Energising Tomorrow: Scaling up Energy Access with Digital Solutions

endev

Learning & Innovation

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EnDev at a glance

31.6 million
People with access to modern energy

7.4 million
Household members with access to electricity

24.2 million
Household members with improved access to modern cooking solutions

102,820
Micro, small and medium-sized enterprises with access to modern form of energy for productive use

2.91 million
tonnes of CO2e saved per year

32,610
Social infrastructures with access to modern form of energy: among them 18,660 schools and 2,135 health centres

As of 2022, 685 million people still lacked access to electricity and 2.1 billion people lacked access to clean cooking technologies[1]. This has a dramatic impact on quality of life, environment, health, education and income opportunities. Energising Development (EnDev), being one of the largest on-the-ground technical assistance programmes for energy access, focuses on facilitating access to modern, renewable energy in more than 20 countries of the world. This is a pivotal factor in strengthening socio-economic development and combatting climate change.

EnDev's drive is to improve the lives of the most vulnerable people; ensuring no one is left behind. Economic opportunities and green jobs are created by building markets for modern, renewable energy. EnDev contributes to reducing greenhouse gas emissions to protect our planet's climate. Its approach is to empower structural, self-sustaining change; kick-starting market and sector development that evolves further without support from EnDev.

As a multi-donor energy access programme, EnDev is currently financed by four donor countries: Germany, the Netherlands, Norway and Switzerland. A number of other government and charitable donors provide additional funding. EnDev is co-managed by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the Netherlands Enterprise Agency (RVO).

1 IRENA. 2024. Tracking SDG 7: The Energy Progress Report.

EnDev Learning & Innovation Agenda

To spur and structure learning and knowledge exchange within EnDev and the SDG 7 community, the EnDev Learning & Innovation Agenda (ELIA) was created in 2020 to facilitate learning and knowledge sharing via regular exchange meetings, as well as to develop knowledge products based on shared experience and research. ELIA encompasses the set-up of a Community of Practice (CoP) on specific thematic topics. Its initial two-year cycle (2020-21) established four Practitioners Groups, each concentrating on distinct themes: Clean Cooking and Behavioural Change, Humanitarian Energy, Productive Use of Energy, and Rural Electrification. For its second cycle (2022-23), ELIA introduced two new Practitioners Groups focusing on Digitalisation for Scale and Innovative Financing, chosen to align with EnDev's strategy and address practical needs identified through practitioner surveys. This document complements the previous ELIA themes with an additional topic on "Digitalisation for Scale" - through which EnDev aims to support analysis and information sharing on digital applications to facilitate the take-off of the energy access sector. The aim is that the knowledge compilation shared in this document will lead to a higher pace of implementation, actively feed into new pilots and project ideas, and generally increase the impact of the EnDev programme and beyond.

The process of setting up the ELIA group on Digitalisation for Scale was supported by the consortium Reiner Lemoine Institute / Enerpirica, which also developed, together with the EnDev experts, the present knowledge product.

How to Read this Report

This knowledge product is the outcome of collaborative efforts aimed at understanding the transformative potential of digital solutions in the energy access sector. Through literature review and most importantly via direct engagement with practitioners worldwide, it provides valuable insights into the current state of digitalisation of energy access; additionally, it analyses the benefits, challenges, and risks associated with digital technologies in this domain.

At the heart of the discussions lies the fundamental question: What is the scalability potential of digital solutions, and to what extent can they actually push the sector, propelling energy access to levels of growth unattainable without digital interventions? The scalability potential of digital solutions in the energy sector refers to the capacity of these solutions to expand their reach, impact, and efficiency across various scales, from individual projects to global operations. This potential is crucial for propelling the sector towards unprecedented levels of growth and accessibility, particularly in energy access for developing regions. The concept of low, medium, and high scaling potential categorises the extent to which digital solutions can be scaled based on factors such as technological feasibility, market readiness, and the ability to adapt to local contexts. Low scaling potential indicates limited scalability due to technological constraints or market resistance, while high scaling potential suggests significant growth opportunities, often facilitated by digital innovations that enhance efficiency, reduce costs, and enable broader distribution of energy services.

Aimed at professionals already engaged in energy access projects, the report analyses the current status landscape of digital solutions by examining the present situation of digital solutions within the rapidly changing field of energy access. It introduces the concept of an "ecosystem of digital applications for scaling energy access" to frame the interconnectedness and comprehensive nature of various digital tools in this dynamic landscape. The categories of this ecosystem are the following:

- Planning and Development of Energy Access Projects
- Financing and Payments for Projects, Energy Suppliers and Consumers
- Learning, Analysis and Capacity Building
- Demand Stipulation and Consumers
- Market Platforms and Matchmaking
- Operation and Management

For each category the report examines the potential of digital technologies to accelerate energy access, identifies barriers, they help to overcome and risks, they bring along, and provides recommendations for leveraging digital solutions to achieve sustainable development goals. Overall, more than 50 digital tools were mapped and analysed. This mapping of digital tools (Section 2) forms the central part of the knowledge product; it can be used as a "toolbox" where the reader can pick out (or get inspired) by digital solutions that are already in operation in other projects worldwide and that might best suit the current challenges of his/her project. The digital solutions showcased are compared and qualitatively evaluated in overview tables. Additionally, readers can access further information through online links and in the Annex (Section 5), which offers detailed insights into individual project experiences, including contact information of implementation partners that might help with further information, if needed.

As the landscape of digital technologies in energy access continues to undergo rapid evolution, Section 3 of the report assumes a more analytical stance. Here, a structured framework is introduced to assess emerging tools that have not been previously addressed. Readers are equipped with a matrix designed to evaluate these novel tools (see table below).

Key driver for scale	Type of risk/challenge
Cost reduction	Data security and data privacy
Risk minimisation	Digital literacy
Aggregation	Data availability
Capacity building	Communication infrastructure
Demand stimulation	Compatibility
Support decision making	Affordability
	Sustainability issues
	Adequacy

With this matrix, readers can scrutinise new tools based on their functional qualities to scale up energy access, and their contribution to overcoming barriers.

The interconnectedness of the various stages within the ecosystem, as well as the complexity of the drivers and risks to scaling up energy access, leads to the conclusion (Section 4) that it is very unlikely that there will be a single digital solution that will be able to trigger disruptive changes across the energy access sector. Rather, it is a “smart combination of smart tools”, adapted to the specific context of a project, that will lead to improvements in scaling up energy access.

Acronyms and Abbreviations

API	Application Programming Interface
BMZ	German Federal Ministry for Economic Cooperation and Development
CSO	Civil society organisation
SADC	Southern African Development Community
EPC	Electric Pressure Cooker
EnDev	Energising Development
GBE	Grüne Bürgerenergie für Afrika (Green People's Energy for Africa)
GDPR	General Data Protection Regulation of the European Union
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICS	Improved cook stoves
ICT	Information and Communications Technology
IoT	Internet of things
IT	Information Technology
KPI	Key Performance Indicator
PAYGO	Pay as you go
PUE	Productive Use of Energy
PV	Photovoltaic
QR	Quick Response (Code)
RBF	Results based financing
RMS	Remote monitoring system
SEforALL	Sustainable Energy for All
SNV	Netherlands Development Organisation
SHS	Solar Home System
USSD	Unstructured Supplementary Service Data
UNIDO	United Nations Industrial Development Organisation

1 Introduction

This guide is a knowledge product established within the framework of the EnDev Learning & Innovation Agenda. It provides an overview and analysis of digital technologies in energy access projects, incorporating feedback and experience from energy access practitioners. The practitioner group on Digitalisation for Scale has been created in 2023 and is part of the 2nd cycle of the EnDev Learning & Innovation Agenda.

Digitalisation is a worldwide trend that affects almost all aspects of our lives, transforming deeply our patterns of production, consumption and societal relations. With a revolutionary speed digital technologies are entering every imaginable sector, from education to healthcare, from finance to agriculture. By digitalisation, we mean the strategic integration of digital technologies to transform business processes, models, and operations, aiming to optimize workflows, enhance productivity, and drive innovation across all aspects of an organisation. It goes beyond mere conversion of data or processes into digital formats (known as Digitisation)[2]. Also in the energy sector, digitalisation is seen as an enabler of profound transitions with high expectations being placed on it as a catalyst to pave the way towards a sustainable and renewable energy supply. While in the conventional energy industries, power utilities, oil and gas companies, have been adopting information and communication technologies already for decades[3], the recent proliferation of smartphones, the (mobile) internet, as well as cost reductions and advances in artificial intelligence and big data are nowadays creating new, promising business opportunities for sustainable solutions for the "energy access" sector in countries that face a lack of energy access. Providing energy – be it electricity or clean cooking solutions – to the millions of unserved communities around the world is a pressing issue, and innovative methods or tools that could accelerate energy access projects and scale-up the market are urgently needed.

But how impactful are digital solutions – are they really the disruptive game changer for the sector, as often heralded, or are they only a rather small piece in the complex challenge of solving the energy access puzzle? The best way to get a sense of this is the feedback from practitioners who actually use digital tools in their projects and who are aware of the country context in which they are applied. EnDev, as a worldwide program with hundreds of experts working on energy access on a daily basis, offers an outstanding – probably unique – opportunity to assess the potential of digital tools in this sector.

Tapping this vast experience, analysing it, and using the results for an improvement and mutual learning within EnDev and beyond, is the key goal of the ELIA group on "Digitalisation for Scale". This report aims to provide practitioners and partners with practical insights, lessons learned and other relevant knowledge related to digital solutions in energy access projects.

The International Energy Agency defines digitalisation as the increasing penetration of digital methods into the physical world. It is characterized by three features:

- **Data:** digital information
- **Analytics:** the use of data to produce useful information
- **Connectivity:** exchange of data between humans and devices/machines through digital communication networks.

2 Gradillas et al. 2023. Distinguishing digitization and digitalization: A systematic review and conceptual framework
3 IEA. 2017. Digitalization & Energy.

All three elements can already be found in the energy access sector. For instance, **data** on rural energy is collected with digital survey tools, via satellite, or by smart meters. Algorithms and digital planning software help to **analyse** such data and optimize the techno-economic design of energy access projects. Finally, telecommunication networks, smartphones and internet platforms, ensure **connectivity** and data transfer between technical devices, users, and operators (examples: mobile payment, PAYGO, remote monitoring). EnDev already uses numerous digital solutions in its projects, as a screening among the practitioners revealed. The surveys and interviews conducted within the ELIA group on Digitalisation for Scale resulted in over 34 digital application cases in EnDev projects across eleven countries. This testifies the rich 'digital' experience within EnDev and beyond - but it also raises the question how to systematize and assess the knowledge. How can we categorise the multitude of digital energy applications used within the EnDev community? How can we ensure that EnDev country projects learn from success – and failures - of others' experiences? How can we stay up-to-date and ensure that solutions that exist on the market (but are maybe not yet being used by EnDev) don't fall under the radar? Moreover, it is essential also to look at the impact of digital solutions. Do they actually provide an added value for the livelihood of rural populations, and – finally - do they have the potential to accelerate and scale up energy access in a sustainable manner?

