minimum transaction sizes of commercial investors. Project aggregation platforms can also serve as an oversight mechanism for national regulators and can help mini-grid operators monitor a portfolio of their own projects. Here they can integrate with remote monitoring solutions.

» Odyssey offers investors a single place to manage their portfolio of investments across operators.«

EMILY MCATEER,
Odyssey Energy Solutions

While there are several generic platforms for monitoring infrastructure projects, Odyssey Energy Solutions is currently the only one specializing in the mini-grid sector. Hence, our analysis of their potential value for the sector is based on their experience in a number of mini-grid program designs in Africa.

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7.2 HOW PROJECT AGGREGATION PLATFORMS WORK

In the case of Odyssey Energy Solutions, developers can upload technical and financial project information onto the online platform. This information is then made available to a selected audience, such as prospective investors or regulators. Information can either be imported automatically (if remote monitoring equipment is in place) via an API or through scanned documents and CSV uploads. The platform is structured in such a way that the asset owner, often the mini-grid operating company, has full control of data sharing.

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Table 1 – Example of information provided by developers on the Odyssey platform

COMPANY WIDE INFORMATION:	INFORMATION ON PROJECTS:
• Organization profile • Business plan	• Location(s) • Load profile • Cost of distribution • Cost per connection • OPEX & CAPEX • Customer classification • Projected revenues • Financial metrics
PORTFOLIO-WIDE INFORMATION:	
• Procurement plans • Billing strategy	

131 – Examples of technical metrics include power quality, availability, distribution planning and installed capacity per generation source, while financial metrics include CAPEX, OPEX and revenues.

Figure 21 – Example of project information presented on Odyssey

Screenshots provided by Odyssey Energy Solutions

Mini-grid sites are often located in areas without GSM coverage, which makes near real time data transfer from sites hard to achieve. A satellite link could be used but is typically too expensive. In cases where GSM coverage is not available, mini-grid operators upload performance data manually. This can reasonably only be done at longer intervals (e.g. monthly). Project aggregation platforms deal with this challenge in two ways: The first is to implement mechanisms to make it easier for operators to upload information manually. Odyssey does this by providing downloadable CSV templates for developers to populate and re-upload. The second is to make sure that expectations of what data can reasonably be gathered from small, rural sites are kept realistic. What is "realistic", depends on the mini-grid and operator. As part of a project for the AfDB, TFE Energy is currently introducing a tier-based approach to performance reporting to include the full spectrum of operator maturity and size. This minimizes the reporting burden on operators as far as possible (based on factors such as the equipment they have installed on site and mobile coverage), while harvesting a sufficient volume of data for due diligence and regulatory oversight.

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Project aggregation platforms can provide a combination of technical and financial data.

7.3 THE DEVELOPMENT OF CROWDFUNDING PLATFORMS

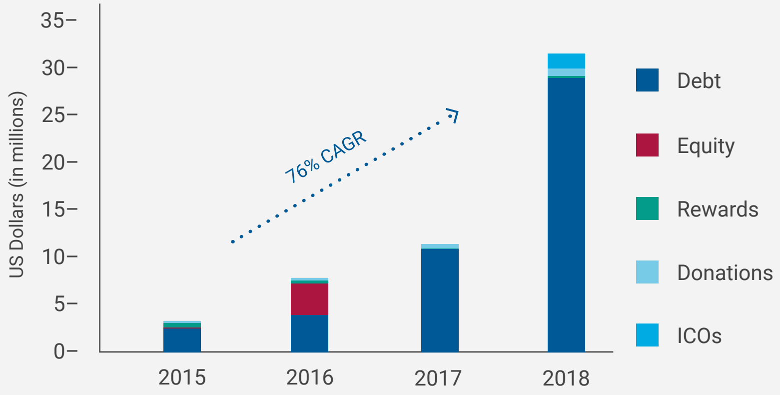
While crowdfunding still only contributes a small fraction to the overall funding requirements of the energy access market, it is nevertheless becoming more important as a source, having grown from $3.4 million in 2015 to $31 million in 2018.[132] This is an annual growth rate of 76%. By the end of 2018, crowdfunding platforms have raised a cumulative total of $54 million.

132 – Energy 4 Impact, Crowd Power – Crowdfunding & P2P Lending for Energy Access, 2019, (link)

Figure 22 – Annual energy access investments raised by crowdfunding platforms (2015-2018)[133]

The amount of capital provided through crowdfunding platforms has grown rapidly since 2015.

The 2016 spike in equity crowdfunding is due to three deals. Since then, no energy access company successfully raised equity through crowdfunding. Equity crowdfunding deals tend to be large, but uncommon (due to regulatory hurdles).



Initially, crowdfunding platforms were focused on seed investments to early-stage energy access companies. However, now they also include larger deals for OGS companies with track records, as well as project finance for mini-grids. The largest debt campaign, closed in 2019, amounted to $7 million for the OGS company Bboxx.[134] Since their fees are typically a percentage of the deal value, crowdfunding platforms have sought to increase campaign sizes to become more viable themselves.

Investor aggregation in the energy access sector is also done by fund managers, such as SunFunder. These differ from crowdfunding platforms in that they aggregate capital from a combination of institutional and accredited individual investors (including high net worth individuals, DFIs, and impact investors) into tailored debt funds. Since they do not operate on digital platforms, they are not included in this analysis.

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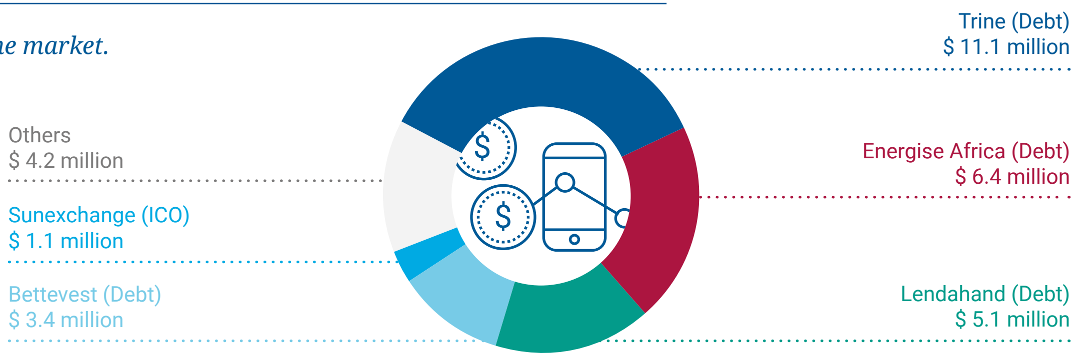
Figure 23 – Top crowdfunding platforms in terms of energy access investment raised in 2018[135]

Debt platforms dominate the market.



133 – Adapted from Energy4Impact, Crowd Power – Crowdfunding & P2P Lending for Energy Access, 2019, (link)
134 – Bboxx, Bboxx receives largest crowd-funded debt raise in the history of solar in Africa, 2019 (link)
135 – Energy4Impact, Crowd Power – Crowdfunding & P2P Lending for Energy Access, 2019, (link)

Table 2 – Energy access companies that have attracted the most crowdsourced finance (2018)[136]

NAME OF COMPANY	ENERGY ACCESS OFFERING	CROWDFUNDING APPROACH	CROWDSOURCED FINANCE RAISED
Bboxx	OGS products	Debt	$7.3 million
Azuri	OGS products	Debt	$1.9 million
Sollatek	OGS products	Debt	$1.7 million
SolarWorks!	OGS products	Debt	$1.5 million
Powerhive	Mini-grids	Initial Coin Offering (ICO)	$1.1 million

7.4 HOW CROWDFUNDING PLATFORMS WORK

Like project aggregation platforms, crowdfunding platforms require a standardized approach to quality verification. Crowd investors want reassurance that they are investing in products and projects that meet certain targets and standards. Low quality, unverified products and projects are less likely to satisfy the end customer (the person benefitting from the energy service), which in turn jeopardizes return on investment and social impact.[137] When conducting technical due diligence, crowdfunding platforms can benefit from industry-wide quality standards.[138]

Energy access crowdfunding platforms can be classified as debt, equity, donation, ICO or reward-based platforms. So far, the most successful are debt platforms. They offer debt to companies with sufficient collateral (usually in assets) to service loans.[139] Returns to crowd investors are typically 5-6% in USD or EUR, per year.[140] Borrowers pay interest rates up to 15%. Loan terms range from 6 to 60 months, depending on the platform and type of project.[141]

In their technical due diligence, debt crowdfunding platforms often review technology choices and performance reports, as well as energy resource assessments. They also assess location-specific risks. This is followed by a legal and financial due diligence, which includes reviews of compliance and creditworthiness of the company and the project. The financial due diligence also includes reviewing the company's business model, cash-flow, budget statements and financial models.

» It is very important to make sure that we bring quality projects to our crowd.«

ROHIT SEN,
Former Strategic Cooperation and Business Development Manager at Bettervest GmbH[142]

Equity crowdfunding platforms are most suited to companies with proven track records.[143] Equity campaigns, however, remain limited due to regulatory barriers. Often fundraising companies are required to be registered in the same country as the crowdfunding platform. At the time of writing, less than 10 equity crowdfunded investments have been completed in the energy access sector.

136 – Energy4Impact, Crowd Power – Crowdfunding & P2P Lending for Energy Access, 2019, (link)
137 – TFE Energy research shows that customers indeed experience increased satisfaction with quality verified products as compared to non-verified products. For more, see: International Finance Corporation, Papua New Guinea: Off-Grid Lighting Market Dynamics, 2019 (link)
138 – Quality standard initiatives in the OGS product sector in use today include the Lighting Global QAF, the GOGLA Consumer Protection Code and the GOGLA Standardized Impact Metrics for the Off-Grid Solar Energy Sector.
139 – Examples of debt platforms include Trine, Bettervest, and Energise Africa
140 – See for example the following cases: Energise Africa (link) and Lendahand (link)
141 – TFE Energy, Case study interview, Rohit Sen, Bettervest
142 – TFE Energy, Case study interview, Rohit Sen, Bettervest
143 – Examples of platforms that offer equity deals include Crowdcube (link), Oneplanetcrowd (link) and Symbid (link)

Donation and reward crowdfunding platforms are well suited for companies at a riskier stage of development and require seed capital for a proof of concept.[144] Companies raising investment through donations and rewards are not forced to show the strong track record required to service debt, nor do they have to present a compelling, long term storyline as is the case with equity-based investment. Reward platforms offer donors non-monetary rewards in exchange for investment, for example free products or publicity.

ICOs involve the sale of tokens (commonly referred to as crypto assets) to crowd investors by an energy access company via an online platform. Early insights from pioneering platforms in this field indicate that tokenizing investments can eliminate some cumbersome and expensive banking procedures.[145] However, if cryptocurrencies become more regulated, their use case could be undermined before it is really proven.