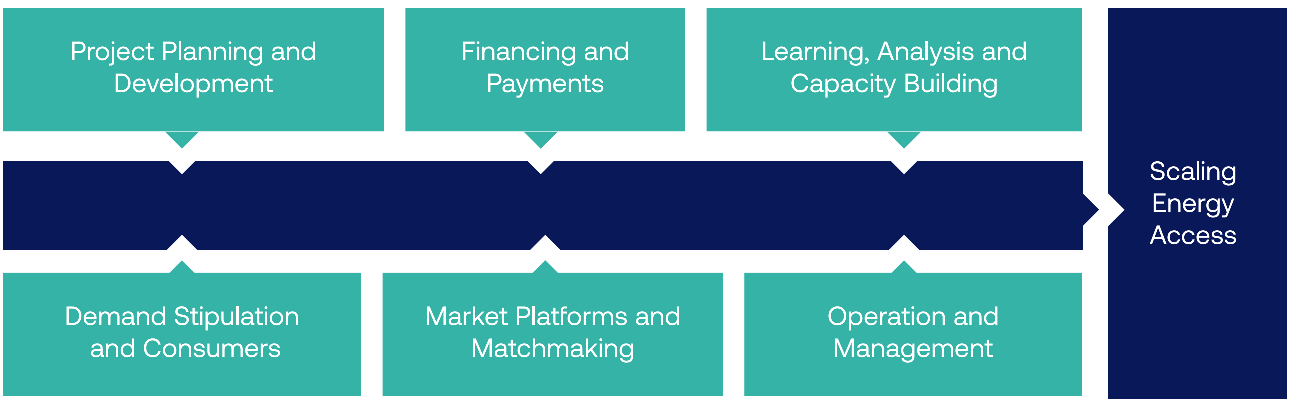
1.1 Methodology and Guiding Principles

In the context of energy access projects, which adopt a practical, market-driven methodology, it becomes beneficial to examine these questions from a project-oriented and a market-oriented viewpoint. This means that digital applications are analysed with regards to their potential to accelerate and scale-up the different sequences of energy access projects. Therefore, the study looks into six key areas which are the typical elements of energy access projects and their market entrance: Planning and Development; Financing and Payments; Learning, Analysis and Capacity Building; Demand Stipulation and Consumers; Market Platforms and Matchmaking; Operation and Management. We summarize them as the "ecosystem of digital applications for scaling energy access" as this emphasizes the interconnectedness and holistic nature of the various digital tools within the energy access context.

A discussion and the outcome of this categorisation is presented in Section 2. As will be demonstrated, this classification scheme allows to bring the large number of different digital solutions into a structured scheme without losing information or missing out possible fields of application in the energy access value chain.

It goes without saying that a mere compilation of digital tools would be of little value without an assessment of their drivers and risks they come along with. Thanks to the feedback of practitioners, gathered through interviews, workshops and questionnaires, it was possible to ascertain the significance of digital tools for energy access projects and also point to some difficulties and limitations.

Figure 1. Ecosystem of digital applications for scaling energy access



A particular aim of this Knowledge Product is to identify and highlight those technologies that show promising economic potential for scaling up energy access. However, environmental and social sustainability aspects should not be overlooked. Therefore, this report is guided by the principles of the UN 2030 Agenda for Sustainable Development with its 17 Sustainable Development Goals (SDGs). The diversity of digital technologies in energy access allows to draw links to a variety of SDGs, with SDG 7 (Affordable and clean energy access) obviously being the most salient one. To a wider extent, digitalisation also promotes SDG 9 (Industry, Innovation and Infrastructure) as well as Climate Action (SDG 13).

The EnDev Learning & Innovation Agenda on Digitalisation for Scale also endorses the 9 Principles for Digital Development, a catalogue of best practices in the use of ICT tools, shared by a wide range of members of the international development community[4]. Building upon these Principles, the German Federal Ministry for Economic Cooperation and Development (BMZ) has outlined five goals to guide projects and programmes within its portfolio (including EnDev)[5]. We applied these principles and goals when identifying and assessing digital tools with the help of the practitioners. In the next chapter, the identified tools are presented along the respective steps of the project value chain.

4 digitalprinciples.org
5 BMZ. 2019. Digitalisation for development

2 Mapping of Digital Tools in Energy Access

The creation of a comprehensive inventory of digital applications for energy access is a challenging task. Digitalisation is a fast-moving issue, with hot topics coming and going. A few years ago, block chain technologies were at the centre of attention, today artificial intelligence (AI) and machine learning are the most discussed trends. Due to the rapid evolution of the digital sector and its continuous innovations also for the energy access sector, the overview presented in this chapter can only provide a limited snapshot. All the more it is important to have a robust classification scheme that allows to assess the digital tools entering the energy access sector in a systematic way.

2.1 Ecosystem of Digital Applications for Scaling Energy Access – Which Tool for which Use?

From the standpoint of practitioners the most convenient way to look at digital tools is through the eyes of a typical energy access project. In this value chain perspective, digital tools will be categorised according to the project phase where they are used to advance, scale up or accelerate project implementation.
The "project value chain perspective" and the "digital tool perspective" offer complementary insights into the evaluation of digital tools within the context of scaling energy access. The project value chain perspective focuses on the overall process of delivering energy solutions, from project development and operations to financial support and learning and innovation. This approach emphasizes the integration of digital tools across various stages of the project lifecycle to enhance efficiency, reduce energy costs, and accelerate deployment. On the other hand, the market perspective categorises digital solutions into distinct areas such as demand stipulation, market platforms and matchmaking and operation and management. This categorization helps in understanding the specific functionalities and benefits of different digital tools in addressing the unique challenges of energy access projects. Combining these perspectives leads to the introduction of the "ecosystem of digital applications for scaling energy access." This concept views the digital landscape as an interconnected network of solutions, rather than isolated technologies. It emphasizes the holistic approach and the collective impact of these digital tools on expanding energy access globally. Each digital component, such as tender platforms or mobile payment systems, plays a crucial role in contributing to the overarching goal of improving energy access. This ecosystem metaphor illustrates the synergistic potential of digital applications in transforming energy access on a global scale, highlighting the importance of a cohesive and interconnected approach to leveraging technology for social good. This ecosystem encompasses the six categories:

- Planning and Development of energy access projects
- Financing and Payments for projects, energy suppliers and consumers
- Learning, Analysis and Capacity Building increasing capacities and knowledge
- Demand Stipulation and Consumers
- Market Platforms and Matchmaking between energy suppliers, consumers, financiers, and innovators
- Operation and Management of energy access projects and programs

The overview of that ecosystem allows to understand why there is no "digital silver bullet" to energy access. The reason is that energy access projects often have multiple barriers to overcome before a market is developed. The planning and development of energy access projects face barriers such as unclear policy frameworks, technical and financial constraints, and environmental impact assessments. Financing and payments for projects are hindered by high initial investment costs, risk perception, and inefficient payment mechanisms. Energy suppliers and consumers encounter challenges related to access to reliable energy sources, infrastructure and connectivity issues, and consumer awareness and education. Learning, analysis, and capacity building are hampered by limited access to training and education, data and information gaps, and resource allocation. Stimulating demand and engaging consumers is difficult due to affordability concerns, preference for traditional energy sources, and marketing and awareness challenges. Market platforms and matchmaking between energy suppliers, consumers, financiers, and innovators are affected by fragmented markets, information asymmetry, and regulatory hurdles. Finally, operation and management is often challenged by lack of data or difficult interoperability of different components and platforms.

Due to the sequential and intertwined nature of the different steps in the value chain, one digital solution alone is unlikely to transform the performance of the sector as a whole. For example, a smart digital solution for operation and maintenance (e.g., a new monitoring platform) will only have limited impact as long as barriers in other value chain phases, such as planning, finance and market development, prevent the market to take off. The access to energy can only be accelerated and scaled up if the transformative potential of digital technologies unfolds across the entire project and market phases.

Figure 2 presents the examined digital technologies, categorised according to the above described ecosystem. Some of these tools are already 'in use' in current EnDev projects; others are known from other project contexts or from the literature. The following sections will introduce and explore the different digital applications in more detail. This categorisation also can be seen as a "toolbox" for practitioners to identify and select digital tools suitable for their individual project's application context.

Figure 2. Categorisation of digital tools for energy access

Planning and Development	Financing and Payments	Learning, Analysis and Capacity Building	Demand Stimulation and Consumers	Market Platforms and Matchmaking	Operation and Management
Geospatial Planning	Loan Eligibility Platform	Exchange and Learning Platforms	Product Comparison Platforms	QR Codes Market Overview	Remote Monitoring Platforms
GISI AI Demand Estimation	Mobile Loan System	Progress Monitoring /Dashboards	DigitalCustomer Service	Digital Marketplaces	RBF Management Platforms
Forecasting Algorithm	Digital Scoring System	Impact Measurement	Smart Appliances/ Productive Use	Web Portals	QR Codes, Value Chain Tracking
Drone Imaging	Crowdfunding	Training Platforms	User-centred Digital Innovations	Smart Contracts	Pay-as-you-go
Survey Tools	Carbon Trading Platforms	E-Learning Services	Demand Side Management		Field Verifications Tools
Design Tools	Digital Tokens	Data Research Centre			Tender Management
	Digital Payments	Data Analytics			AI in RBF Verification

2.2 Digital Tools for Planning and Development of Energy Access Projects

Digital planning and project development tools have become a crucial element for energy access projects in the past years. They are of immeasurable value when it comes to accelerating, increasing efficiency and de-risking energy access projects. The highest uncertainties and possible sunk costs are related to the project planning phase. Reducing development costs and planning risks is therefore an important contribution to scaling energy access. There are two main types of digital planning tools: (1) on the macro-level: planning tools for national or regional energy access projects, often on basis of geospatial data: (2) on the project-level: engineering design tools to streamline and facilitate the design, dimensioning and drafting of specific technical projects.

Overview of tools

Geospatial planning and GIS analysis
Tools for macro-planning accelerate the identification of suitable project locations, while avoiding high transaction costs for field trips and logistics.

Geospatial portfolio planning, based on satellite data, digital maps and image recognition, has proven very successful to set-up (least-cost) portfolios especially for top-down planning purposes in the rural electrification sector.

Geographic Information System (GIS) analysis supports the identification of suitable settlements, estimate their population and electricity demand and propose cost-optimised electrification schemes, usually by distinguishing between grid connection, mini-grids or off-grid solutions (SHS) as most suitable electrification solution. There are commercial providers of such solutions such as the US-based company Powerhive[6] or French IED[7], both of which focus on overall planning and identifying the most cost-effective options for mini-grids. Recently, there is also a trend towards open-source data and open-source software. A prominent provider of free GIS data, with a particular focus on sustainable energy in developing countries, is the data portal Energydata.info, operated by the World Bank. It currently hosts over 900 free energy-related GIS datasets from 193 countries in the world, as well as a number of browser-based software applications[8] for using and visualising this data. Another prominent example of user-friendly visualization of GIS data is the platform Nigeria SE4ALL, an initiative from the Ministry of Power, which aims to empower better electrification planning in Nigeria[9]. Although the focus of GIS applications for energy access, as mentioned above, has been primarily in the field of rural electrification, there are now also planning tools that relate to the field of clean cooking. In analogy to the GIS-based electricity demand, integrated clean cooking planning platforms show the availability of biofuel resources, demographic

6 https://www.powerhive.com/technology - Site Wizard for Analysis, Reconnaissance, and Mapping (SWARM)
7 https://www.ied-sa.fr/en/tools-and-training/our-tools/geosimgb.html
8 https://energydata.info/apps
9 https://nigeriase4all.gov.ng

data and location-specific clean cooking practices in rural areas. The rural electrification agency of Nigeria, for instance, has developed, in the framework of a partnership with SEforALL, a geospatial model for the expansion of clean cooking solutions, distinguishing between different technological options such as biomass, LPG and e-cooking[10]. Similar tools are also offered by Energydata.info on an open-source basis, for instance the clean cooking planning tool (CCPT), which has been developed in the framework of the World Bank-ESMAP program[11].

AI based processing of satellite imageries
It remains to be seen how the further development of digital planning tools based on geospatial data will develop, especially with regards to the rapid advances in **artificial intelligence and image recognition**. These tools can produce important data for planning and prioritization of energy access projects and for the development of project portfolios. A prominent example is the high resolution settlement layer which indicates populated areas based on processed satellite imageries[12].