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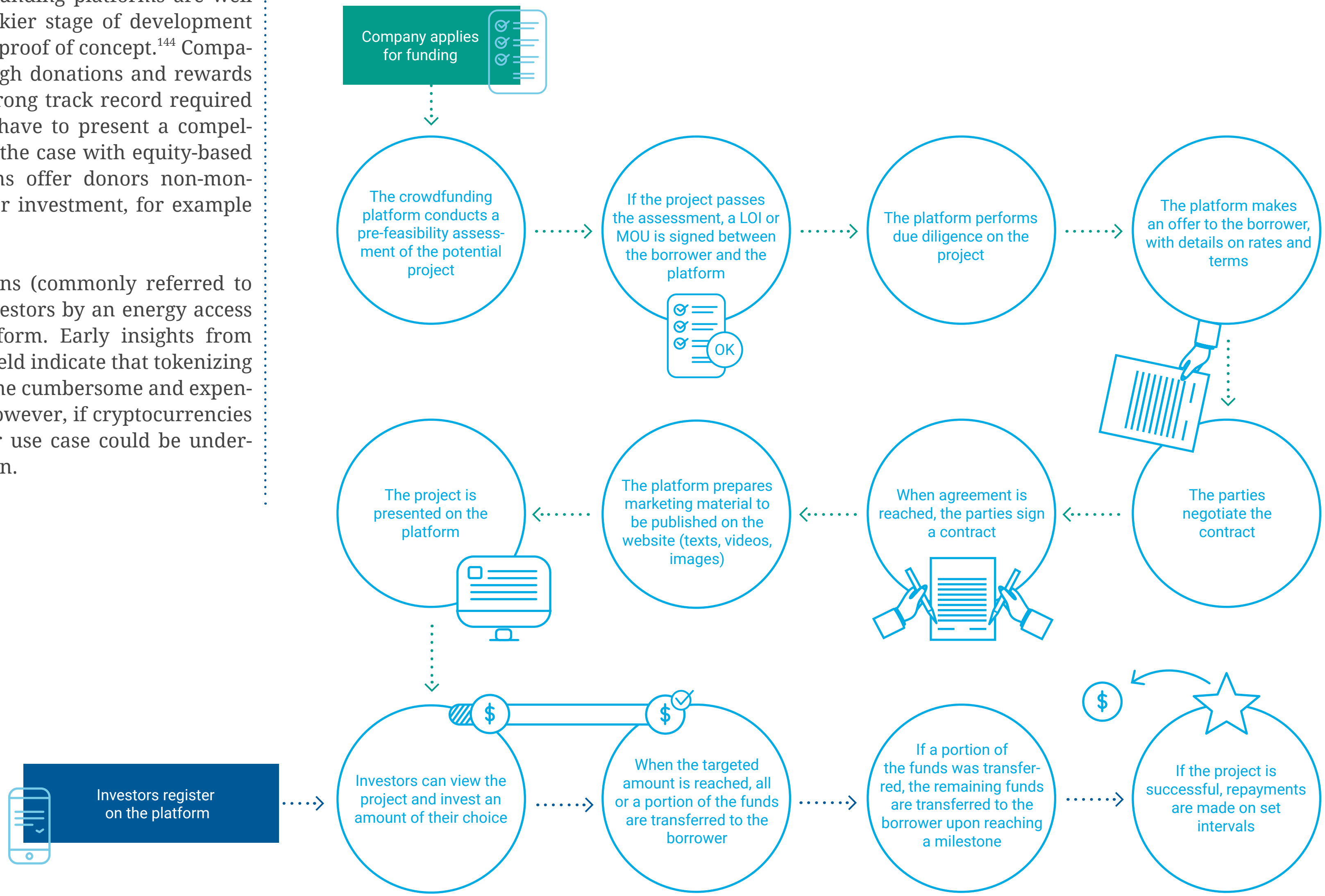
Figure 24 – Overview of the crowdfunding process[146]



144 – Examples of donation platforms include StartSomeGood (link) and M-Changa (link), while reward platforms include Indiegogo (link) and Kickstarter (link).
145 – For an energy access-related example, see Sunexchange (link). For other renewable energy examples, see WePower (link) and Cryptoleaf (link)
146 – TFE Energy analysis

7.5 HOW DIGITAL AGGREGATION PLATFORMS ADDRESS THE MAIN CHALLENGES OF ENERGY ACCESS

7.5.1 IMPACT ON SCALE

Digital aggregation platforms can provide a window into the data and insights coming from digital operations tools and via data sharing protocols. This allows rapid and widespread dissemination of data to investors and policy makers, and increases transparency and accessibility, which is essential for mini-grid and OGS companies to scale.

Crowdfunding platforms also support scalability of the market by connecting projects to a broader investor group and leveraging social media tools such as dedicated marketing campaigns.

7.5.2 IMPACT ON COST

Through project aggregation platforms, the transaction costs of identifying and evaluating electrification investment opportunities can be reduced because investors are not forced to search for and evaluate individual projects on a case-by-case basis. Instead, they can have access to all the required due diligence data of a portfolio of projects at a single point of interface.

7.5.3 IMPACT ON RISK

Standardized performance data of mini-grid projects and OGS products presented on aggregation platforms encourage all energy access companies to meet quality criteria, which ultimately reduces investment risk.

As part of the due diligence they perform on behalf of investors, crowdfunding platforms leverage data to assess systemic risks related to countries, technologies and

» People who are registered on our platform receive newsletters and we do digital marketing through social networking sites such as Facebook and LinkedIn. That is how potential investors are informed about upcoming projects. This is the basic difference between getting a loan from bettervest and from a bank. The bank will not do any marketing or PR for you. They will just do the due diligence and then give you the money.«

ROHIT SEN,
Former Strategic Cooperation and Business Development Manager at Bettervest GmbH[147]

currencies. In some cases, the platforms themselves guarantee loans, which mitigates the risk of non-payment.[149] Aggregation platforms limit investors' exposure to unsystematic risk via portfolio diversification.[150] A recent analysis of mini-grid project aggregation in India found that by aggregating 10 projects into a portfolio, the transaction cost was reduced substantially.[151]

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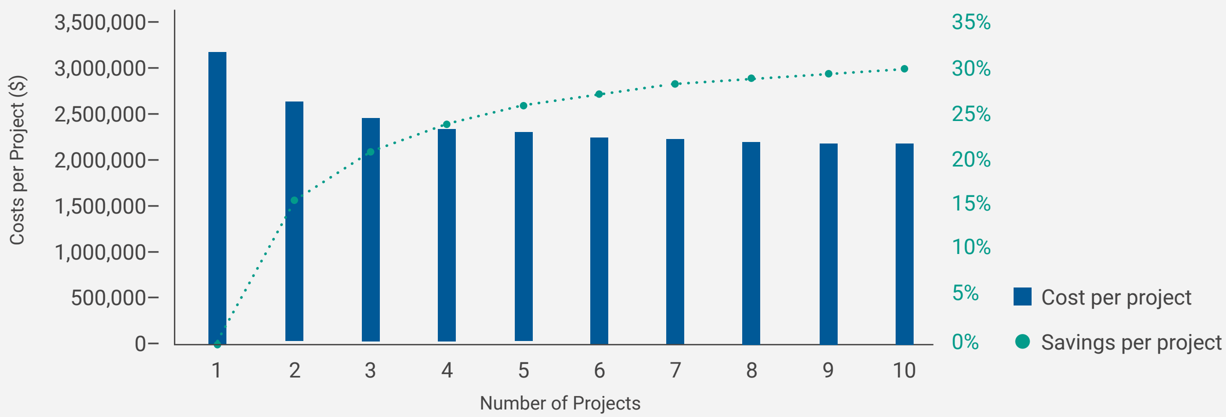
Figure 25 – Transaction cost savings per aggregated mini-grid project (data from 2015)[148]

Transaction costs can be significantly reduced through scale.
Project costs presented on the vertical axis are 2015 numbers.



147 – TFE Energy, Case study interview, Rohit Sen, bettervest
148 – UNEP, Crossboundary, Stanford University & UC Berkeley, Increasing Private Capital Investment into Energy Access: The Case for Mini-Grid Pooling Facilities, 2015 (link)
149 – For example: SIDA, Crowdfunding Guarantee, 2017 (link)
150 – Conversely, systemic risks cannot be mitigated through aggregation.
151 – Malhotra, A. et al. Scaling up finance for off-grid renewable energy: The role of aggregation and spatial diversification in derisking investments in mini-grids for rural electrification in India, 2017 (link)

7.6 CHALLENGES TO DEPLOYMENT

The success of project aggregation platforms is dependent on the quality of incoming project data from mini-grid sites. However, projects are sometimes located at sites without internet availability, which makes data transfer at short intervals difficult. Smaller operators also rarely use sophisticated monitoring infrastructure. Moreover, reaching consensus on the metrics to be included in standardized reporting frameworks is a challenge due to the large number of diverse stakeholders involved. This delays the adoption of reporting frameworks and the impact of project aggregation platforms.

Another challenge is economic. Currently, the margins of most energy access companies are thin. As a result, digital aggregation platforms struggle to generate revenues from them.

For crowdfunding, the main challenge is unfavorable financial regulation that limits the flow of funds in and out of energy access markets and increases transaction costs.

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For crowdfunding the main challenge is unfavorable financial regulation.

7.7 LOOKING AHEAD

Project aggregation platforms could in the future be driven by new government policy and subsidy schemes. Often, analyses of the various energy access routes unfairly compare unsubsidized mini-grid tariffs and OGS product prices with highly subsidized utility tariffs. Subsidies, for example in the form of results-based financing (RBF), can level the playing field. RBF can provide ex-post, measured subsidy payments to mini-grid developers and OGS product suppliers for quality service delivered to customers. Standardized performance reporting protocols and digital platforms can measure quality of service. The GMG QAF, for example, can be used by a funding organization (usually national regulators or DFIs, but this could even be crowdfunded donors) to automatically determine, whether the RBF applicant meets eligibility criteria. If coupled with a project aggregation platform, the funding organization can easily review performance records on an online monitoring dashboard.

A second possible development is that the increase of deal sizes enabled by project aggregation platforms may link the energy access market with a much broader set of potential investors. This could eventually encourage the entry of institutional investors who seek stable, long-term investments with inflation-related returns, but need large minimum transaction sizes.[152] In the future, project

152 – UNEP, Crossboundary, Stanford University & UC Berkeley, Increasing Private Capital Investment into Energy Access: The Case for Mini-Grid Pooling Facilities, 2015 (link)

aggregation platforms could also reduce project CAPEX through wholesale procurement of components.

Crowdsourcing platforms are getting ever better at standardizing due diligence and investor marketing processes and tapping into larger funding groups. They could start using digital planning tools to further automate and standardize project oversight and impact measurement.

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FURTHER READING

IIED's report, ***Moving More Money – Can aggregation catalyse off-grid financing?***, 2019, (link), provides an overview of the value of consolidating companies and assets into portfolios and bundling financing in the off-grid sector. The report features case studies.

Energy 4 Impact's report, ***Crowdfunding & P2P Lending for Energy Access***, 2019, (link), provides an overview of the state of the energy access crowdfunding market in 2018. It features deep dives into all forms of energy access crowdfunding, along with a variety of examples.

UNEP, CrossBoundary, Stanford University & UC Berkeley's report, ***Increasing Private Capital Investment into Energy Access: The Case for Mini-Grid Pooling Facilities***, 2015, (link), discusses how project aggregation can reduce investment risks and transaction costs in the mini-grid sector.

Energy 4 Impact and NREL's report, ***Financial and Operational Bundling Strategies for Sustainable Micro-Grid Business Models***, 2018, (link), discusses potential implementation strategies for project aggregation and financial bundling in the mini-grid sector.

Photo by Random Institute on Unsplash

8 FUNDING DIGITAL SOLUTIONS FOR OFF-GRID ENERGY ACCESS

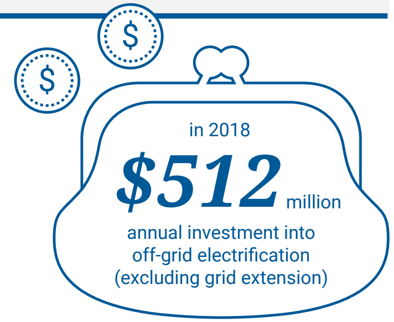
KEY POINTS

- Digital solutions for energy access still receive far too little funding, especially when considering their disproportionate impact towards achieving universal energy access. Traditional investors in energy access often focus on direct impact metrics, overlooking the enabling impact of digital technologies. However, the investor landscape is changing.
- OGS companies have so far been more successful than mini-grid companies at raising funding for in-house development of digital solutions.
- Applying digital solutions, such as smart meters or digital planning, which increase transparency and support data-based decision-making, is becoming more important in both the OGS and mini-grid sectors to raise funds for the core business.