Drone imaging
On the project-level, for example for the design of mini-grids for a village, **drone imaging** can support the mapping and site selection process, as demonstrated in an example in Zambia[13]. For the planning of specific projects, it might also be necessary to collect data on site and/or through door-to-door customer interviews, for example to obtain information on household energy demand patterns.

10 https://www.seforall.org/system/files/2022-01/Nigeria_IEPT-Clean_Cooking_Report.pdf
11 https://energydata.info/cleancooking/planningtool/
12 https://www.ciesin.columbia.edu/data/hrsl/#data

13 https://www.dnv.com/power-renewables/webinar/registration/bankable-mini-grid-site-development-webinar.html

How Digitalisation is Transforming Energy Access Planning in Nigeria

Unlocking energy access through digital innovation in Nigeria! The NigeriaSE4ALL project showcases the power of digitalisation in integrated project planning, impact monitoring, and capacity building to enhance energy access across Nigeria. The offgridplanner tool, a product of the PeopleSuN project, streamlines off-grid system planning by optimizing distribution grids and designing energy converters and storage solutions. With features like map-based consumer selection, demand estimation, spatial grid optimization, and generation system design optimization, the tool enables automatic building identification from OpenStreetMap, tailored generation system design, and identification of ideal locations for solar home systems. Users can explore the tool without registration or enhance their experience by creating an account for increased computing power and model storage.

The NigeriaSE4ALL platform, a data portal enriching electrification planning in Nigeria with real-time insights derived from various data sources, supports electrification research and serves as a basis for decision-making in both public sectors and private markets. By visualizing data online under an open-data license, stakeholders can access valuable information to drive electrification planning across Nigeria effectively. Experience a new era of electrification planning with digitalisation at its core - transforming how we plan, monitor, and build sustainable energy solutions for a brighter future. It can help project developers to identify suitable locations for off-grid electrification projects in an efficient and user friendly way.

After site identification, a project development tool such as the offgridplanner can be used to conduct a pre-feasibility study. Its integrated demand modelling tool leverages survey data to forecast electricity demand and costs in non-urban Nigerian areas, categorizing consumers based on geographical zones and wealth categories for precise predictions. By efficiently identifying consumers and calculating optimal setups for grid connectivity using clustering algorithms and minimum spanning trees, the tool ensures optimal grid design. Moreover, the tool excels in designing off-grid energy systems by integrating various energy converters like PV systems and diesel generators. Leveraging satellite data and advanced modelling tools, it minimizes costs while providing stakeholders with valuable insights for strategic decision-making for their investments.

Before the advent of digital tools like the offgridplanner, planning and implementing off-grid energy systems in Nigeria was a complex and time-consuming process, often hindered by a lack of accurate data and inefficient processes. Now, with the offgridplanner and the NigeriaSE4ALL platform, the process is streamlined, enabling automatic building identification, tailored generation system design, and the identification of ideal locations for solar home systems. These digital innovations not only make the planning phase more efficient but also allow for precise predictions of electricity demand and costs, ensuring optimal grid design and reducing costs, thereby revolutionising how energy access projects are planned and developed.

Demand forecasting
Improved **algorithms for demand forecasting** - the most critical component in the development of electrification projects – might bring significant improvements in the coming years. An example of a digital solution that addresses demand forecasting is the RAMP tool[14], which generates load/demand profiles that can be used to model rural electricity systems. However, regardless of the ingenuity of demand forecasting, GIS analysis, maps and satellite images might not always bear the most recent data and granularity needed for a more detailed planning.

Survey tools
Here, digital **survey tools** can provide considerable efficiency gains compared to conventional methods (questionnaires, spreadsheets), as they automatize the collection, aggregation and analysis of data. There are several commercial solutions on the market, such as Survey CTO[15] or Kobo Toolbox[16]. Of course, these tools are not only used in energy access projects, but also in any other contexts of socio-economic data collection. Within in the energy access value chain, they are also useful for the remote monitoring and project management (see section 2.1.6).

Design tools
Finally, a further element in the (project-) planning of energy access projects is the use of the "classic" engineering **design tools**, such as the HOMER[17] software, which assists planners with the detailed sizing of the power generation system and the layout of the distribution grid of hybrid minigrids. In addition, new tools are constantly emerging that attempt to integrate the above-mentioned functions into a comprehensive platform or tool. A successful example of such a tool is offgridplanner[18]. It combines the features of automatic identification of buildings from OpenStreetMap with spatial optimization of the distribution grid as well as qualitative and quantitative demand forecasting for Nigeria, and design optimization of the generation systems (PV systems, battery systems, inverters and diesel-engines) and automatic identification of buildings that are better to be served by individual solar home systems.

Scaling potential

As shown in the previous section, digital tools are well established and already widely used in the planning of energy access projects.

Reduce planning risks
Clearly, the greatest potential for scale-up lies in the macro-planning tools that can be used to identify and plan large project portfolios: Geospatial planning, GIS analysis, AI and algorithms. Exclusively based on data analysis, they can enormously increase the efficiency of planning processes (reduce planning costs, reduce planning risks), thereby pushing the acceleration of energy access in remote regions. For example, in West Africa, where public data on settlement structure, population and energy demand is often scarce or not accurate enough, these tools are very important for scaling up the planning process of energy access projects to cover thousands of households.

Reduce planning costs
Drone imaging and digital survey tools, which are usually only used at household/village level are associated with a low/medium scaling potential for the planning process. The scaling potential for detailed technical design tools like HOMER is often perceived as limited due to their typical usage in individual projects. However, it is important to acknowledge the existence of tools tailored for national electricity access planning. These tools, although less prevalent and more intricate, cater to larger spatial scales. For instance, the Reference Electrification Model (REM[19]) and the Open Source Spatial Electrification Tool (OnSSET[20]) are notable examples. REM automates electrification planning, determining cost-effective system designs to efficiently deliver electricity access to populations of varying sizes. It identifies optimal electrification modes for individual consumers, such as grid extension, mini-grids, or solar home systems. Similarly, OnSSET, developed by KTH, assesses and compares seven technology configurations across grid-extension, mini-grids, and standalone systems categories. These tools exemplify approaches that consider broader spatial scales and offer comprehensive solutions for electricity access planning.

14 https://rampdemand.org/
15 https://www.surveycto.com/
16 https://www.kobotoolbox.org/
17 https://www.homerenergy.com/
18 https://offgridplanner.org/
19 https://tatacenter.mit.edu/portfolio/reference-electrification-model-a-tool-for-rural-electrification-planning/
20 http://www.onsset.org/

Risks and challenges

Obviously, there are also weaknesses associated with the use of digital planning tools.

Affordability
For top-down planning tools, the risk of lacking availability and/or poor quality of (satellite) data in particular can affect the planning accuracy of rural energy access projects. Data obtained through drone imagery and field survey tools are certainly more reliable, but the use of these tools is more expensive. The detailed engineering design tools (such as HOMER) undoubtedly work at the highest level of accuracy, but as mentioned above, they can only be used for individual projects.

Data security
A barrier that affects most digital planning tools is data security and privacy, which must also be considered when collecting data for rural energy planning. An example might be sensitive private household data collected with field survey tool.

Adequacy
As with many digital applications, there is also a risk that the purely data-driven applications, such as geospatial and GIS analysis, but also drone imagery, are not adequately adapted to the planning challenge. In other words, practitioners must always ensure that the digital planning tool they choose is also the most appropriate and best suited solution for the actual planning of socially sustainable energy access projects.

Summary table – “digital toolbox” for energy access planning

The following table summarizes the classification of the digital tools of this section including a (qualitative) assessment of each tool’s potential for scaling up energy access as well as the related risks and challenges.

Type of tool	Area of application	Suppliers / Examples	Drivers for scale	Risks and challenges	Scaling potential
Geospatial portfolio planning / GIS analysis	Macro planning of rural electrification projects, biomass resource analysis (clean cooking)	Powerhive IED Energydata.info NigeriaSE4all	Reduce planning costs Reduce planning risks	Data availability Adequacy	*High*
Artificial intelligence, image recognition, algorithms	Planning of rural electrification projects, potential site identification	HRSL data	Reduce planning costs Reduce planning risks	Data security Adequacy	*High*
Forecasting algorithms	Demand forecasting	RAMP Demand	Reduce planning risks	Data security Adequacy	*High*
Survey Tools	On-site collection of data relevant for planning (household size, energy consumption patterns...)	Kobo Toolbox Survey CTO	Reduce planning risks	Data security Affordability	*Medium*
Design Tools	Engineering and technical planning of electrification projects, system design and system optimisation	HOMER offgridplanner OnSSET REM	Reduce project development costs and risks	Adequacy Affordability	*Low* *(High[21])*
Drone imaging	Planning of rural electrification projects, site assessment, infrastructure inspection, environmental impact assessment	available on the open market for independent use in the planning of energy supply projects, professional drone imaging services	Reduce planning costs Reduce planning risks	Data security Adequacy Affordability	*Low*

*details: see Annex

21 When integrated into macro-level planning tools

2.3 Digital Tools for Financing and Payments for Projects, Energy Suppliers and Consumers

Financing – be it through private sector financing, international financial institutions or donors – is the precondition for realizing any energy access project. This chapter provides an overview of the digital tools that can help overcome the barriers to securing finance, but also the barriers with regards to channelling funding towards the beneficiaries and reducing the investor's risk. This last point is often a challenge given the fragmented structure of energy access projects, where many individual but small transactions need to be handled, each of which with an amount in the microfinance[22] range – for example loans for households to purchase improved cook stoves.

Overview of tools

Digital credit/loan eligibility platforms
A promising tool that could help accelerate and scale up the overall volume of financing handled within energy access programmes are **digital credit/loan eligibility platforms**. They help automate what would otherwise be a cumbersome and uneconomical task for classical financiers: checking the creditworthiness of each individual beneficiary. In the framework of the RBF-financed "ProPoor" project in Rwanda, EnDev has developed a digital tool to check the eligibility of customers by taking into account various sources of data, such as geographical location, national ID and other publicly available statistic information, to evaluate the customer's socio-economic status.

Digital scoring systems and mobile loans systems
The eligibility platforms could be further refined in **digital scoring systems** that development finance institutions (DFIs) or investors use to obtain a personalized assessment of a client's financial capability and predict his credit repayment behaviour. Proponents of such approaches argue that this would lead to better credit decisions and enable financial services to be tailored exactly to the needs of the customer. Personalised creditworthiness[23] scores could also be used by other digital finance tools, such as **mobile loan systems.** Enabled by the increasing penetration of smartphones and the success of mobile money in certain regions of the world, mobile loans can be offered via smartphones/mobile phones to rural customers who were previously unserved by banks or other mainstream financial services. One example for a mobile loan provider using also a digital scoring system is the Kenyan company Tala[24]. Potential borrowers using the app must agree to allow access to their mobile usage data and provide certain personal information. Depending on the algorithm-calculated score, the user is subsequently granted a loan, which is sent in the form of mobile money and paid back with the telephone.

Crowdfunding
In terms of securing finance (or 'fundraising') for large-scale energy access programmes, the most prominent – and mature - digital tool is crowdfunding. Numerous online platforms for green **crowdfunding** have also financing options for energy access projects (mini-grids, SHS, clean cooking, productive use equipment) in developing countries in their portfolio, such as Bettervest[25], Crowd4Climate[26] or EnergiseAfrica[27]. The strength of digitalisation here is that crowdfunding platforms can potentially be visible worldwide; and hence be supported from various investors in different countries. The digital processing of payments and distribution of rewards or returns allows even small investments to be handled efficiently.