Figure 26 – Overview of investment in energy access[155]

$2.3 billion
cumulative investment in the off-grid market by 2018

81%	of total investment was absorbed by SHS companies
91%	of funds were invested into companies that have a PAYGO business model
$51 billion	annual investment required to acheive SDG7 by 2030
7,500	mini-grids are currently planned, mostly in Africa, and mostly solar-diesel hybrids



8.1 INVESTMENT INTO OFF-GRID ENERGY ACCESS COMPANIES

The off-grid energy access sector had attracted $2.3-$2.4 billion in cumulative funding by 2018. 81% of this went to SHS companies, a subcategory of OGS product companies. 71% of the funding came from private capital markets. Funding has grown rapidly in the past years. In 2018 the total was $512 million, a 50-fold increase from the $10 million in 2010.[153] Market projections vary. However, on the current trajectory, growth will likely continue in both the mini-grid market and the OGS market.[154]

Traditionally, the sector has been funded by a small group of international development banks and private sector agenda investors. The ten largest funders have contributed more than two-thirds of the total in the form of equity, grants and debt. These include FMO, responsAbility, SunFunder, NorFund, CDC Group, Helios Investment Partners, OPIC, SIMA Fund and DBL Partners.[156] As the market continues to mature, the funding landscape is starting to expand to strategic investors and investors from Asia and Africa.

Funding in the off-grid energy access market has not been equally distributed. The comparatively mature OGS sector has received more than 80% of the total investment.[157] It also attracts larger individual deal sizes of both equity and debt. In most cases, parent companies are funded

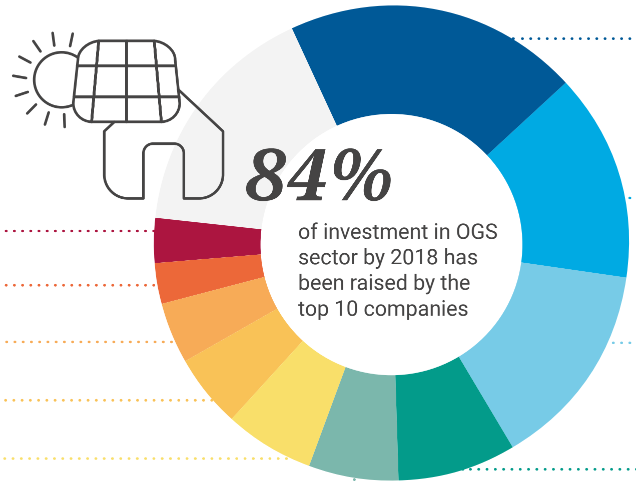
153 – Wood Mackenzie, Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile, 2019 (link)
154 – GOGLA, Off grid solar market trend report, 2018 (link); ESMAP, Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers, 2019 (link)
155 – ESMAP, Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers, 2019 (link); Wood Mackenzie, Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile, 2019 (link)
156 – Wood Mackenzie, Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile, 2019 (link)
157 – Wood Mackenzie, Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile, 2019 (link)

Figure 27– Off-grid energy access funders 2019 (examples)[158]

directly. In some cases, however, funding is provided to a subsidiary or special purpose vehicle tasked with the expansion of a company into a new region, country, sector or product, or financing discreet assets such as portfolios of accounts receivables from OGS PAYGO contracts.

158 – Analysis: TFE Energy

Figure 28 – Top 10 ***OGS companies*** *in terms of cumulative funds raised by 2018*[159]



The mini-grid sector is in an earlier development phase. It still relies heavily on grant support. Large mini-grid developers, however, already participate in predominantly equity-based investment rounds. They are often funded by infrastructure investors, on the basis of individual projects, a project portfolio or specific country expansion.

Current business models in the energy access market depend strongly on scale, experience and organizational maturity. This is reflected in the highly concentrated investment into a small number of off-grid companies: the top 10 OGS companies have received 84% of the total funding into the OGS sector. Similarly, the top 10 mini-grid companies have received 77% of the total investment into the mini-grid sector.[160]

Strategic investors have invested over $375 million in the energy access market in the last few years alone, with 78% of deals being equity-based.[161] Strategic equity investors differ from traditional infrastructure investors, such as FMO or Helios. They place less emphasis on the returns of individual energy assets or on the margin of OGS products. Instead, they particularly value the long-term growth potential of a business and intangible assets, such as technology development, brand, customer relationships, market insights and organizational capacities.

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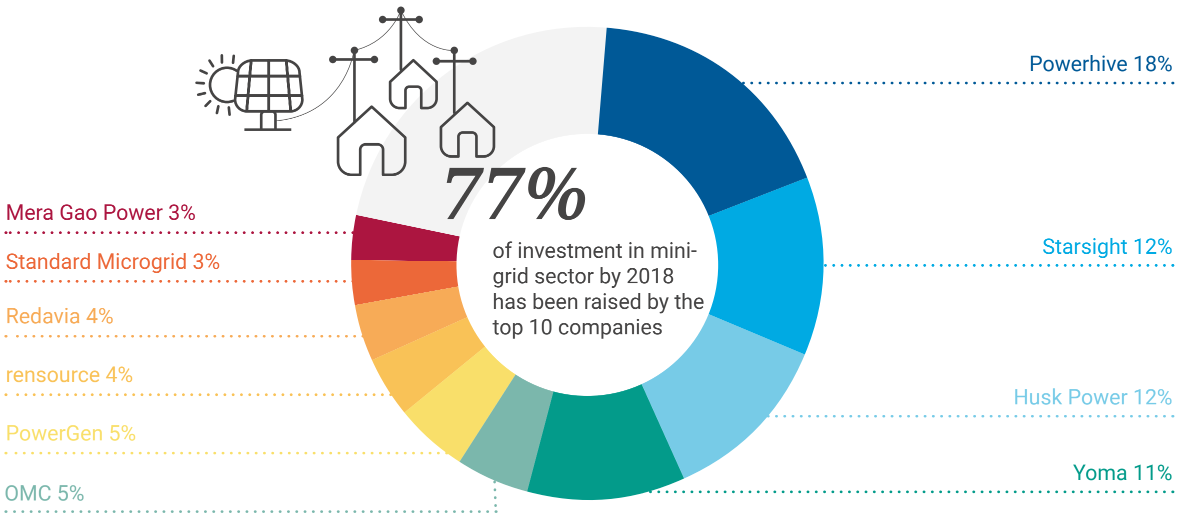
159 – Wood Mackenzie, Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile, 2019 (link)
160 – Ibid.
161 – Ibid.

*Figure 29 – Top 10 **mini-grid companies** in terms of cumulative funds raised by 2018*[162]



8.2 INVESTMENT INTO DIGITAL SOLUTIONS FOR OFF-GRID ENERGY ACCESS

As described in previous chapters, digital solutions play an important role in facilitating more investment into the off-grid energy access market. Technologies like mobile payments and smart meters enable data-driven business models and decision-making – something valued highly by investors for reducing risks, and for creating a stronger linkage between investment and specific electrification or impact results. This is reflected by the fact that 91% of investment is absorbed by off-grid companies utilizing PAYGO-based business models, which systematically collect and analyze operational and customer data.[163] However, funding for the digital solutions themselves, that enable the energy access market (as well as other development markets) is still scarce.

Large OGS companies have been the most successful at funding the development of their digital solutions. They have done so on the back of funding rounds for their energy access work and by increasingly positioning the development of digital solutions as core to their operational success and ongoing expansion.

Mini-grid developers do not yet get much funding to develop digital solutions. They typically receive infrastructure funding for a set of mini-grid sites or for limited business development, rather than corporate funding that could be channeled into research and development. However,

» In the past a smaller proportion of our funding was going into R&D and digital solutions. Whereas now, our most recent Series D funding round led by Mitsubishi Corporation is directed towards bringing new digital solutions to our existing markets as well as expanding into new ones.«

CHRISTOPHER BAKER-BRIAN, Bboxx[164]

162 – Ibid.
163 – Wood Mackenzie, Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile, 2019 (link)
164 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx

mini-grid developers can utilize a portion of their funds to purchase digital solutions on a case-by-case basis.

Digital solutions specialists still find it difficult to raise funds. Only a handful of venture capital (VC) investors, strategic investors, development organizations and foundations have recognized the importance of funding the enabling technology environment.

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Image provided by Nabin Raj Gaihre, Village Data Analytics

8.3 A CHANGING INVESTMENT LANDSCAPE

Traditionally, the investment landscape in digital solutions for energy access has been dominated by American and European players. There is a particularly strong ecosystem in the USA. An example is the close collaboration between HOMER Energy, Odyssey Energy Solutions and Factor[e].[165]

» In the last six months we are seeing a lot more interest from Asian investors who see Africa as a new frontier and are looking to invest into businesses that are predominantly operating in Africa. That is something that we did not see two years ago. Our Series D is the most recent example of Japanese interest in Africa and in PAYGO solar energy globally.«

CHRISTOPHER BAKER-BRIAN, Bboxx[169]

Now, the investment landscape is becoming more diverse. More East Asian investors, especially from Japan, such as Mitsui, Mitsubishi, Sumitomo and Marubeni are entering the market. Mitsui recently invested in OMC Power and M-KOPA[166] and Mitsubishi in Bboxx.[167] Additionally, African venture capital investors, such as Kupanda Capital and Kawisafi, have invested in broader frontier market digital solutions companies like Lendable, Fraym and Nithio.[168]

8.3.1 GRANTS

There are some energy-access specific grants geared towards innovation. Examples include the USAID Development Innovation Ventures, OFID grants and DFID grants. A key indicator for many grants is population electrified per dollar. However, because digital solutions are enablers and do not directly provide power to households, they often do not qualify. Other grants come from companies or organizations that link specific technologies to the social impact of energy access. They include, for example, Google's Social AI challenge, European Space Agency (ESA) or National Aeronautics and Space Administration (NASA) innovation grants, or the GSMA Innovation Fund for work connected to mobile networks.

165 – Analysis: TFE Energy
166 – Mitsui and Co. has invested in M-Kopa and OMC (link)
167 – Financial Times, Mitsubishi invests in pay-as-you-go solar energy supplier to Africa (link)
168 – Kawisafi's investment portfolio (link); Kupanda Capital's investment portfolio (link)
169 – TFE Energy, Case study interview, Christopher Baker-Brian, Bboxx

Perhaps the most active grant supporters of digital solutions so far have been a number of private foundations including the Good Energies Foundation, Shell Foundation, IKEA Foundation, DOEN Foundation and Rockefeller Foundation. They seek to develop an enabling ecosystem to scale the off-grid market. The Shell Foundation, for example, funded several digital solutions specialists with relevance to the energy access sector, such as Odyssey Energy Solutions, Fraym, and SparkMeter. Through Power Africa, they have also funded the development of digital technologies within off-grid companies. An example is the grant to the Paygee team at Mobisol to make their in-house digital payments solution available to other market participants. This is one of the first examples of grants helping productify a digital solution.