Digital tokens
The idea of aggregating small, even smallest amounts, into considerable funding volumes is taken to the extreme in the concept of digital tokens, which has enjoyed some popularity in solar electrification projects in the past years with the emergence of the block chain and digital ledger technology. One example is Solar Coin[28], where tradeable digital tokens (solar coins) are issued for each kilowatt hour of energy produced. The SunExchange[29], a block chain-based solar panel micro-leasing platform is another example: investors can acquire on a crowd sale basis even very small shares of the project's assets (e.g. a single solar cell of the solar system of a rural hospital) and receive lease or rental payments as the system produces energy

22 Microfinance encompasses financial services for individuals and small businesses underserved by traditional banking, including microcredit, savings and checking accounts, microinsurance, and payment systems
23 Having enough money for banks to be willing to lend someone money

24 https://tala.co.ke/
25 https://www.bettervest.com
26 https://www.crowd4climate.org/
27 https://www.energiseafrica.com/
28 https://solarcoin.org/
29 https://thesunexchange.com/

How Digital Tools are Revolutionising Bioenergy Markets in Kenya

Multiple organizations, including SNV, 4R Digital, Inclusive Energy, GIZ, Sistema.bio, and African Bioenergy Partnership Limited (ABPL), are collaborating on a project funded by the Netherlands Enterprise Agency under the African Bio digester Component (ABC) in Kenya. This project integrates Smart Biogas meters into the 'Cavex' digital carbon trading platform to expand the market. By leveraging biogas and bioslurry to reduce carbon emissions, the initiative targets overcoming adoption barriers for smallholder and commercial farmers in low-income countries.

Through carbon financing, the project aims to subsidize costs and enhance bio digester distribution. The Carbon Value Exchange (Cavex) platform by 4R Digital allows small carbon credit producers to sell to corporate buyers, improving market transparency. Inclusive Energy's Smart Biogas monitoring system will gather bio digester data in Kenya for Cavex integration. The project is developing a methodology to convert smart meter data into verified offset credits for sale, exploring carbon financing opportunities for biogas users. Aligned with existing programs in Kenya and focusing on sustainable agriculture, energy access, and climate objectives, this project aims to boost the bio digester market while offering insights for future growth and investment prospects.

By leveraging digital technologies like Cavex and Smart Biogas monitoring systems, the initiative streamlines the transition to sustainable energy, improves market transparency, and explores carbon financing opportunities for biogas users, contributing to future scalability and investment in the clean energy sector.

This innovation not only overcomes adoption barriers for smallholder and commercial farmers by leveraging biogas and bioslurry to reduce carbon emissions but also enhances market transparency and explores carbon financing opportunities, thereby significantly improving the efficiency and and accessibility of bioenergy financing.

Source: SNV. Unlocking climate finance to promote the use of bio digesters through digital innovation. (2023)

Carbon trading platforms
Another digital concept for financing energy access projects are carbon trading platforms. The idea is that data from (solar) mini-grid operators, clean cooking projects is processed to measure, quantify and verify avoided CO2 emissions. These can be transformed into digital carbon credits, and subsequently monetized, for example on the Voluntary Carbon Markets, thereby contributing to project finance. The Danish company Carbon-Clear[30] operates such a carbon credit verification platform, exclusively dedicated to the creation and processing of carbon credits for energy access projects. The carbon credits are generated by aggregating so-called "micro carbon avoidances" of off-grid solar electrification devices, that can be tracked via the systems' individual PAYGO functionality. A global example is ATEC's eCook[31], a high-efficiency electromagnetic induction stove with a Global SIM for real-time data connection, integrates with carbon trading platforms for automated payments (PAYGO), usage tracking, and digital carbon credit verification. EnDev has similar experiences in a pilot project in Kenya, where the Carbon Value Exchange (CaVEx)[32] platform is used to verify carbon avoidances of bio digesters for household clean cooking. Similar to CarbonClear, the carbon avoidances are measured by smart meters to generate revenues through carbon credits which can be finally sold on the voluntary carbon markets. Another digital approach to generate revenues for financing energy access is currently field-tested in Uganda by the German company Inensus[33]. Excess electricity generated by rural solar mini-grids is used to operate energy-intensive Bitcoin mining computers or cloud-based AI solutions. These use AI to determine when and how much energy is needed to solve cryptographic problems and generate new blocks.. The revenues generated by these services are additional financial flows that help to make the financial structure of mini-grids more attractive.

To complete the presentation of digital finance tools, this section also refers to **PAYGO** and **RBF management**, as both have a significant role in controlling financial cash flows of energy access projects: while RBF management coordinates the disbursement of funds, PAYGO controls the collection of payments. As both tools are likewise important in the operation and management of energy projects as well, they are described in more detail in section 2.1.6.

30 https://www.carbonclear.earth
31 https://www.atecglobal.io/
32 https://4rdigital.com/digital-technology-can-unlock-access-to-climate-financing-for-micro-clean-energy-and-nature-based-initiatives/
33 https://sustainsolar.co.za/en/green-bitcoin-mining-a-game-changer-for-mini-grids-in-africa/

Scaling potential

It is generally difficult to assess the scaling potential of digital financial solutions for energy access.

High outreach to people
At first glance, technologies related to mobile telecommunication services (e.g. mobile loan systems) seem highly promising with this regard, as mobile phone-based financial services (mobile money) have a broad reach and are widespread in many developing countries. However, as pointed out the in next section, the size of the mobile loan offered in these schemes is often too small to allow individual customers the purchase of energy access devices; therefore, only a medium scaling potential is assigned to these technologies. Crowdfunding platforms also appear to have high scaling potential, as they can reach a large audience of investors, including individuals, institutions and organisations, regardless of their geographical location. However, the fact that these platforms currently only fund singular, selected projects means that the scaling potential is more likely to range at the medium level.

Cost reduction
A high scaling potential is assigned to digital loan eligibility platforms as they can significantly accelerate the due diligence process for loan recipients, whereas the potential for scaling up energy access is deemed low for solar tokens or other approaches (e.g. monetization of excess energy for Bitcoin mining). These niche applications bear an interesting potential as "add-on" solutions to generate certain extra revenues for energy access projects, but so far, they are not considered to become fundamental game-changers in the energy access sector.

Risks and challenges

As outlined above, digital finance innovations feature many interesting advantages for the energy access sector (aggregation, easier access to financing, lower transaction costs), but they also come with certain challenges.

Data security
Data security and data privacy concerns have to be mentioned here in first place. Digital transactions are susceptible to cybersecurity threats such as hacking, identity theft, and fraud. Especially populations suffering from low digital literacy (e.g. marginalized populations in rural areas) must be protected against these threats, e.g. when promoting energy access through mobile loan schemes. Additionally, as pointed out by practitioners, mobile loan systems often offer only relatively small loan sizes which are not sufficient to finance energy access devices (SHS, clean cook stoves). With regards to data privacy some experts also question whether a purely data-driven, digital approach to lending would be socially acceptable and sustainable in development contexts[34]. Algorithm-based digital scoring systems are particularly debatable here, as they could potentially further exclude already marginalized groups from financing energy access solutions.

Adequacy
Another issue concerns the appropriateness (adequacy) of the digital finance tools, e.g., the question of whether they represent a context-adapted solution to the energy access challenge. This particularly concerns token/distributed ledger approaches, which have received a lot of attention a few years ago during the block chain rush, they have not yet triggered a big leap in financing energy access projects and must today be considered a niche application in the sector.

34 Siwale & Cécile Godfroid (2021): Digitising microfinance: on the route to losing the traditional 'human face' of microfinance institutions, Oxford Development Studies

Summary table – “digital toolbox” for energy access finance and payments

The following table summarizes the classification of the digital tools of this section including a (qualitative) assessment of each tool’s potential for scaling up energy access as well as the related risks and challenges.

Tool	Area of application	Suppliers / Examples	Drivers for scaling	Risks and challenges	Scaling potential
Digital credit/loan eligibility platforms	Evaluate customer creditworthiness of to obtain loans for energy access devices	EnDev “ProPoor” project (Rwanda)	Risk reduction Cost reduction (of financial transactions)	Data security/Data privacy	*High*
Mobile loan systems	Customers can remotely apply for loans (with smartphone/mobile phone)	Solutions often offered by mobile network operators	Outreach to people without access to banking services	Data security/Data privacy Adequacy (loan amount offered often too small)	*Medium*
Digital scoring systems	In conjunction with digital loan eligibility platforms or mobile loan systems Prediction of credit payback behaviour	Tala	Reduce risks of financial transactions	Data security/Data privacy Social Sustainability Adequacy	*Medium*
Crowdfunding	Aggregate small amounts from investors to finance energy access projects	Bettervest klimja EnergiseAfrica	Aggregation	Adequacy	*Medium*
Carbon trading platforms	Digital carbon credits to contribute to project finance	Carbon Value Exchange (CaVEx)* CarbonClear	Cost reduction (additional source for financing projects)	Adequacy (niche application)	*Medium*
Digital tokens	Aggregation of tradeable digital shares of project assets	SolarCoin The SunExchange	Aggregation	Adequacy (niche application)	*Low*

*details: see Annex

2.4 Digital Tools for Learning, Analysis and Capacity Building

Digital tools for learning, analysis, and capacity building play a crucial role in addressing the typical challenges in energy access. One significant challenge lies in the lack of awareness and understanding among communities and stakeholders regarding sustainable energy solutions, especially what solution fits to which context. Digital platforms offer educational resources, training modules, and interactive tools that enhance knowledge dissemination and capacity building, empowering individuals to make informed decisions about energy access. Moreover, these tools facilitate data analysis and monitoring, enabling stakeholders to assess energy access projects' success as well as failures and to share best practices.

Overview of tools

Progress monitoring platforms / dashboards-
Digital tools for learning, analysis, capacity building - show how experiences, results and lessons learned can be processed in a meaningful way in order to generate improvements in future project cycles. A well-known tool, particularly for the strategic/political steering of energy access programmes are so-called progress monitoring systems. They are usually embedded in online information systems (websites) that centralize information on energy access progress and other sector developments. Data is often aggregated into key performance indicators (KPIs) such as electrification rates or the clean cooking penetration in rural households. These parameters are often visualized on digital dashboards, which can inform policymakers about the achievements of their programmes, but also point to barriers and the need to make adjustments. Energy access monitoring is also important for the private sector to identify business opportunities for their products and solutions. Dashboard-based progress monitoring is offered to some extent by classic management platforms - such as Odyssee or Prospect - but also customized solutions are in use. As an example, EnDev Rwanda has developed its own energy access online information system (OMIS) that consolidates electrification data from solar companies and mini-grid developers across the country combined with a dashboard analysis to inform the national energy development agency of Rwanda about the progress of solar electrification programs. A particularity of the OMIS solution is, that it features an interface to an RBF management scheme (see Section 2.7) where sales data of solar systems is automatically transferred to the monitoring system.

Impact measurement
A feature often desired in the context of development programmes is **impact measurement.** The idea is that a monitoring system should not only track the apparent achievements in terms of energy access (counting the number of electrified households, the dissemination of clean cook stoves, etc.), but also measure their actual impact on the livelihoods of the targeted populations and the environment. Digital impact measurement solutions could, for example, tap into public databases on rural health, schooling, employment or gender data in order to identify potential correlations with progress on energy access. Of course, impact measurement activities could also be supported by digital field survey tools (see Section 2.6) to assess socio-economic impact on-site, or with geospatial analysis (see Section 2.2), for instance to verify whether clean cooking projects have succeeded in reducing deforestation.

Empowering Communities: The Digital Transformation of Energy Access in Sierra Leone, Guinea, and Liberia

IT4Renewables offers transformative benefits for communities in Liberia, Sierra Leone, and Guinea, particularly in enhancing clean cooking and electricity access, thereby positively impacting the lives of their people. The platform serves as a catalyst for change, empowering individuals, businesses, and experts to address pressing energy challenges. In these countries, access to clean cooking solutions and reliable electricity is often limited, leading to health hazards, economic burdens, and barriers to social development.

Through its marketplace, local businesses can showcase clean cooking solutions and renewable energy products, making them more accessible to households in need. This not only improves health outcomes by reducing indoor air pollution but also alleviates the economic burden of traditional cooking methods. Furthermore, the learning platform plays a pivotal role in educating engineers and non-engineers on renewable energy technologies and practices. By equipping community members with the necessary skills and knowledge, IT4Renewables empowers them to drive clean energy initiatives in their respective regions. Additionally, the web portal serves as a centralized hub for data and insights, enabling informed decision-making and strategic planning for expanding electricity access. By providing valuable information on energy consumption patterns, resource availability, and market trends, the platform facilitates the development of targeted interventions and investment strategies.
IT4Renewables contributes to significant improvements in the quality of life for people in Sierra Leone, Guinea, and Liberia. By promoting clean cooking and enhancing electricity access, it not only mitigates health risks and economic burdens but also fosters social and economic development. Through its collaborative approach and innovative solutions, IT4Renewables empowers communities to build a more sustainable and resilient future. Generally, digitalisation enhances the efficiency, scalability, and impact of clean cooking and energy access initiatives by improving information dissemination, education, market connectivity, data management, and remote monitoring.

Before the introduction of digital tools like IT4Renewables, communities faced limited access to clean cooking solutions and reliable electricity, leading to health hazards and economic burdens. Now, through a digital marketplace and learning platform, IT4Renewables empowers local businesses and community members with the necessary skills and knowledge to drive clean energy initiatives, improving health outcomes, alleviating economic burdens, and fostering social and economic development.

E-learning / Exchange and learning platforms
Analysing data, collecting information and presenting it on digital dashboards would be of little value if the insights did not promote a learning and capacity building process to improve future projects. E-learning services and exchange and learning platforms are the digital answers to this challenge. EnDev Sierra Leone, within the framework of its IT4Renewables program, is working on a digital learning platform[35] to train engineers, technicians, but also non-engineers about renewable energy and clean cooking technologies. The main objective is to scale up renewable energy access through online education services that are provided by the platform. A further scaling is intended by extending the online training services beyond Sierra Leone, to reach also Liberia and Guinea. The development of such transnational digital learning platforms is of course not only practiced by EnDev, but can also be found in other contexts. For example, the Southern African Development Community (SADC), in cooperation with UNIDO, is building a transnational training platform (CORE Academy[36]) that offers certified online training courses for practitioners in the field of decentralized renewable energy.

Scaling potential

Monitoring platforms and impact measurement helps to identify which strategies and interventions are most effective in improving energy access.

Support decision making
By understanding the social and environmental impact of different approaches, governments and organizations can prioritize in those that yield the greatest benefits. Impact measurement also provides data to demonstrate the value and effectiveness of energy access initiatives for potential investors; moreover, it contributes in building trust among partners and stakeholders, leading to greater collaboration. In summary, although these digital tools may not directly increase electrification rates or the dissemination of clean cooking solutions in the short run, they do contribute to scaling up energy access in the long term and can therefore be rated high in terms of scaling potential.

Capacity building
Similarly, digital learning tools, such as learning platforms, have significant potential for scaling up, albeit primarily in the long term. Their ability to reach diverse learners (e.g., students, engineers, technicians, male and female audience) and to provide continuous access to learning materials over long distances makes them key tools in paving the way for scaling up energy access.

Risks and challenges

Progress monitoring platforms and impact measurement offer valuable insights into the effectiveness of energy access programmes and help identify areas for improvement. However, certain risks should also be considered:

Data availability and security
Data collected for the platforms may not always be available or may not be accurate and reliable enough to support informed decision-making. Concerns about data privacy and security might also pose a risk, particularly if sensitive information is involved.

Affordability
Affordability constraints can pose significant barriers to the implementation and utilization of progress monitoring platforms, particularly in resource-constrained settings. Costs associated with data collection, analysis, and platform maintenance may exceed available budgets, limiting the potential to set up these tools.

Digital literacy
With regards to learning and training platforms, one must mention digital literacy and social sustainability as a further challenge. Experience has shown that platforms, particularly those developed within the context of development cooperation, frequently overlook or inadequately include certain demographic groups, for example individuals with limited education and digital literacy, women, as well as poorer and older populations.

35 https://new.renewables-salone.info
36 https://sacreee.org/index.php/article/launch-cornerstone-rural-electrification-core-initiative

Summary table – “digital toolbox” for learning, analysis and capacity building

The following table summarizes the classification of the digital tools of this section including a (qualitative) assessment of each tool’s potential for scaling up energy access as well as the related risks and challenges

Tool	Area of application	Suppliers / Examples	Drivers for scaling	Risks and challenges	Scaling potential
Progress monitoring platforms / dashboards	Steering of energy access programmes Visualisation of KPIs Reporting	Odyssey Prospect OMIS platform (EnDev Rwanda)*	Support Decision Making	Data availability Affordability Data Security/Privacy	*High*
Impact measurement	Assess socio-economic and environmental impact of ongoing energy access projects	ERIS South Africa	Support Decision Making	Data availability Affordability Data Security/Privacy	*High*
E-learning / Exchange and learning platforms	train engineers, technicians or other stakeholders	SACREEE IT4Renewables (EnDev Sierra Leone)*	Capacity Building	Digital Literacy (social) Sustainability	*High*

*details: see Annex

2.5 Digital Tools for Demand Stipulation and Consumers

This section is dedicated to the role of the user in the value chain of energy access projects. The beneficiaries - be it households, small businesses or public institutions (health centres, schools) – are paramount for scaling up energy access markets: their needs and desires ultimately determine the demand for products and services and influence the development of solutions offered by the private sector. Only tangible benefits for the users, such as improvements of livelihoods and better prospects for the socio-economic situation, can guarantee the success of energy access projects. Therefore, the design of new solutions – also digital solutions – should be considerate of the users' needs and take into account the local socio-economic conditions. Ideally, users should also be "empowered" by such solutions, i.e., receive autonomy over their own decisions, actions, and interactions, especially when new technologies enter the energy access sector. This category therefore aims on tools, which stipulate the demand of the consumers for energy solutions taking into account their specific needs.

Overview of tools

Comparison platforms for off-grid appliances
A good example of a digital tool promoting such user empowerment are c**omparison platforms for off-grid appliances.** The VeraSol Platform[37], operated by Lighting Global and ESMAP is a freely accessible online platform that enables rural customers to identify and compare various types of off-grid products on the market, such as solar home kits, domestic appliances or productive use equipment. The platform, which can be accessed via a standard web browser, helps users choose the product that best meets their needs in terms of performance and quality, thereby also encouraging competition and innovation between the manufacturers.

Smart appliances
In some cases, the domestic appliances themselves are equipped with digital functions. A prime example of such smart appliances are e-cookers with digital features. In Bangladesh, EnDev supported the local development of an improved electric pressure cooker (EPC)[38] which has an integrated electricity meter and a digital tool to control cooking time. Thanks to these features, users can control their energy consumption and manage their cooking behaviour to save electricity and money. Similar developments are taking place in other parts of the world. PowerUp[39], a Uganda-based e-cooking start-up, likewise offers e-cookers with digital electricity meters, which even have a data interface that allows them to be integrated into PAYGO systems. In principle, the approach of outfitting end-user devices with digital features to manage electricity consumption can be imagined for all types of end-user appliances, provided that this digitization is economically viable and brings benefits to consumers. Moreover, digitalization in Bangladesh enhances the efficiency and sustainability of solar-powered charging stations for e-rickshaws (see text box below). Productive use of energy (PUE) equipment, for instance, is an area with great potential for introducing digital innovations into the hardware of a variety of agricultural machinery, food processing, cooling, freezing, drying or irrigation equipment. In Malawi, EnDev supported the MAEVE[40] Project in equipping digital PAYGO devices into solar portable water pumps for "pump-preneurs" offering irrigation services to smallholder farmers. Similar smart irrigation devices are also offered by the start-up Pay'N'Pump[41] in Uganda.

Customer service
An often-overlooked aspect in the work with rural clients is **customer service**. Certainly, remote monitoring systems (section 2.1.4) or PAYGO systems can inform rural energy service providers about service needs - but this information reaches the service company without direct interaction with the end-user. A user-centric digital tool that facilitates user communication are Unstructured Supplementary Service Data Codes (USSD-Codes). Being usually entered via the keypad of a mobile phone USSD codes offer several advantages, as they require only simple mobile phones without internet access or special apps. This makes them more accessible to users in rural areas, where not everyone has a smartphone or a stable internet connection. EnDev Kenya has developed a USSD scheme to improve customer service and facilitate the communication between enterprises and end users for a biogas development project. This project picks up on a widespread trend in Kenya, where USSD codes are often used by public service providers, for example by the state-owned power utility[42] to interact with the customers, who can manage their bills, report outages, or apply for new electricity connections

37 https://data.verasol.org/
38 https://waltonbd.com/kitchen-appliances/multi-cooker-electric
39 https://www.powerup.works/products
40 https://maeveproject.mw/
41 https://paynpump.com
42 https://www.kplc.co.ke/content/item/3671/kenya-power's-977

via this digital tool. There are undoubtedly other examples of digital customer service that could be imaged. For example, QR codes could be used not only for product tracking (see chapter 2.1.4), but also to give customers via smartphone scan access to product information as well as real services.

Scaling potential

What is the potential of user-centred digital innovations to scale up energy access? As the tools presented in this section have a rather indirect effect, it is difficult to make a clear assessment.

Demand stimulation
Product comparison platforms, for instance, unlock scalability through demand stimulation, as they enable users to make informed decisions when purchasing energy access devices. However, similar to marketplaces (see section 2.1.5) they face certain difficulties (digital literacy, acceptance of the platform) and therefore receive only a medium potential. The same goes for the smart appliances. Their potential for scaling would be rated high, if truly ground breaking disruptive products, attracting masses of consumers, were on the horizon.

Cost reduction
However, the identified user innovations (digital e-cookers, smart irrigation devices), only cover market niches, and hence justify so far only a low rating of the scaling potential. As customer service is a relatively important element in improving user acceptance, digital innovations in this area (such as the USSD system) are assigned a medium potential for scaling up energy access, if they come along with reduced service costs.

Enhancing E-Rickshaw Operations: The Digital Pathway to Sustainability and Efficiency

The digitalisation of energy access in the context of e-tuk-tuks in Bangladesh brings numerous benefits to both garage owners and drivers, revolutionizing the traditional charging process while leveraging renewable energy sources. The integration of grid-connected solar systems into the garages offers a sustainable solution, reducing reliance on conventional energy sources and mitigating environmental impact. By harnessing solar power, garage owners can access clean energy without incurring additional costs, enhancing their operational sustainability, and contributing to a greener future.

Moreover, the implementation of a net metering system allows garage owners to not only consume solar electricity but also to feed surplus energy back into the grid, potentially generating additional revenue streams. This incentivizes the adoption of renewable energy technologies and promotes energy self-sufficiency within the community. The digital features incorporated into the charging process enable intelligent management and remote monitoring, enhancing efficiency and reliability. The remote monitoring system allows for real-time monitoring of charging activities and solar feed-in, providing valuable insights for optimization and troubleshooting. Payment via mobile money provides convenience, security, and accessibility for transactions, reducing reliance on cash and facilitating seamless payments. This ensures optimal performance of the charging infrastructure, minimizing downtime and maximizing productivity.

Digitalisation enables more efficient and sustainable operation of charging stations, resulting in cost savings for E-rickshaw drivers, longer battery life, and reduced charging tariffs. These benefits not only enhance the economic viability of electric vehicle usage but also contribute to the growth of the customer base, driving further adoption of clean transportation solutions. By embracing renewable energy technologies and leveraging digital innovations, Bangladesh's transportation sector can pave the way towards a more sustainable and resilient future.