8.3.2 STRATEGIC INVESTORS

Over the last few years, a small number of VC and strategic investors has started to invest into digital solutions. They are interested in digital solutions that are key success factors to the industry and offer a high degree of scalability. An example is the French utility Engie, which sees Africa as a strategic growth market and laboratory for new solutions and business models.[171] The company has invested into Taos.ai, a digital solution to find mini-grid sites using drones.[172] The tool was developed in-house by PowerCorner, a mini-grid developer funded by Engie. Furthermore, Engie recently acquired Mobisol, a leader in developing in-house digital technologies such as Paygee. Engie's portfolio in energy access also includes Simpa, Fenix and Tractebel.[173]

» Utilizing the grant from Scaling Off-grid Energy, the Paygee team was able to develop an innovative, comprehensive software solution that enables PAYGO solar providers to reduce credit risk, make data-based informed market decisions, and improve their customer experience.«

ANDREW HERSCOWITZ,
Coordinator for Power Africa[170]

Additionally, strategic investors from outside the energy sector have started participating in the market through at least 31 joint ventures and commercial partnerships.[174] An example is the recent partnership between M-KOPA and MasterCard, in which M-KOPA develops PAYGO technologies based on MasterCard's "Quick Response" payment technology.[175] Another example is the partnership between Bboxx and GE in the Democratic Republic of Congo that has brought together GE's remote monitoring platform and Bboxx's cloud-based platform.[176]

Photo by Tom Fisk from Pexels

170 – Mobisol Launches Paygee, a Powerful Operating System for the PayAsYouGo Industry (link)
171 – Engie in Africa (link)
172 – Taos.ai might not be operational any longer
173 – Analysis: TFE Energy
174 – Wood Mackenzie, Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile, 2019 (link)
175 – Mastercard, Centenary Bank and M-KOPA Solar roll-out first of its kind energy solution in Uganda (link)
176 – Bboxx and GE partner in DRC (link)

8.3.3 VENTURE CAPITAL

Venture capital for digital solutions in the off-grid electrification space is still scarce. Factor[e], with support from the Shell Foundation, is a pioneer. The company positions itself as an “impact development fund” at the seed /early stage. Its investments start at less than $500,000. In the off-grid energy access market, Factor[e] looks at either pure digital solution companies, or funds digital technology development within OGS or mini-grid companies. Among its portfolio companies are ZOLA Electric, HOMER, SparkMeter, Ferntech and Odyssey Energy Solutions.

The sector needs to, and likely will, attract more venture capital, especially from investors with development or climate change agendas. An example is the recent investment into SparkMeter by Bill Gates’ Breakthrough Energy Ventures (BEV).[178] The development of AMMP Technologies is another interesting example. It was incubated by the German utility E.ON, via the mini-grid developer Rafiki Power. After participating in the incubator Rockstart, AMMP Technologies has now received investment from an undisclosed group of VC investors from outside the energy access space.[179]

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Figure 30 – Funders interested in digital solutions for energy access (examples)[177]

177 – Analysis: TFE Energy
178 – Quartz, Bill Gates-led $1 billion fund expands its portfolio of start-ups fighting climate change (link)
179 – TFE Energy, Case study interview, AMMP

» *Factor[e] is an impact development venture fund. We take the mindset of venture builders, and develop companies that are driven by technology innovation, driven towards impact, and are fundamentally organized to scale.* «

Seth Silverman, Factor[e][180]

FURTHER READING

Wood Mackenzie Power and Renewables published a report in February 2019 entitled ***Strategic investments in off-grid energy access: Scaling the utility of the future at the last mile*** (link). This report provides the most comprehensive currently available overview of investment in the energy access sector and changes in the investor landscape.

The World Bank's ESMAP team published a report in June 2019 entitled, ***Mini-grids for half a billion people: Market outlook and handbook for decision makers*** (link). It provides an overview of the mini-grid sector's anticipated growth and financing, as well as a market outlook until 2030.

Image provided by Nabin Raj Gaihre, Village Data Analytics

180 – TFE Energy, Case study interview, Seth Silverman, Factor[e]

9 CONCLUSION AND RECOMMENDATIONS

Digital solutions provide data-driven, real time, precise, efficient information to enable decision-making in the energy access sector. These solutions reduce uncertainty (and, in time, risk), enable scale, and ultimately reduce costs to bring better energy to more people and faster. In the course of our research, many leading off-grid electrification companies stressed that without digital solutions their businesses would be neither viable nor scalable. A growing number of digital specialists now offer solutions tailormade to the OGS and mini-grid markets. They complement and sometimes replace internal capacities of OGS and mini-grid companies themselves, allowing them to focus on their core business functions of delivering energy products and servicing customers in frontier markets.

Our findings show that companies that successfully deploy digital operations already benefit greatly from them.

Despite the widespread recognition of their value, the deployment of digital solutions still significantly lags behind the core businesses processes of OGS sales and mini-grid infrastructure construction and operation. And despite digital solutions being a key enabler and accelerator of the large-scale energy access we need to achieve SDG7, they are not yet sufficiently recognized by the funding community. This hampers their deployment and growth.

To date, the most impactful and established digital solution in energy access is digital payments to enable the PAYGO business model. This is increasingly complemented by the use of digital planning, digital operations and digital platforms in both the OGS and mini-grid markets.

The challenges to a faster deployment of digital solutions differ depending on the solution, but typically include the maturity of the underlying digital technologies, regulatory hurdles, customer acceptance, and availability of local, skilled labor. Figure 31 compares the solutions by their potential impact and ease of deployment in a qualitative manner and based on the research conducted for this report. In the case of digital payments, for example, the potential impact is very high, as it addresses a particularly challenging operational aspect of OGS and mini-grid companies. However, their deployment relies heavily on national regulations, interlinked with a country's larger financial ecosystem. In certain markets the challenges appear almost insurmountable. By comparison, the ease of deployment of digital operations is higher as challenges are mostly within the company itself. Our findings show that companies that successfully deploy digital operations already benefit greatly from them and have learned how to train both office and in-field staff.

Despite digital solutions being a key enabler and accelerator of large-scale energy access, they are not yet sufficiently recognized by the funding community.

In future, we expect the use of digital solutions to accelerate, driven by the growth of the electrification market, by the growth of available datasets, by the increasing capabilities of underlying data technologies, and by the growing number and experience of digital solutions providers. There is also room for growth across geographies, especially from Africa to Asia.

There is also a strong case to be made for more interconnection or even integration of different digital solutions. This is starting to happen within the digital planning toolchain and within digital operations. It will also increasingly happen across the four digital solutions types presented in this report. For example, digital operations and digital payments data could be connected to digital planning to further reduce the default risk of electrification companies.

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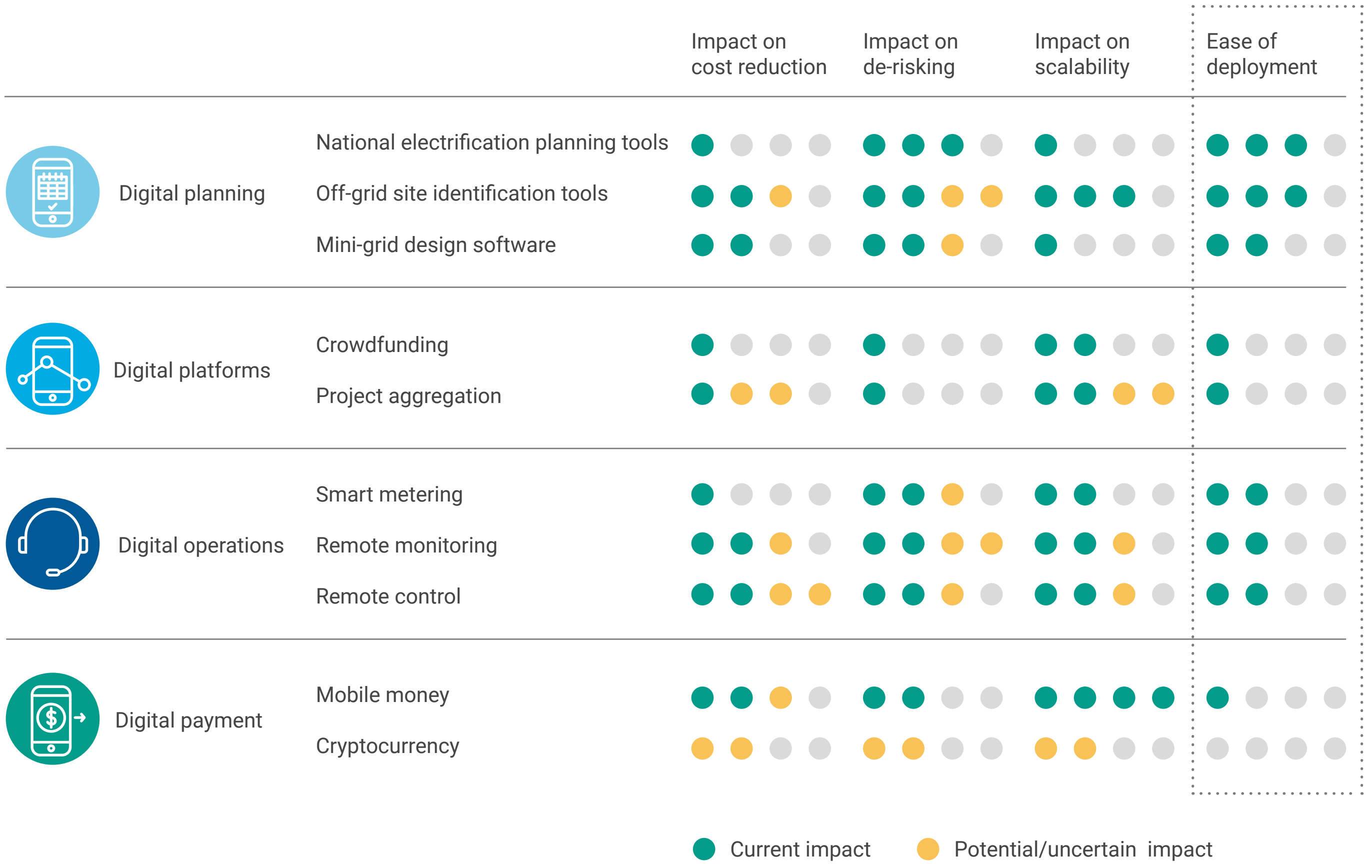
Figure 31 – The impact and challenges of digital solutions in the off-grid energy access market[181]



Taken together, digital solutions are key to achieving viable off-grid electrification business models.

The digital solutions presented in this figure are not exhaustive. Solutions were selected based on their prevalence and attention in the market. Rankings are qualitative and derived from case studies and market expert interviews. The impact of some solutions that are not sufficiently tested is still uncertain.

181 – Qualitative analysis by TFE Energy, based on market interviews and case studies

9.1 RECOMMENDATIONS FOR FUTURE RESEARCH

This research is one of the first assessments of how digital solutions can transform energy access. The goal was to detail the types of digital solutions and use cases, and to estimate what value they can add. There is much scope for further research. Below are three suggestions.

- **Detailed quantification of economic value and social impact of digital solutions:** This study did not systematically quantify and compare the cost and value of digital solutions. The same is true for measuring the social impact of applying digital solutions. One aspect to highlight is that the effect the application of digital solutions needs to be equally beneficial to women and men. Discussions with stakeholders indicated that there is interest in a study that builds upon the work presented here. An independent consultant could compare anonymized data and conduct a series of pilot projects to compare the value and impacts of digital solutions.

- **Creation of a global digital solutions database:** The energy access industry is fragmented and spans many different markets. At the same time, digital technologies, solutions and business models evolve rapidly. During the research, we noticed that many market participants and experts do not have an overview of what is being done elsewhere. There is a particular disconnect between companies operating in Africa and those operating in Asia. For this study, a significant effort was made to identify and cluster over 250 companies and funders, as well as around 200 market experts. This stakeholder map could be converted into a searchable, regularly updated database. This could be initiated by industry associations such as AMDA, ARE or GOGLA.

- **Creation of a global investor database for digital solutions:** There is no good overview of the investor, grant and donor landscape for technologies that help achieve energy access. Our research shows that there is a growing and diverse pool of funding opportunities in different geographies, offering different funding options and often coming from different angles (technology, impact, regional business). Creating a searchable, regularly updated database would be useful.

Image provided by Sam Duby, TFE Energy

9.2 RECOMMENDATIONS FOR DIGITAL SOLUTIONS PROVIDERS

- **Focus on immediate customer value:** Digital technologies usually have two types of value proposition: Firstly, they make an existing process cheaper, faster or better. Secondly, they offer new options and functionalities. Energy access companies work on very slim margins and have little room for experimentation. Therefore, to be successful, digital solutions need to show immediate, tangible benefits to users.

- **Improve the quality of data and predictions:** The industry needs to continue to test and improve the quality of data used and the accuracy of their models. This requires ongoing validation and a realistic assessment of what is the currently verified value proposition of a digital solution versus the medium-term plan or ambition (which are also important to communicate, but without blurring the line).

- **Establish good data practices:** Digital solution companies are usually very conscious about the data protection needs of electrification companies and their customers. However, they need to give more thought to other questions of data best practices, including ensuring that their models do not embed biases (e.g. on gender, on geography, or customer economics) and that data is secure from hackers.

Image provided by Sam Duby, TFE Energy

9.3 RECOMMENDATIONS FOR ELECTRIFICATION COMPANIES

- **Establish data-driven decision making:** Currently only leading energy access companies are at the scale where they regularly make data-driven decisions. Their number will increase as the market grows and matures, as debt funding becomes more prevalent, and as a secondary market for mini-grid infrastructure is established. To make data-driven decisions, companies need to systematically gather data, organize it in a functioning database, analyze it and make it available to decision-makers in a user-friendly interface. Bboxx, for example, has used economic data to more quickly access debt in Togo. In addition to economic indicators (e.g. payment rates, unit economics, risks), it is useful to measure impact indicators (e.g. growth in energy consumption, growth in household income, but also village level changes). Energy access companies should be conscious about "build or buy" decisions as the landscape of third-party solution providers grows.

- **Make proprietary digital solutions available to the wider market:** Many first movers developed proprietary digital solutions, mostly for digital operations, but

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also for digital planning and even digital platforms. As there is increasing specialization in the market, it makes sense to replace in-house solutions with specialist solutions, if they are better. If the in-house solution is better, then it can be made available to the market at large, opening up a new revenue stream. This is what Mobisol has done with their mobile payment platform Paygee (supported by a USAID grant).

- **Create data and innovation partnerships:** Companies can profit from peer-to-peer data sharing in non-competitive situations. Data can be shared in an anonymized and aggregated manner under an NDA or through data sharing platforms such as those being used by AMDA. In addition, companies can initiate joint pilot projects or joint applications for grants. The digital planning tool Village Data Analytics, for example, has benefitted from several such data exchanges. Partnerships can also be fostered through co-locating teams and opening up business or research processes to one another. Such partnerships could be additionally incentivized by donors through mechanisms such as grants.

9.4 RECOMMENDATIONS FOR INVESTORS AND BANKS

- **Adopt and drive digital solutions:** Investors and banks financing either companies or infrastructure portfolios should themselves adopt digital tools. In the market assessment and due diligence process, they can, for example, make use of independent digital planning solutions to assess the areas of operations or sites of energy access companies. Once an investment is made, they can link up to the company's operational data. In addition, investors and banks can encourage their portfolio companies to establish data-driven decision-making processes and fund the testing and piloting of new solutions. The Shell Foundation, for example, funds innovation pilots for portfolio companies.

- **Strategic investors – discover opportunities:** While utilities like Engie, energy companies like Shell, or mobile network companies like Orange or Digicel invest into energy access products and companies, there is room for new strategic investors to specifically look at digital solutions. Digital solutions could be attractive strategic investments for multinational engineering companies such as Mitsubishi, GE, ABB or Siemens. Their own solutions are typically not a fit for the off-grid electrification market, and they are driving digitalization in grids already. Schneider Electric, with its energy access fund, is an example. Digital solutions for energy access could also be interesting strategic investments for companies seeking to expand internet or mobile coverage or working on agricultural value chains. Strategic investors can also look for digital solutions than can be spun out of OGS or mini-grid companies as own products or companies.

- **VCs – complement know-how:** As the off-grid energy market scales, digital solutions will become highly investible. To assess them requires an understanding

Companies can initiate joint pilot projects or joint applications for grants. The digital planning tool Village Data Analytics, for example, has benefitted from several such data exchanges.

of the dynamics of both digital technologies and frontier markets. This combination of know-how is rarely found. Factor(e), Gaia Impact Fund or Kupanda Capital are examples. Understanding how to scale technology solutions to other frontier, developing or industrialized markets will also be important.

- **Impact investors – broaden approach:** Impact investors often look for measurable impact results. In the case of energy access, these can be the number of households electrified or the kWh supplied. When it comes to digital enablers, the impact is very substantial, but indirect and more difficult to measure. Developing impact metrics for enablers will be key to the future development of the sector as a whole.

9.5 RECOMMENDATIONS FOR GOVERNMENTS

- **Create data guidelines:** Governments need to protect the data rights of users of electrification services and products by establishing clear guidelines for good practices. However, this needs to be done in a way that does not place undue burdens on the companies working with the data, nor should it suffocate data collection and usage for industry-wide learning and de-risking.

- **Create enabling financial regulations:** Both digital payments and crowdfunding platforms require conducive financial regulations to operate. This is covered well in other reports (for examples, refer to the chapter on digital payments).

- **Use digital planning tools for electrification:** Governments planning electrification in their countries should make best use of available digital solutions themselves. One example is the use of digital planning tools to support electrification strategies, providing clear planning metrics on least cost/ highest service electrification planning, as well as structures to de-risk tenders for mini-grids. Another example is the use of digital platforms to monitor the status and performance of the national off-grid sector. It is important that these tools are very user-friendly and regularly updated.

- **Use digital solutions to link subsidies to measurable performance and quality assurance indicators:** Governments can demand that energy access companies that receive public funding adhere to certain reporting standards. This can be supported by digital solutions, such as smart meters. The case for digital solutions becomes even stronger as several governments contemplate the introduction of results-based subsidy schemes that require monitoring and verification methods. Digital solutions can also support traditional utilities in managing their customer base and provide valuable service and consumer information that will improve service delivery and maximize planning efficiencies.

The case for digital solutions becomes even stronger as several governments contemplate the introduction of results-based subsidy schemes that require monitoring and verification methods.

9.6 RECOMMENDATIONS FOR DONORS

- **Adapt procurement processes:** Donors increasingly use digital solutions, especially platforms and planning tools, for their own work. This is positive. Often, however, their traditional procurement process emphasizes past experience and track-record. This places unrealistic constraints on innovative solutions. A better way of assessing digital innovations is through deeper technology vetting. Setting aside a percentage of total program contract value for new solutions could change the procurement structure, too. This could be used for pilots.

- **Create more funding windows for digital innovation:** Overall, while there are many programs that support energy access businesses directly, there is little support for the enabling technologies behind them. Private donors (such as foundations) can usually fund innovations directly and easily (examples are the Good Energies, DOEN or Rockefeller Foundations). Public sector technical and financial assistance programs, however, typically work through tenders for pre-defined challenges and programs. Since they are the largest financial contributor to the energy access sector, designing more effective funding windows for innovation would have a catalytic impact. Below are two suggestions:
  - Raise the threshold for direct awards (sole sourcing) for innovative private companies from the current ca. $50,000 to the $200,000 to $500,000 required for pilots. This could be linked to deeper technological vetting and requires an adjusted approach to risk.
  - Create regular innovation challenges for digital solutions that support energy access, comparable to the World Food Program's accelerator, the European Space Program's business applications program or the Google Impact Challenge. USAID runs an innovation challenge for energy access, the Development Innovation Venture, however, it focuses on the end-consumer impact, not on digital enablers. Such programs could actively design partnering opportunities between digital enablers and electrification companies.

- **Increase technology know-how:** Donors traditionally have deep expertise in fields such as infrastructure, finance, regulations, development and energy access markets. Their expertise with different digital technologies, by comparison, often lags behind the sector. This has multiple effects, not the least of which is slow adoption of tools that improve internal efficiencies. The lack of expertise in the digital space also impacts the kinds of investments promoted through different grant schemes slowing down digital innovation.

- **Incentivize data sharing:** Donors can support existing data sharing initiatives by companies and incentivize the ethical sharing of data. This could be done, for example, by giving the companies that have the data a financial incentive to share it in an anonymized, aggregated and quality-checked manner. From this, an "energy access data pool" could be created. Interested parties (such as those developing new digital solutions for the sector or university researchers) could interact with this data pool. Interaction could be just query-based (i.e. data does not leave the pool), as is done with

Photo by Sergio Souza from Pexels

USAID's DHS data set. It could also be shared in specified formats for specified uses. Or it could be made available in useful user interfaces (as the World Bank does with its country data).

- **Support standardization in the industry:** Donors are well placed to encourage standardization in the energy access industry (an example is the QAF for mini-grids). Standardization and digitalization are mutually enforcing. A standardized set of metrics can help design digital solutions. Inversely, the technical capabilities of digital solutions (such as smart meters) can define what metrics can be collected in an automated manner.

9.7 LOOKING BEYOND THE OFF-GRID ELECTRIFICATION MARKET

The off-grid energy access market has been a testbed for digital solutions, utilizing cutting edge digital technologies to enable business with remote customers in challenging geographies. The social impact of off-grid electrification has attracted global talent and resources to this field. The learnings can be used to cross-pollinate other markets.

- **On-grid in developing countries:** Traditional utilities in developing countries can learn from the off-grid solutions presented here. For example, digital planning tools can be used to plan for grid-extension as much as for mini-grid site selection. Similarly, many of the payment and operating technologies can help to more efficiently run a power grid.

- **Off-grid in industrialized countries:** The much larger off-grid market in industrialized countries can be attractive for the digital solutions companies mentioned here. Companies, such as SparkMeter, PowerGen and Ferntech, are already exploring this opportunity. However, energy access companies have limited resources to commit to developing these relationships. A workshop or study could help to investigate the potential of cross learnings.

- **Other off-grid markets:** There are other data-driven industries working in the same off-grid markets. This includes telecoms and internet service providers. They have similar challenges (e.g. when it comes to building network infrastructure) and have driven important solutions (e.g. PAYGO). There is room for more collaboration across these industries, as electrification provides the basis for many others.

- **Diesel replacement:** According to a recent IFC study,[182] about 20 to 30 million sites in developing countries use diesel generators, at a fuel spend of around $50 billion per year. Replacing diesel with solar and batteries is increasingly economical. Digital solutions, especially digital operations, are key to making this alternative work effectively.

Traditional utilities in developing countries can learn from the off-grid solutions presented here. For example, digital planning tools can be used to plan for grid-extension as much as for mini-grid site selection.