Risks and challenges

The risks and challenges of the digital tools developed for the user, are mainly related to digital literacy, social acceptance, adequacy and affordability.

Digital literacy
Comparison platforms for energy access products are effective only if a substantial number of users visit them and are capable to use the information to enhance their purchasing decisions. Individuals with higher digital literacy are often more likely to trust online platforms and engage in online shopping, which directly impacts their willingness to visit and use comparison platforms effectively. Therefore, enhancing digital literacy among users can significantly boost the utility of these platforms by increasing user trust and facilitating better-informed purchasing decisions.

Affordability
The key challenge for user-centric digital innovations of new products (or services) is often their affordability. New products must demonstrate that users are willing to pay a premium for the digital features (e.g. the digital electricity meter in an e-cooker) as it offers added value and benefits. Obviously, also the appropriateness of the digital solution to the specific socio-economic context is a recurrent challenge that has to be carefully assessed. A solution that might work in one context (or country) might not the adequate answer to the energy access situation in another context.

Summary table – "digital toolbox" for demand stipulation and consumers

The following table summarizes the classification of the digital tools of this section including a (qualitative) assessment of each tool's potential for scaling up energy access as well as the related risks and challenges

Tool	Area of application	Suppliers / Examples	Drivers for scaling	Risks and challenges	Scaling potential
Product comparison platforms	Allow users to identify and compare off-grid products on the market	VeraSol Platform	Demand stimulation	Digital literacy Sustainability (maintenance, credibility)	*Medium*
Customer service	Facilitate the interaction between users and service providers / suppliers of energy access products	USSD code for customer service (EnDev Kenya)*	Cost reduction (service costs)	Digital literacy Adequacy Communication infrastructure	*Medium*
Smart appliances	Smart devices to improve user acceptance	Electric pressure cookers (EnDev Bangladesh*, PowerUp Kenya) Smart irrigation devices (MAEVE Malawi, Pay'N'Pump Uganda)	Demand stimulation	Affordability Adequacy Communication infrastructure	*Low*

*details: see Annex

2.6 Digital Tools for Market Platforms and Matchmaking between Energy Suppliers, Consumers, Financiers, and Innovators

Achieving the global goal of universal access to modern energy services requires a growth-oriented, market-driven approach. Only functioning, efficient markets can ensure that energy access products and services reach the large number of customers in the still unserved regions of the world. In an ideal scenario, such markets should be self-sustaining: Interested customers from rural areas buy on their own initiative (possibly supported by micro-loans or subsidies) the energy access devices best suited to their needs, which are then supplied, installed and maintained by local companies. We collect and assess tools in order to show how they can help create, establish and scale such markets.

Overview of tools

Digital marketplaces
One possible approach is to encourage the matchmaking between customers and businesses on so-called **digital marketplaces**. EnDev Sierra Leone is about to set up a web-based marketplace platform – "IT4Renewable Marketplace[43]" which shall allow individuals, businesses, and experts to highlight their products and services. The application (which is about to go online likewise in Liberia and Guinea) will also be used for quality control and certification and awareness building.

Sector web portals
Another example, closely linked to digital marketplaces are **off-grid product comparison platforms** which are featured in more detail in Section 2.5. These platforms, and in a broader sense, all kinds of **sector web portals** fulfil the function of market development. In the framework of the IT4Renewable project of EnDev Sierra Leone, a new web portal overview of the national energy access market in order to facilitate the exchange among its stakeholders. The portal suite of EnDev Liberia also includes an education and learning platform which will be presented in Section 2.4.

QR codes
An interesting alternative to the conventional field verification tools has been developed by EnDev Senegal for a cook stove dissemination program. For this project, **QR codes** are printed on a sticker and subsequently attached to cook stoves manufactured in local workshops. The scanning of QR codes at different stages makes it possible to monitor the entire distribution chain (retailers, distributors, dealers) and ultimately prove that the product has reached the end user. Furthermore, the collected data is fed into a platform for gaining a better market overview. The platform improves knowledge of the traceability of improved cook stove distribution and facilitates timely data collection and analysis.

Smart contracts
For the sake of completeness, one could also mention **smart contracts** as potential elements of digital market development. Smart contracts – for instance based on block chain protocols – can be used in peer-to-peer electricity schemes on mini-grids in rural electrification, where consumers (prosumers) actively participate in energy trading, and thereby creating markets or energy exchange[44].

43 https://new.renewables-salone.info

44 Kirli, Desen, et al. "Smart contracts in energy systems: A systematic review of fundamental approaches and implementations." Renewable and Sustainable Energy Reviews 158 (2022): 112013.

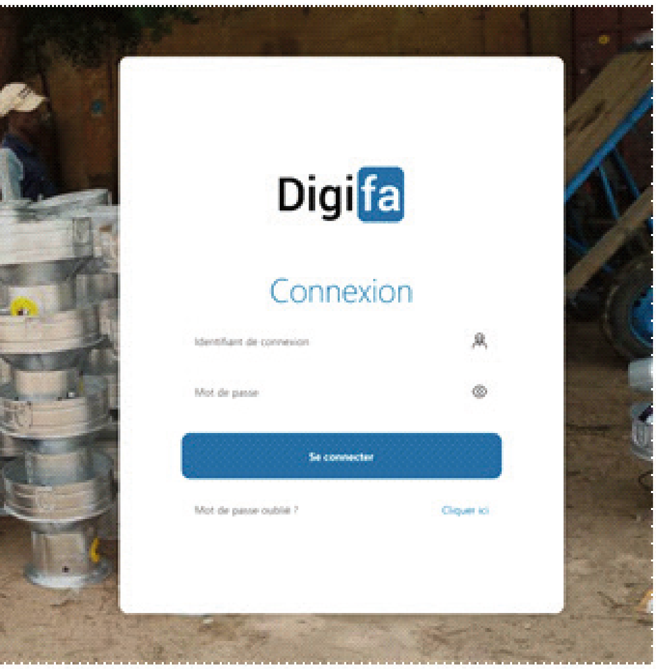
QR Code Tracking: A Game-Changer in Senegal’s Cook Stove Distribution

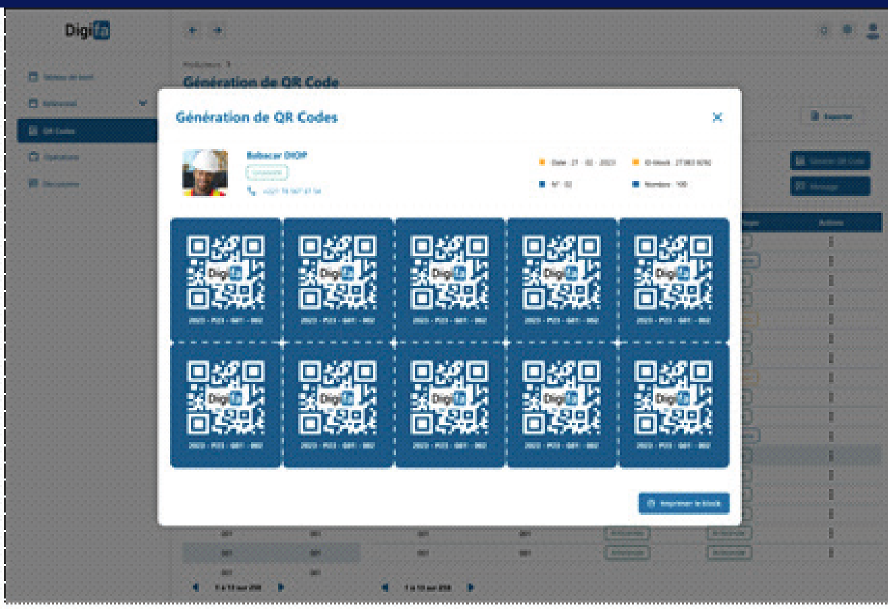
A digital marketplace represents a ground breaking advancement for the improved cook stove production and sales management in Senegal. By integrating a database management system with a Geographic Information System (GIS), this platform offers a comprehensive solution for monitoring, reporting, and verification processes, ushering in a new era of efficiency and effectiveness.

In Senegal, where access to clean cooking solutions is crucial for public health and environmental sustainability, this digitalisation strategy holds immense promise. With nearly 83 % of rural households relying on traditional biomass for cooking, the platform’s ability to streamline the distribution of improved cook stoves is particularly significant. By providing stakeholders with real-time insights into cook stove production, distribution, and sales, the platform enhances the traceability and transparency of these essential devices. This transparency not only fosters accountability but also instils confidence in consumers, encouraging widespread adoption of improved cook stoves across communities. Moreover, the digitisation of data collection tools streamlines processes and eliminates inefficiencies, enabling stakeholders to make informed decisions promptly. This agility is particularly valuable in a dynamic environment like Senegal, where adapting strategies in response to changing needs and circumstances is paramount.

A novel feature of this platform involves the incorporation of QR codes printed on stickers attached to each new cook stove manufactured in local workshops. These QR codes are scanned at different stages of the distribution chain, including retailers, distributors, and dealers, ensuring accurate tracking of the cook stoves’ journey. Finally, the QR codes can also be scanned to provide proof that the cook stove has arrived at the end user, further enhancing accountability and transparency in the distribution process.

This innovative platform, with its QR code tracking system, represents a significant step forward in advancing public health, environmental sustainability, and socioeconomic development in Senegal. By leveraging digital technology and innovative solutions, it empowers communities and fosters a cleaner, healthier future for low-income households. Before the introduction of digital tools, the distribution of these stoves was inefficient and lacked transparency, hindering their adoption. Now, with a digital marketplace integrated with GIS and QR code tracking, the process is streamlined, providing real-time insights and enhancing accountability, thereby encouraging wider adoption and improving livelihoods.





QR Code generation for a producer :

This is an interface for an administrator to generate a QE code for an FA producer.

Scaling potential

Digital tools for market development are instruments that unfold their scaling potential in a rather indirect way:

Aggregation
Market platforms can significantly enhance the scalability of energy access in digital markets by facilitating the aggregation of large volumes of data, customers, and financial flows. These platforms can promote and compare products, facilitate access to information, and create matchmaking opportunities between consumers and producers. This not only increases efficiency but also democratizes access to energy solutions by connecting those in need with providers, thereby fostering a more equitable distribution of resources. Additionally, the aggregation of data can lead to insights that inform policy decisions and investment strategies, further accelerating the scale-up of energy access.

Demand stimulation
Although it is difficult to measure this kind of impact, there is no doubt that well-designed market platforms (marketplaces, product comparison platforms and sector web portals) offer a certain scaling potential as they stimulate demand and foster the exchange of information, ideas and expertise in the sector, and with this competition on the supply-side and thereby serving as a catalyst for scaling up energy access. Due to certain limitations and risks related to the mainstreaming of these platforms (see paragraph below), their overall scaling potential is currently only rated as medium. Digital contracts have so far lacked to prove their impactfulness for the energy access sector, and, despite pilot electrification projects where they are in use (P2P electricity exchange), their general ability to scale up is deemed to be low.

Risks and challenges

A significant hurdle for web portals or digital marketplaces is maintaining their relevance and interest for their intended audience over an extended period. Unfortunately, some web portals and digital marketplaces struggle to reach the essential user base required for the network effect[45] to become effective, despite having access to both online and offline networking opportunities.

Sustainability
Very often, especially in the development context, web portals struggle to attract and retain users in the long run, which ultimately may lead to their abandonment after a few years of operation. Therefore, in order to ensure their sustainability, web portals require regular maintenance and updates to keep content fresh and interesting. Moreover, effective promotion is essential for driving traffic to the web portal. If updates are infrequent or non-existent, users may lose interest and the portals may fall idle.