182 – International Finance Corporation, "The Dirty Footprint of the Broken Grid", 2019 (link)

APPENDIX
A1 THE GLOBAL ENERGY ACCESS CHALLENGE

A1.1 ELECTRIFICATION AND DEVELOPMENT

Access to electricity is inextricably linked to the larger development agenda. It is not only a basic development need in its own right, but also has wider implications. For one, it is a health issue. Electricity replaces hazardous energy sources, such as petrol, kerosene and candles. The impact on agricultural and commercial activity, and by extension on job creation, is also significant. Research indicates that access to electricity results in improved efficiencies for farms and small businesses.[183] Yet, while electricity access directly improves peoples' lives, it does not automatically lead to higher income levels. For this, additional enablers are needed. They include access to finance and capacity building for small businesses (such as connecting farmers and fishermen to value chains). Productive electric appliances have a particularly high development potential as they increase income levels and stimulate the local economy. Examples of such appliances are food processing tools (like maize mills and seed oil presses), water pumps and harvesting tools, or fabrication equipment (like welding machines).[184]

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Image provided by Sam Duby, TFE Energy

A1.2 LEVELS OF ELECTRICITY ACCESS

There is no single, globally accepted definition of what constitutes modern energy access. For the purposes of this report, we use the definition provided by the International Energy Agency (IEA): Access to modern energy means "household access to a minimum level of electricity, household access to safer and more sustainable cooking and heating fuels and stoves, access that enables productive economic activity and access for public services."[185] This report focuses on access to electricity. Whilst basic electricity access is an important step in the right direction, households' and commercial or public facilities' level of service must be able to increase over time to reach levels consistent with reliable grid access. This is reflected in the Multi-Tier Framework (MTF) developed by ESMAP.[186]

183 – See section 2.8 Further reading for examples of the impact of electrification.
184 – For evidence on the positive impact on small business, see examples from Kenya (link) and India (link). For evidence on the positive impact on agriculture, see an example from Guinea-Bissau (link)
185 – IEA, Africa Energy Outlook, 2014, (link)
186 – The framework is currently reassessed and refined and will be updated

Table 3 – The multi-tier framework (MTF) for assessing electricity access[187]

		Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	Power capacity	Min 3W	Min 50W	Min 200W	Min 800W	Min 2kW
	Daily consumption	Min 12Wh	Min 200Wh	Min 1kWh	Min 3.4kWh	Min 8.2kWh
	Examples of energy services	Lighting, mobile charging	Mobile charging & TVs	Refrigeration	Maize milling, water pumps	All other loads
Availability (duration)	Hours per day	Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening	Min 1 hr	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
Energy supply options		Solar lanterns, solar home systems, mini-grids, grid	Solar lanterns, solar home systems, mini-grids, grid	Solar home systems, mini-grids, grid	Mini-grids, grid	Mini-grids, grid

A household or business is considered to have access to basic electricity, when the quality of service is consistent with at least Tier 1. This is sufficient to power lighting and mobile device charging. However, over time, access should increase to Tier 5. Higher tier access is needed to power productive uses, such as running welding or milling machines.

A1.3 THE RURAL ELECTRIFICATION IMPERATIVE

87% of the 840 million people without access to electricity live in rural areas.[188] This is unsurprising, because the business case for supplying rural areas with electricity is much more difficult than for urban areas. Unelectrified rural communities often have relatively low demand for energy due to small populations, low population density, limited use for energy (mainly small residential and agricultural loads) and a limited ability to pay for energy services. These conditions, in conjunction with the high cost of extending grids to isolated rural areas and the reliance on grid extension as the primary approach to rural electrification in the past, are the reasons for the slow pace of rural electrification in many developing countries. Today, decentralized systems are increasingly

187 – The World Bank, Beyond Connections: Energy Access Redefined, 2015 (link)
188 – The World Bank, Tracking SDG7: The Energy Progress Report, 2019 (link)

regarded as a viable alternative electrification approach, because of their fast deployment rates, maturing supplier landscape and ever decreasing costs. This calls for an integrated approach to electrification, incorporating both grid extension and decentralized systems.

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Photo by Annie Spratt on Unsplash

A1.4 RURAL ELECTRIFICATION WITH GRID EXTENSION

A centralized electrification approach entails the deployment of large, megawatt-scale power plants (traditionally coal, nuclear and hydro power stations) that generate three-phase alternating current (AC) electricity. High voltage grids transmit electricity over long distances to areas where demand is concentrated. Close to the point of use, voltage is stepped down to lower levels to be accessible for industrial, commercial and residential users. Tariffs paid for grid electricity can often be set at low levels as a result of economies of scale from aggregating demand across a large number of consumers. In addition, subsidies can be easily administered, making energy tariffs an important political tool. Centralized grids can supply high power capacities, provided that installed generation capacity matches demand, and transmission and distribution (T&D) infrastructure is properly maintained. This is particularly important for commercial and industrial activities, which require large amounts of energy. High available power capacity also means that customers can increase their consumption without any constraints.

However, grid extension to rural areas is often challenging. The average cost of extending the grid in sub-Saharan Africa is between $20,000 and $30,000 per kilometer.[189] As a result, it costs utilities about $2,500 to connect a rural household to the national grid, which is more than double the cost of connecting it to a mini-grid.[190] High grid connection costs are in stark contrast to the limited revenue potential from electricity sales in rural villages. National utilities often cannot recoup the cost of their investments. The degree to which governments can subsidize this viability gap is often limited by a lack of funds. Often, high transmission and distribution losses add to the challenges. Moreover, laying a cable is not equivalent to supplying electricity. In many instances, grid-connected villages are still not meaningfully electrified, because grid power outages are frequent and/or individual households are not connected due to the high costs of "last mile" infrastructure. As a result, the IEA projects that, leading up to 2030, less than a third of the world's unelectrified population will be electrified by grid extension, leaving more than two thirds to be electrified with decentralized systems.[191]

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189 – Longe, O.M., Rao, N.D., Omowole, F., Oluwalami, A.S. & Oni, O.T. A Case Study on Off-grid Mini-grid for Universal Electricity Access in the Eastern Cape of South Africa, 2017 (link)
190 – Attia, B. & Shirley, R. Distributed Models for Grid Extension Could Save African Utilities Billions of Dollars, 2018 (link)
191 – IEA, Energy Access Outlook 2017: From Poverty to Prosperity, (link)

A1.5 RURAL ELECTRIFICATION WITH DECENTRALIZED SYSTEMS

Decentralized electrification entails the deployment of many small nodes of power generation close to load centers. While this approach cannot leverage the economies of scale of the grid, it eliminates inefficiencies and costs associated with long-distance T&D. Crucially, while the national grid is typically run by a government-controlled entity that can receive tariff directives and absorb large-scale sovereign debt, distributed generation is often a private sector play. This requires different financing solutions. In the case of mini-grids, it also requires a specific regulatory framework.

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Image provided by Nabin Raj Gaihre, Village Data Analytics

A1.5.1 OGS PRODUCTS

OGS products are standalone systems that supply basic energy services. The smallest, pico-solar products (solar lanterns between 0-11Wp), typically provide partial or full Tier 1 energy access on the MTF. This includes basic lighting and mobile device charging services. SHS usually range between 11 and 200Wp, consistent with Tier 2 access. Smaller SHS normally offer lighting and mobile device charging. Larger systems can also power fans, televisions, DVD players and refrigerators. Across the world, OGS products are currently used by around 360 million people and products worth $1 billion are sold annually. By 2022, revenues could reach $8 billion.[192]

OGS product suppliers operate on a retail sales business model. When the market was still in its infancy, companies would only sell products one-off in cash. Cash sales today still dominate the market. However, since many customers do not have enough disposable income to buy a product outright, the PAYGO model has evolved. It allows customers to pay a small down payment, followed by regular installments. As a result, many OGS companies have in effect become consumer finance companies. PAYGO models typically operate on a lease-to-own basis, where ownership of the system is transferred to the customer after the purchase amount has been paid off – typically after about 2 years. PAYGO models depend on mobile money infrastructure, which in turn requires suitable financial regulations and telecoms infrastructure. As a result, PAYGO is not evenly spread. 86% of the market is in East Africa and only 2% in Asia.[193]

A1.5.2 MINI-GRIDS

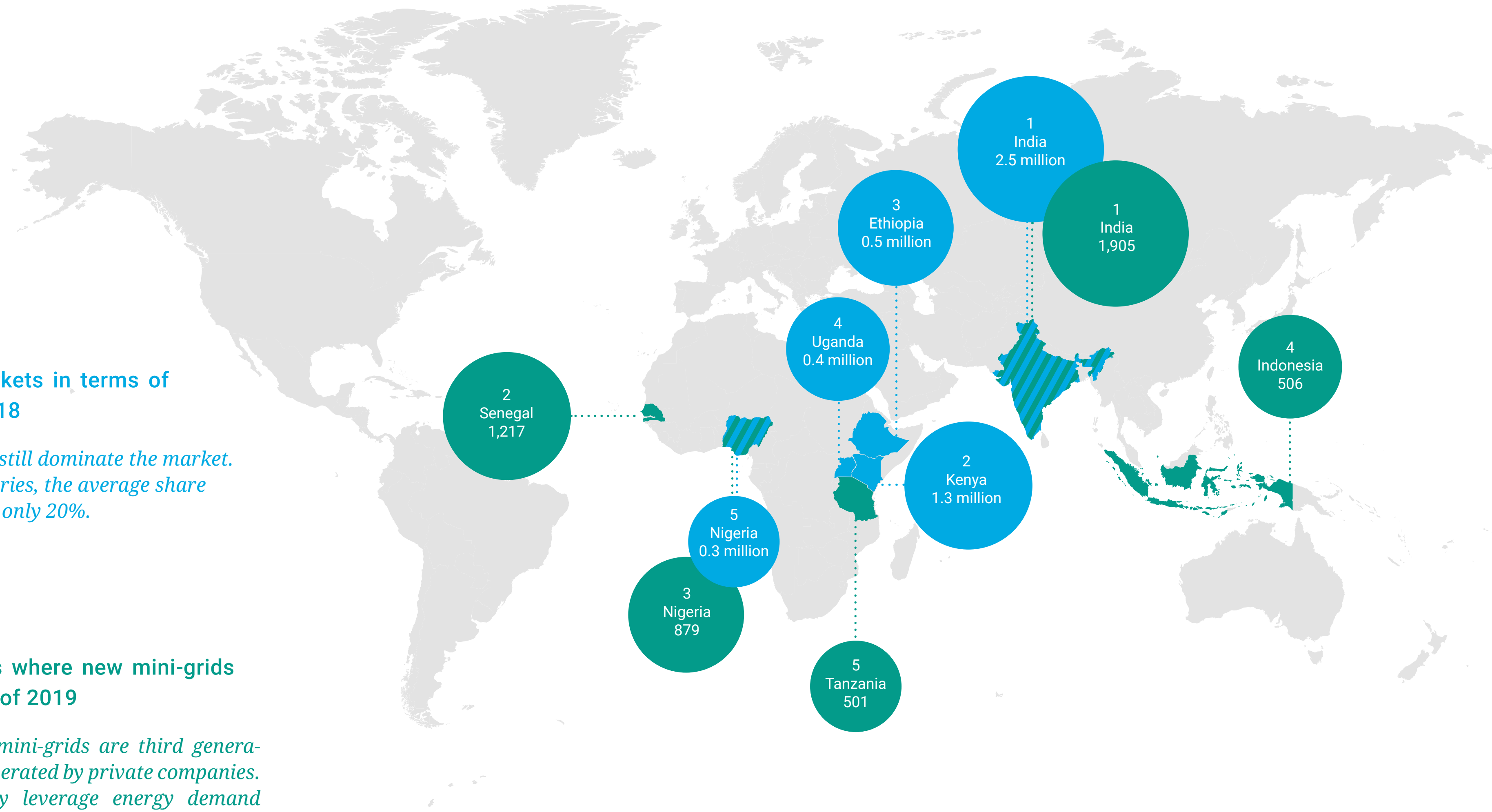
Mini-grids are village-scale or regional power grids that operate in an islanded, or occasionally interconnected mode. They typically provide Tier 3 to 5 services on the MTF. Electricity is generated from one or more sources. The main renewable source is solar, the main non-renewable source is a diesel generator. Other renewable sources are typically biomass and hydro. Most mini-grids that run on renewable sources are backed up by a battery bank to account for variability in energy supply. To date, no consensus has emerged on a preferred classification of different mini-grid types. This leaves installed capacity as a rough, initial metric.

Table 4 – OGS product configurations and examples of suppliers

Type of OGS product	Power capacity	Examples of suppliers
Solar lanterns	0 - 11 Wp	d.light, Greenlight Planet, Bright Products
Solar home systems	11 - 350 Wp	Zola Electric, Mobisol, Bboxx

192 – The World Bank and GOGLA, Off-Grid Solar Market Trends Report, 2018 (link)
193 – The World Bank and GOGLA, Off-Grid Solar Market Trends Report, 2018 (link)

Figure 32 – Top 5 OGS markets in terms of units sold in 2018 [194,195] & Top 5 countries where new mini-grids are planned, as of 2019[196]



Top 5 OGS markets in terms of units sold in 2018

Cash-based sales still dominate the market. In the top 5 countries, the average share of PAYGO sales is only 20%.

Top 5 countries where new mini-grids are planned, as of 2019

The majority of mini-grids are third generation mini-grids operated by private companies. They increasingly leverage energy demand estimation software, project size and layout planning software and remote monitoring infrastructure.

194 – The World Bank, Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data January-June, 2018 (link)
195 – The World Bank, Global Off-Grid Solar Market Report: Semi-Annual Sales and Impact Data July-December, 2018 (link)
196 – The World Bank, Mini-grids for half a billion people, 2019 (link)

In 2018, around 19,000 mini-grids operated globally (all forms of generation technologies and all types of consumers). An additional 7,500 are planned.[197] The private mini-grid sector in energy access is still young, but it has experienced significant growth over the past decade. Between 2008 and 2016, the number of people connected to mini-grids in Asia increased three-fold to a total of 8.8 million, while the number of people connected in Africa increased six-fold to 1.3 million.[198]

Mini-grid developers and operators have an infrastructure business model. They can be distinguished in terms of ownership, customer base and monetization approach. Ownership can be private, cooperative, public or a hybrid of these. Most new mini-grids developed for energy access today are private. Under the community ownership model, mini-grids are owned and operated by cooperatives of community members. Community-owned mini-grids are often developed by third party entities, because local communities rarely have the required expertise.[199] Utility-owned mini-grids are developed and operated by a public utility and funded by the government. Tariffs are typically the same as main grid tariffs, because utilities can cross-subsidize mini-grid tariffs with revenue collected from their grid customer base. In the case of a hybrid ownership model, one entity might own the generation assets, while another owns the distribution assets. Different entities might also be responsible for development, operations and maintenance respectively.

A key success factor for rural mini-grid operators is to stimulate demand for energy. For residential demand this can be done by assisting households to purchase electrical appliances through micro-financing schemes. For commercial customers the promotion of productive uses, such as water pumping, welding and milling, helps.

Operators either sell electricity units (kWhs) or an energy service, such as lighting or water pumping. In the case of the former, the user only pays for the units consumed. In the case of the latter, a flat rate is paid for the use of a predetermined set of appliances connected to the mini-grid, often for a predetermined time. PAYGO or prepaid mechanisms have become the standard revenue collection method. Customers make payments to top up their credit. If their account has credit, the meter will dispense electricity (energy services). Once credit is exhausted, the meter locks access to electricity. Payments can be made by cash, scratch cards or mobile money.

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Table 5 – Mini-grid configurations

Type of mini-grid	Configuration	Examples of developers/operators
Nano-grids	Often DC, max 5kWp	Mera Gao Power, Devergy, Mesh Power
Mini-grids	AC, 5 - 100kWp	PowerGen Renewable Energy, RVE SOL, Husk Power
Regional mini-grids	AC, >100kWp	Rift Valley Power, Ruaha Energy, Virunga Power

197 – The World Bank, Mini-grids for half a billion people, 2019 (link)
198 – IRENA, Policies and Regulations for Renewable Energy Mini-Grids, 2018 (link)
199 – European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF), Mini-Grid Policy Toolkit, 2014 (link)

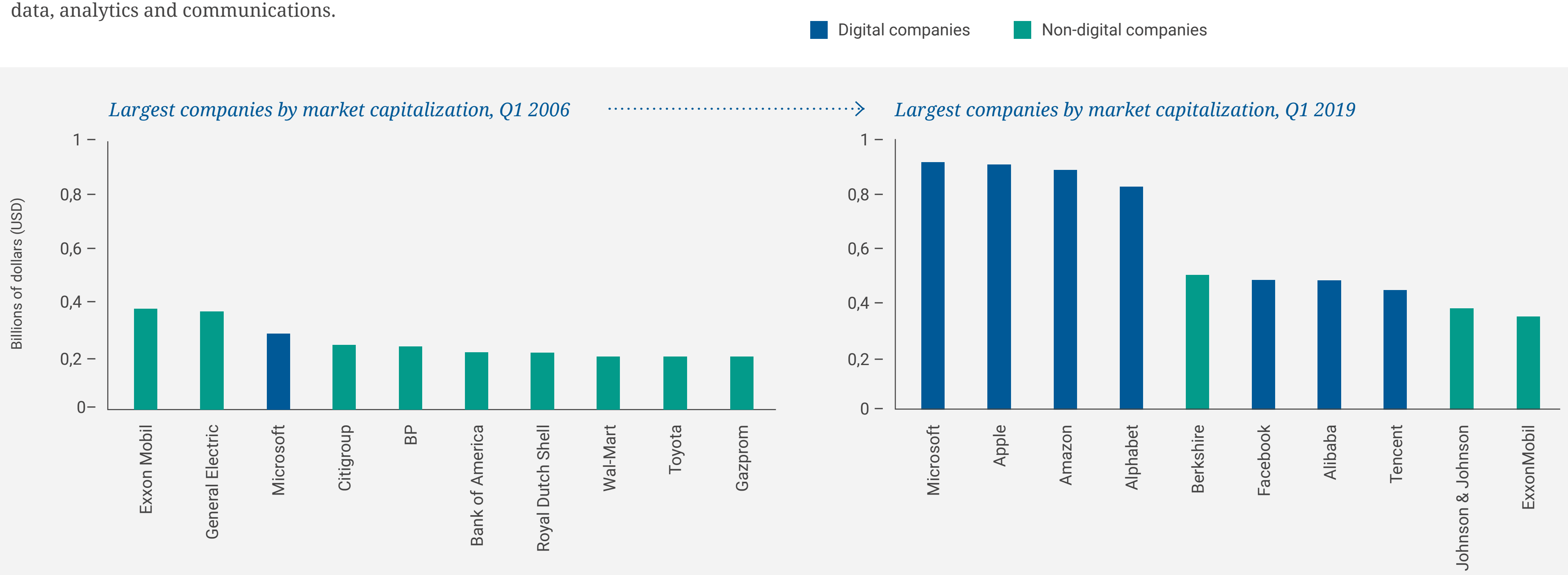
A2 THE DRIVERS OF DIGITALIZATION

Digital technology is increasingly intertwined with every activity in the world. Advances in mobile phone technology and computers have led to their deep integration into our everyday lives. The commercial sector leverages digital technology to optimize businesses processes, to improve predictions or make operations safer – to name just some applications.

The rise of digital technologies and the value the market attributed to them is reflected in the valuation of companies as shown in Figure 34. In 2006, only one technology company made the list of the top ten largest companies by market capitalization. Over the last decade, the number has grown to seven. Microsoft, Apple, Amazon and Alphabet alone are valued at 40% more than the entire 2006 list. The rise of technology companies and the digitalization of our world is driven by fundamental technological advances in data, analytics and communications.

Figure 33 – Ten largest companies by market capitalization in 2006 and 2019[200, 201]

In just over a decade, the top ten of most valuable companies has shifted from non-digital to digital.



200 – YCharts, Market capitalization, accessed on June 12, 2019 (link)
201 – Financial Times, FT Global 500, 2006 (link)

A2.1 ANALYTICS: EVER CHEAPER AND FASTER PROCESSING

In 1965, Gordon Moore, co-founder of Intel, predicted that by 1975 the number of transistors on a processor would go from 64 to 65,000, translating to a doubling every year.[202] Moore revised his prediction in 1975 to a doubling every two years, starting in 1980.[203] This became known as "Moore's Law". Figure 34 shows that the prediction has held true. When Intel released its Pentium processor (P5) in 1995, it consisted of 3.1 million transistors. In 2019, intel processors utilize more than 1 billion transistors. As a result, processors are becoming ever faster and smaller, and require less power. This makes computers more capable.[204]

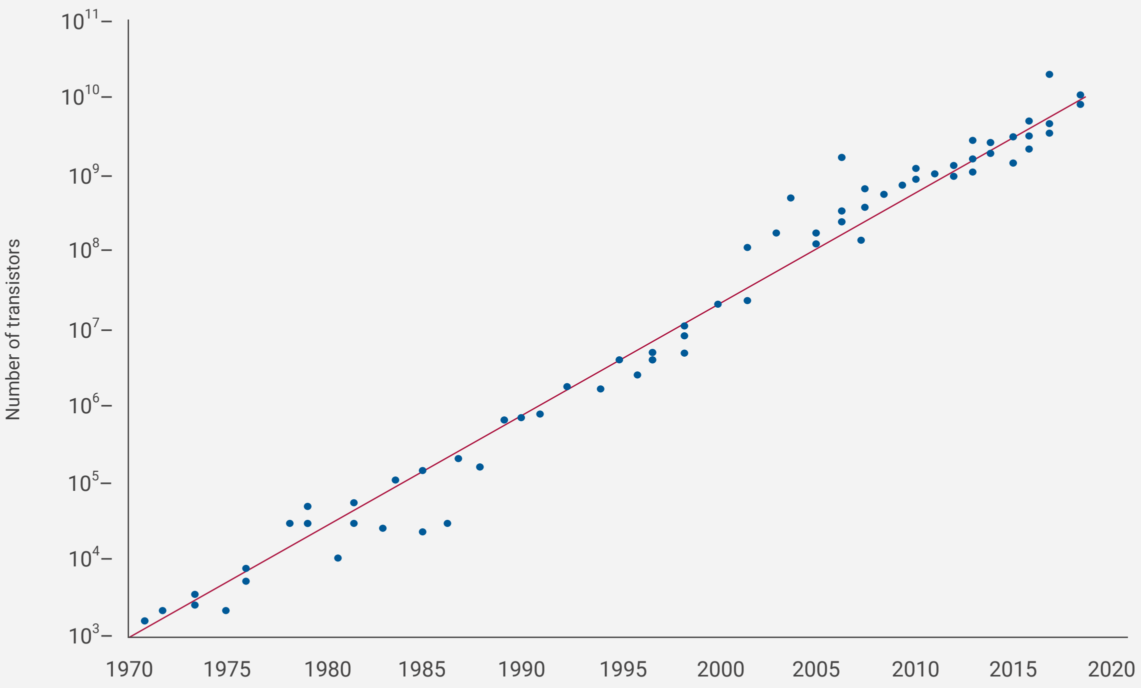


Figure 34 – Moore's law[205]

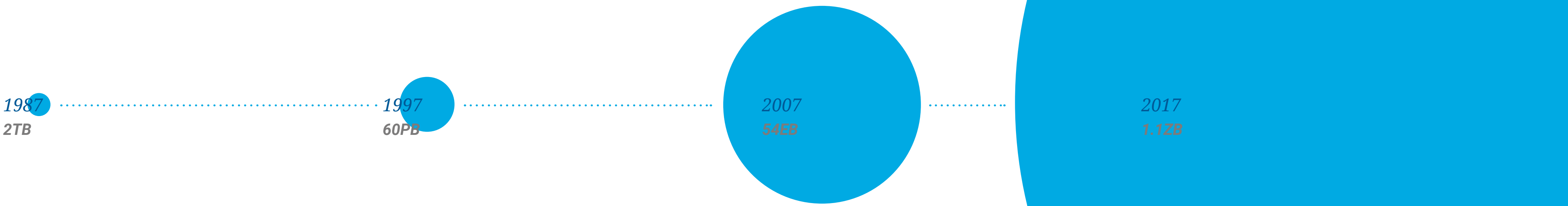
The number of transistors on silicon microchips has grown at an exponential rate over the last 40 years. This increase correlates with an increase of processing power.