Digital literacy
For portals addressing rural populations (e.g., energy access product comparison platforms), a lack of digital literacy can also pose a risk to the uptake of such platforms. Rural communities may also be generally sceptical or reluctant to the use of online platforms; hence building trust and credibility among rural consumers is crucial for the success of digital marketplaces.

Data security
Trust and security concerns are also the key concerns for the use of smart contracts in the energy access sector. In the case of peer-to-peer electricity trading, a high level of trust is required between participants and robust security mechanisms need to be set up in order to prevent fraud or unauthorized access. Overcoming legal and regulatory barriers can also be a challenge when dealing with smart contracts. Very often, the question of adequacy is also raised, i.e., whether smart contracts are actually the appropriate and best-suited means, especially in project environments where only very small amounts of energy are exchanged among the users.

45 The network effect is the phenomenon where the value of a product or service increases as more people use it, leading to a positive feedback loop that enhances its utility and appeal.

Summary table – “digital toolbox” for market platforms and matchmaking development

The following table summarizes the classification of the digital tools of this section including a (qualitative) assessment of each tool’s potential for scaling up energy access as well as the related risks and challenges

Tool	Area of application	Suppliers / Examples	Drivers for scaling	Risks and challenges	Scaling potential
QR codes	Product tracking, facilitate payment transactions, data collection, user feedback mechanisms, market transparency	EnDev Senegal*	Cost reduction Aggregation, Demand stimulation	Adequacy Digital Literacy	*High*
Digital marketplaces	Matchmaking between customers and businesses	EnDev – IT4Renewable Marketplace (Sierra Leone)*	Demand stimulation	Digital literacy Sustainability (maintenance, credibility)	*Medium*
Sector web portals	Inform about products and services, create community of players in the sector	ITRenewable Web portal (Sierra Leone)*	Demand stimulation	Digital literacy Sustainability (lacking maintenance, credibility)	*Medium*
Smart contracts	Peer-to-peer electricity exchange	ME Solshare, (Bangladesh)*	Cost reduction	Data security Sustainability (social acceptance) Adequacy	*Low*

*details: see Annex

2.7 Digital Tools for Operation and Management operation and management

What digital tools exist that can enhance the scalability and efficiency of managing and operating energy access projects? Of all the phases of the project value chain, the operation and management phase is probably the most critical one. Customer payments have to be guaranteed, the quality of the equipment has to be ensured, and this over a period of several years and often for a large number of (dispersed) customers in remote rural areas where on-site interventions and investigations are very expensive. These barriers are addressed by a number of digital tools designed for system operators, rural service companies, project owners or national/international development agencies.

Figure 3. International Players and value chain of PAYGO systems. (Source: EnDev)

Pay-As-You-Go (PAYGO)
The most prominent tool, PAYGO, is today a widely accepted standard in large energy access projects where customer payments for energy services must be managed. PAYGO systems are mostly used in the field of rural electrification projects (mini-grids, SHS), but there are also attempts to apply them in the clean cooking sector[46]. PAYGO is a prime example of the convergence of several digital and ICT technologies: mobile money, smart meters, smartphone apps, remote data communication, mobile networks, IoT and data processing. Due to time and space limitations, an exhaustive description of all aspects and features cannot be given in this report, but there are several studies[47,48] dealing in detail with PAYGO technologies and businesses, including a scoping study by EnDev49, which provides a structured analysis of the PAYGO sector (see figure below) and the experiences with PAYGO from a practitioner's perspective.

Remote monitoring
The key feature of PAYGO, the ability to remotely control and potentially lock or disconnect the system in the event of non-payment by the customer, is closely linked to the second key digital tool for energy access project management in which it is often embedded: remote monitoring. Connected via a telecommunications link to a (cloud-based) server, remote monitoring systems are especially appreciated in the mini-grid sector, as they allow to monitor in real time a range of technical parameters such as the performance of the generation system, the distribution system (smart meters) or the battery status. Monitoring systems provide companies managing rural energy assets with the data they need to plan and optimize maintenance operations, reducing the frequency of component replacements as well as logistics and labour costs.

Digital platforms
One form of 'extended' remote monitoring is monitoring platforms. These can be used to monitor entire portfolios of mini-grids, even from different suppliers installed at different locations. Commercial monitoring platform solutions are for instance offered by Powerhive[50] as well as the Dutch company AMMP[51]. The high amount of data that could be potentially processed by a monitoring system has motivated developers to conceive various sophisticated analytical tools, such as AI-based algorithms for fault detection and predictive maintenance that are claimed to significantly reduce operation costs.

Management tools
The concept of remote monitoring platforms is taken to the next level in so-called management platforms which, besides monitoring of technical parameters, can also facilitate project management, coordinate finance, and even manage procurement processes (tender management) within rural energy projects. Odyssey Energy Solutions[52] is a commercial provider of such a platform, but still very often project owners develop themselves in-house solutions specifically tailored for the framework of their projects. Users of management platforms are often larger national entities (regulators, rural electrification authorities) as well as implementing agencies that need to supervise and manage large energy access programs in an efficient manner. The EnDev community has quite some experience with such management platforms, using them mainly for RBF management. For example, a project of EnDev's sister project GBE (Green People's Energy) uses the platform Odyssey to manage RBF applications for productive use equipment, and to verify the installation of the assets remotely. Another example is a tailor-designed platform for EnDev Kenya (ABC project/Sofy, developed by KMPG) which is used for RBF verification of bio digester sales. Besides the aforementioned examples of commercial or customized platforms, there are also attempts to establish open-source, free solutions. The platform Prospect[53] is such an example. Developed by the Access to Energy Institute (ATEI), it is intended to be versatile enough to adapt to a variety of monitoring and verification contexts in different countries.

Field verification
In rural energy access programs, even fully digitally managed, the RBF verification process still often requires site visits to confirm the actual installation and performance of the equipment on the ground. Here, digital field verification tools come into play. In a project on productive use of energy in Benin,

46 PAYGO for clean cooking addresses mostly higher tier cooking components, for instance LPG cook stoves with digital smart meters connected to the gas cylinder (example: https://www.paygoenergy.co/).
47 For example: Mazzoni, D. 2019. Digitalization for Energy Access in Sub-Saharan Africa. Challenges, Opportunities and Potential Business Models. FEEM Working Paper No. 2 2019.
48 https://www.lightingglobal.org/resource/paygo-market-attractiveness-index-2021/
49 https://endev.info/wp-content/uploads/2022/06/Scoping-Study-Enabling-Environment-for-PAY-AS-YOU-GO-for-Energy-Access-in-Ethiopia.pdf
50 https://www.powerhive.com/technology - Honeycomb
51 https://www.ammp.io/
52 https://odysseyenergysolutions.com
53 https://prospect.energy

field verification agents use the tool Kobo Toolbox integrated into Odyssey to carry out surveys of the project's implementation process. Another example is from Liberia, where EnDev developed its own survey tool, an Android-based mobile app (RE Collect App[54]) for monitoring the status of renewable energy in the country.

Scaling potential

The most prominent tool featured in this section, PAYGO, is also the one with the greatest scaling potential. PAYGO is the prime example of the success of a single digital solution for scaling up energy access as one interview partner pointed out it "revolutionized the energy access sector".

Cost reduction
Many large electrification projects – especially those with a high number of customers - would not be manageable without PAYGO: by allowing customers to pay for energy services incrementally, and by operating these payments in a smart way (e.g., mobile payments) PAYGO models have helped, since their introduction in the late 2000s, to mainstream energy access solutions for large parts of rural populations in various countries. Despite certain risks and challenges (see next section), PAYGO therefore still has a paramount role to play, especially in the field of rural electrification with minigrids and SHS as it's reducing costs for payment transactions.

Aggregation
Remote monitoring and monitoring platforms, which are sometimes used in association with PAYGO, also offer interesting potential for scaling. However, it must be emphasized that this potential is more on the level of efficiency gains (e.g. in terms of lower maintenance, logistics and labour costs), which primarily benefit rural energy service companies or mini-grid operators. One can only speak of high scaling potential for the energy access sector under the assumption that the efficiency gains are substantial enough to counterbalance the increased costs of hardware and software for monitoring systems (see next section on risk and barriers), and that these gains can indeed lead to the expansion and extension of additional systems or projects.

Regarding management platforms (e.g., for RBF management) it can be stated that they likewise have promising scaling potential. Designed specifically to facilitate the management of large energy access programs, they are garnering increasing interest in the implementing agency community, including EnDev, but also beyond. By streamlining processes and minimizing the need for manual intervention, organizations can allocate resources more efficiently, allowing them to reach more beneficiaries within the same budget. Set aside certain compatibility and interoperability barriers (see next paragraph), the fact that management platforms are already in widespread use proves that they are on the verge of becoming a standard digital tool, like PAYGO, for the upscaling of energy access projects.

Field verification tools allow for efficient collection of data about infrastructure, households, and communities, making them essential tools for organizations managing large energy access project. As mentioned previously, field verification tools are very versatile and can also be used in other context of the ecosystem, for example for project planning. Given their indispensability and widespread adoption, they exhibit significant potential to contribute, in conjunction with other (management) tools, to scale-up energy access projects, while still requiring on-site interviews, which limits the scaling potential to a medium level.

54 https://collect.renewables-liberia.info/

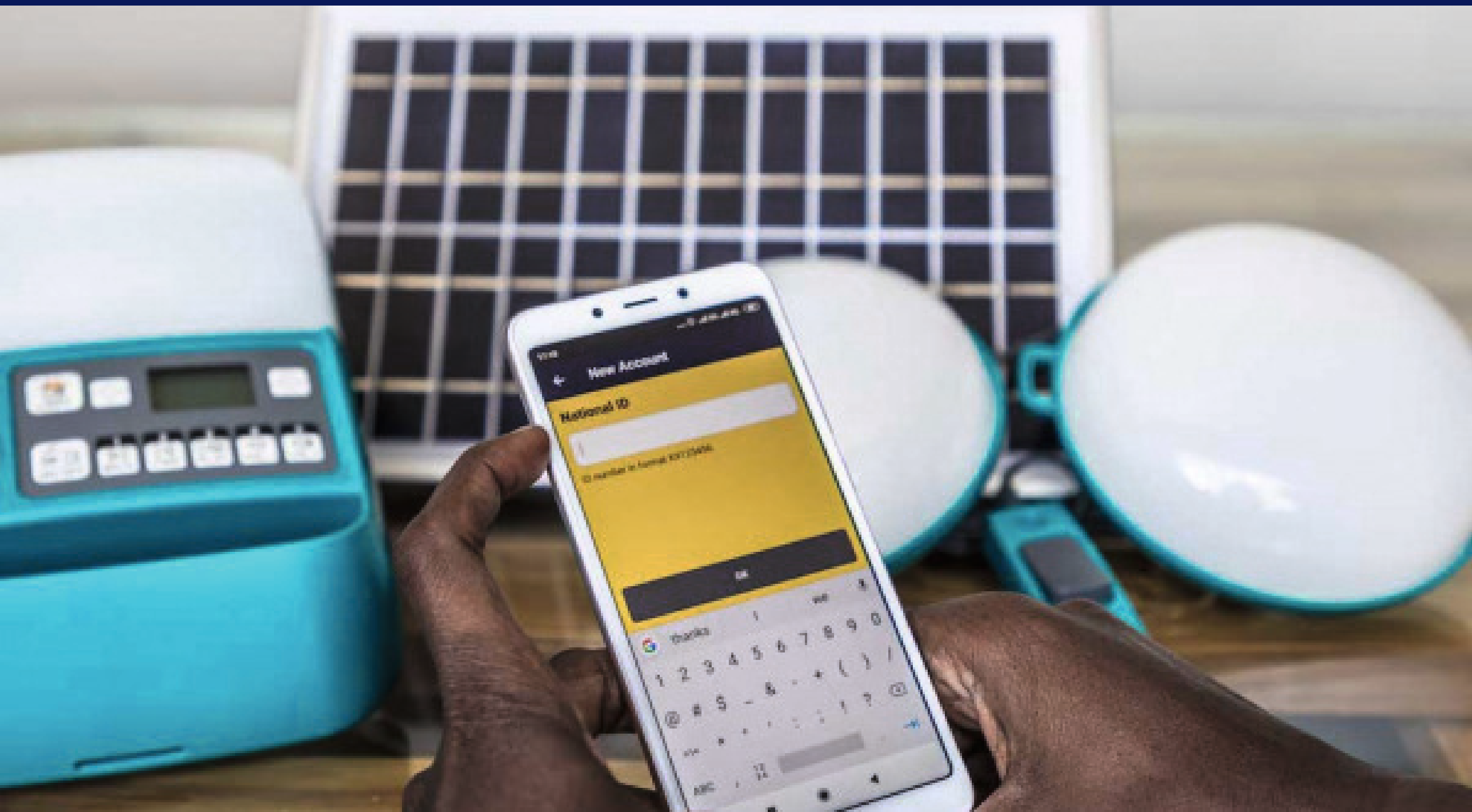
From Labour to Light: The Impact of Digital PAYGO in Malawi

The Yellow and Maeve projects in rural Malawi have demonstrated the transformative power of Pay-as-You-Go (PAYGO) systems in providing energy access and improving the lives of local communities. In the solar irrigation project, farmers transitioned from traditional, labour-intensive water pumping methods to a smart, clean energy-powered system. This not only improved efficiency but also offered more flexibility through instalment payments and group purchases, enabling those with limited financial means to access the technology.