202 – Fairchild Semiconductor, Cramming more components onto integrated circuits, 1965 (link)
203 – Intel Corporation, Progress In Digital Integrated Electronics, 1975 (link)
204 – IEA, Digitalization and Energy, 2017 (link)
205 – TFE Energy research, based on various data sources

A2.2 DATA: GENERATING AND STORING EVER LARGER DATASETS

Global internet traffic has grown from 2 TB in 1987 to 1.1 ZB in 2017 – a growth factor of 555 million over the last 30 years. Today, not only computers and phones, but many other connected devices, including watches, cars or machines generate data. Intel predicts that each autonomous vehicle will generate approximately 4 TB of data every day, equivalent to the data generated by 3,000 people.[206]

Figure 35 – Global internet traffic[207]



The amount of data that is generated and stored globally grows very rapidly.

KB	kilobyte	10^3 bytes
MB	megabyte	10^6 bytes
GB	gigabyte	10^9 bytes
TB	terabyte	10^{12} bytes
PB	petabyte	10^{15} bytes
EB	exabyte	10^{18} bytes
ZB	zettabyte	10^{21} bytes
YB	yottabyte	10^{24} bytes

206 – Intel, Data is the New Oil in the Future of Automated Driving (link)
207 – IEA, Digitalization and Energy, 2017 (link)

A2.3 COMMUNICATIONS: EVER IMPROVING CONNECTIVITY

Digital ecosystems often gather data in one place, store it in another and process it in yet another. The transmission of large amounts of data requires a communications network that has both reach and bandwidth. Over the last decade, connectivity to the internet has grown from 1.5 billion users to nearly four billion and mobile subscriptions have grown from less than one billion to over five billion. Growth has been led by the developing world, which in 2018 made up 74% of internet users and 73% of mobile broadband subscriptions.

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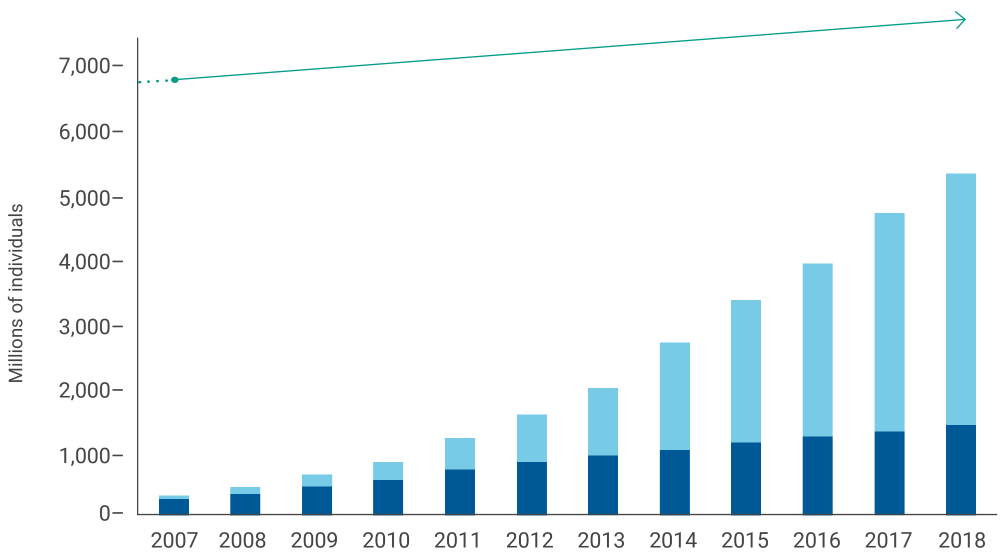
Figure 36 – Global connectivity rates[208, 209]

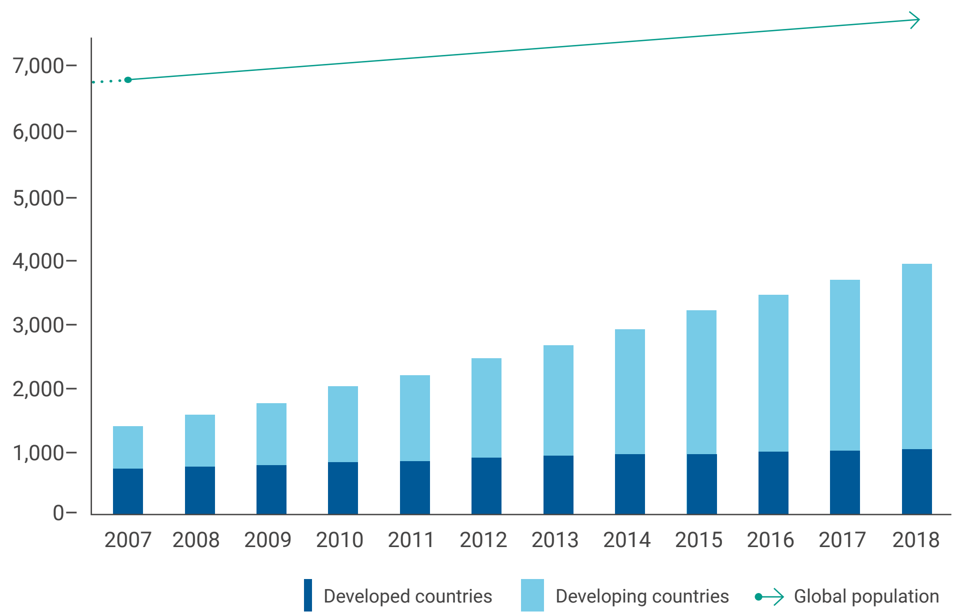
People in developing countries are increasingly better connected. However, there is still a large population without internet access.

In developing countries, between 2018 and 2007, mobile-broadband subscriptions grew by 50% every year and internet users by 15%. Data is from the World Bank; 2018 is predicted.

Mobile-broadband subscriptions



Individuals using the internet



208 – The World Bank, Population, total, accessed on June 12, 2019 (link)
209 – ITU, Statistics, accessed on June 12, 2019 (link)

A3 ABBREVIATIONS

AC	Alternating current
API	Application programming interface
C&I	Commercial and industrial (solar rooftop)
CAGR	Compound annual growth rate
CAPEX	Capital expenditure
CRM	Customer relationship management
DC	Direct current
DEARs	Distributed energy asset receivables
DFI	Development finance institution
DHS	Demographic and health survey (USAID)
EO	Earth observation
EPC	Engineering, procurement and construction
ERP	Enterprise resource planning
GSM	Global System for Mobile Communications
HDX	Humanitarian Data Exchange
HOT	Humanitarian Open Street Map
ICO	Initial coin offering
IoT	Internet of things
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt-peak
KYC	Know-your-customer
LAN	Local area network
LCOE	Levelized cost of energy
LPWAN	Low-power wide-area network
LSMS	Living standards measurement study (World Bank)
MNO	Mobile network operator
MTF	Multi-tier framework
ODK	Open data kit
OGS	Off-grid solar
OPEX	Operational expenditure
PAYGO	Pay-as-you-go
QAF	Quality assurance framework
SAIDI	System average interruption duration index
SAIFI	System average frequency index
SDGs	Sustainable development goals
SEFA	Sustainable Energy Fund for Africa
SHS	Solar home system
Solar PV	Solar photovoltaic
SPV	Special purpose vehicle
T&D	Transmission and distribution
USSD	Unstructured supplementary service data
VC	Venture capital
VRE	Variable renewable energy
WAN	Wide area network

A4 LIST OF INTERVIEWED STAKEHOLDERS

Case studies

Peter Lilienthal (HOMER Energy)
Svet Bajlekov and Stine Carle (AMMP Technologies)
Seth Silverman (Factor[e])
Arthur Jacquiau-Chamski (SparkMeter)
Thibault Lesueur (Solaris Offgrid)
Maud Duprat and Christopher Baker Brian (Bboxx)
Emily McAteer (Odyssey Energy Solutions)
Stefan Zelazny (Engie Mobisol)
Alessandro Pietrobon (Zola Electric)
John Kikenda and Kieran Campbell (PowerGen Renewable Energy)
Rohit Sen (formerly Bettervest)
Nabin Raj Gaihre (Village Data Analytics)

Market experts

Ben Attia (Wood Mackenzie)
Catherina Cader (Reiner Lemoine Institute)
Nikhil Jaisinghani (formerly Mera Gao Power)
Kendall Ernst (formerly Rocky Mountain Institute)
Kerstin Fritzsche and Ayodeji Okunlola (IASS)
Nicholai Lidow (LIB Solar)
Stewart Craine (Village Infrastructure Angels)
Nathan Williams (Carnegie Mellon University)
Ricky Buch (formerly General Electric Off-Grid)
Matthew Cullinen (PACT)
Fabio de Pascale (Devergy)
Afnan Hannan and Callup Yap (Okra Solar)
Michael Goldbach (New Sun Road)
Salma Islam (ME SOLshare)
Kate Steel (Nithio)
Daniel Waldron (CGAP)
Maria Knodt and Davinia Cogan (Energy4Impact)
Christopher Baker-Brian (Bboxx)
Cassandra Pillay (UNIDO)
Alexandre Guillemot (Deepbloo)
Laura Gillen and Olaf Veerman (Development Seed)
Clare Boland Ross (Rockefeller Foundation)
Dimitry Gershenson (Facebook)
Jessica Stephens (AMDA)
Harsh Thacker (CES India)
Olafimihan Oresanya (Rubitec Solar)
Avi Jacobson (SunFunder)
Frauke Adam and Viktor Sinenko (RTSoft)
Ashish Shrestha (World Bank, ESMAP)
Joan Tarragó (Ferntech)
Eco Matser (Hivos)
Nidhi Bali and Umang Maheshwari (Smart Power India)
Dimitris Mentis (World Resources Institute)
Jens Burgtof (GIZ)

ABOUT TFE ENERGY

TFE is dedicated to achieving universal energy access and to improving investments into remote infrastructure. Our team consists of data technology experts on the one side and village electrification experts on the other. This breadth allows us to continuously test and validate new data technologies in the field and work towards specific solutions – such as Village Data Analytics – that create tangible value to the electrification ecosystem. We are always looking for passionate, talented people to join our teams in Munich/Germany and Cape Town/South Africa (for open positions see here).

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