Similarly, in the solar home system project, low-income households that previously relied on candles for lighting were provided with solar panels through a PAYGO model. This allowed them to pay gradually over 24 months, after which they owned the system without the need for further payments. The system was designed to automatically lock in case of payment default, but the default rate was reported to be low, at about 1% and the interest rate on PAYGO is 50 %, which is spread out over the entire payment period.

The success of these projects has not only expanded energy access across rural Malawi but has also demonstrated the potential for scaling up such initiatives. By mitigating the financial risk associated with electrifying remote areas and utilizing data-driven insights to enhance operational efficiency, PAYGO systems have the potential to significantly enhance energy accessibility and affordability for low-income communities and remote regions.

The story of the PAYGO success in the Malawi project is a testament to the power of innovative financing models in driving sustainable energy solutions and fostering greater financial inclusion. It showcases how technology, coupled with flexible payment options, can truly transform lives and communities, paving the way for a brighter and more sustainable future for all. Before the introduction of these digital tools, farmers and low-income households struggled with traditional, labour-intensive methods and limited access to clean energy. Now, thanks to digital applications, farmers can switch to efficient, clean energy-powered irrigation systems, and households can afford solar home systems through flexible, instalment payments, significantly improving their quality of life and economic opportunities.



Capacity building
QR codes are a promising way to improve energy access, but it is not easy to assess their actual potential for scalability. This is due to the limited number of projects that have used QR codes, resulting in insufficient feedback to assess their impact on the energy access sector. However, QR codes are also very versatile, and many other applications beyond product tracking (such as the example mentioned in Senegal) can be imagined: For example, QR codes could be used for payment transactions (e.g. in combination with PAYGO), provide users access to product information, facilitate data collection and feedback mechanisms for energy access projects, or even provide access to training materials or educational content related to energy access issues. Because of this versatility, QR codes are also considered in this report to have high scaling potential.

Risks and challenges

Despite the high scaling potential of digital innovations in the field of operation and management, certain barriers and risks should not be forgotten.

Affordability
The feedback from practitioners interviewed for this report suggests that the relatively high additional cost of certain digital solutions might pose a barrier. PAYGO, for instance, requires hardware, telecommunication devices, and management software. As some practitioners pointed out, especially in low tier electrification programs (e.g. SHS with small system size), rural service companies often refrain from PAYGO features for cost reasons, all the more if the GSM coverage in remote regions is feeble and smartphone use is not widespread among the rural population. Also, a low digital literacy is seen as an obstacle to PAYGO expansion, as certain digital skills are required from the beneficiaries, for instance to carry out mobile payments.

Compatibility
With regards to digital management platform, experts have pointed to the recent proliferation of a variety of different platforms in use (commercial providers, but also self-developments), and expressed concerns about their compatibility and interoperability. To address these issues, a few things need to be considered before procuring or even developing a new platform: Platforms should be transversal, open source, compatible, and accommodate data from other APIs. This would promote the wider use of these platforms and make them interesting also for smaller players in the market. Some practitioners also expressed concern that very often only donors or international organizations are using digital management platforms, while government institutions (e.g. national rural electrification agencies) and other local partner are doing so to a lesser extent. To make the most of the collected data, and to facilitate and automatize data sharing and visualization, it would be desirable for national public institutions in partner countries to take ownership by adopting and operating digital tools themselves.

Adequacy
A general challenge related to all digital tools featured in this section is the question whether their use is the adequate solution for the specific project context. Several interviewed experts reminded that it should be carefully scrutinized whether the implementation of new digital tools for management and operation provides real added value for the project. “Digitalisation for the sake of digitalisation”, as one expert pointed out, should be avoided if non-digital measures would be more appropriate - for example training the skills of local technicians and repair personnel might often improve the quality of operation and maintenance of rural energy systems better than setting up high-end digital monitoring systems.

Summary table – "digital toolbox" for operation and management

The following table summarizes the classification of the digital tools of this section including a (qualitative) assessment of each tool's potential for scaling up energy access as well as the related risks and challenges

Tool	Area of application	Suppliers / Examples	Drivers for scaling	Risks and challenges	Scaling potential
Pay as you go (PAYGO)	Facilitate payment transactions	Various suppliers (see overview in Figure 3)	Cost reduction (payment transactions)	Affordability Adequacy Digital literacy Communication infrastructure	*High*
Remote monitoring / Monitoring Platforms	Monitoring of the technical status of energy access systems, predictive maintenance, fault detection	Odyssey Powerhive AMMP	Cost reduction (e.g., service and maintenance costs)	Affordability Adequacy Communication infrastructure	*High*
Management platforms	RBF management Procurement management	Prospect ABC project/Sofy (EnDev Kenya)*	Cost reduction (management costs) Aggregation	Affordability Adequacy Compatibility	*High*
Field verification tools	In conjunction with Management Platforms	Kobo Toolbox RE Collect App (EnDev Liberia)*	Cost reduction Aggregation	Affordability Adequacy Communication infrastructure	*Medium*

3 Scaling of EnergyAccess: Drivers and Risks

The previous section presented the classification of digital tools from the perspective of the project value chain, showcasing various examples from the EnDev context and beyond. Based on the tools presented in the previous section, it was also discussed which factors are essential to contribute to scaling up energy access and what challenges and risks are associated with using these tools – each of it in the specific context of the project value chain. It's important to note that the landscape of digital technologies and the energy access sector is constantly evolving, which may lead to the emergence of new tools not (yet) covered in the present overview. How can these tools be evaluated? This section aims to provide a guideline for evaluating future tools independently. By following this guideline, practitioners can assess the potential of new tools using their own resources and expertise.

3.1 Drivers for Scaling up

In this section, we explore the drivers of digital tools that enable the expansion of energy access and highlight their transformative potential to improve energy efficiency policy and practice. Digital operation and management tools like remote monitoring or PAYGO, can be seen as solutions to **reduce costs** as they facilitate managing energy access projects on the technical and operational level. Other tool types, like geospatial analysis, design software or field survey tools for project planning, rather serve to **minimize risks** associated with (planning) uncertainties. Digital tools to support finance and payment, likewise reduce (financial) transaction costs and minimize finance risks. Finally, a category describing the largest number of tools is platforms. Management and monitoring platforms, marketplaces or web portals are often seen as typical tools for scaling up energy access projects, as they **aggregate** large amounts of data and enable the efficient management of large numbers of customers or market participants. These qualities might be the reason why digital platforms are often so appreciated by national or international development agencies (including EnDev) or owners of large project portfolios. Other platforms, like web-portals, or training platforms rather promote energy access through learning and **capacity building**, while progress monitoring platforms and impact measurement can **support decision making**, by providing relevant information to governments, stakeholders and investors. One important driver for energy access should not be forgotten: the user. Digital innovations that directly bring added-value to the user, increase user-convenience and user-friendliness can **stimulate demand** for off-grid products and therefore also contribute to scale up energy access markets.

Table 1 summarizes these key drivers and lists some of the associated digital approaches and tools.

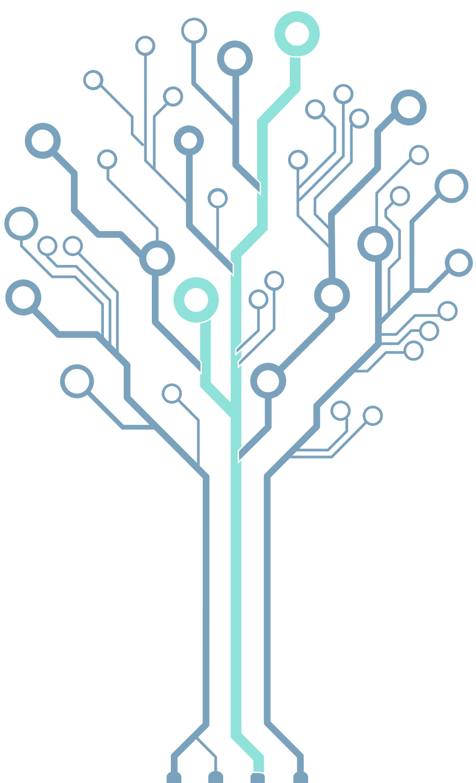


Table 1. Summary of key drivers for scaling up energy access with digital tools

Key driver for scale	Digital approach to support scaling	Digital tools
Cost reduction	• Reduce maintenance costs • Reduce planning / development costs. • Reduce cost of payment collection	• Remote monitoring • Geospatial planning • Project planning • Survey tools • PAYGO
Risk minimization	• Reduce planning risks. • Reduce project roll-out risks • Reduce finance risks	• Geospatial planning. • Design software • Survey tools • Loan eligibility platforms • Mobile loans
Aggregation	• Platforms to increase efficiency by aggregating large amounts of data, customers, financial flows.	• Monitoring Platforms • Management platforms • RBF Management • Crowdfunding Platforms
Capacity building	• Increase technical skills • Strengthen networks • Building / strengthening awareness on sustainability	• Training and e-Learning platforms • Exchange platforms
Demand stimulation	• Market transparency, make information available for the user • Increase user convenience • Improve customer service quality • Increase affordability for the user • Customer empowerment	• Marketplaces • Offgrid-appliances transparency databases • digital tools for improved customer service
Support decision making	• Measure and evaluate social and environmental outcomes • Improve data availability for informed decision making • build credibility and trust with partners and stakeholders	• Progress monitoring (dashboards) • Impact measurement

Practitioners may use this scheme to scrutinize whether new digital approaches – potentially envisaged in new energy access projects - actually support one or more of the drivers for scaling up energy access:

- Has the approach potential to aggregate in order to increase the efficiency of processes?
- Can risks be minimized (e.g. finance risks, project risks)?
- Can costs be minimized?
- Can learning and capacity building be promoted?
- Can demand be stimulated, i.e., are the solutions designed to meet the needs of the users?

3.2 Challenges and Risks

Having identified suitable digital solutions with a promising potential for scale-up, however, does not automatically guarantee their success in the actual project roll-out. During the workshops and interviews within the ELIA group on Digitalisation for Scale, practitioners pointed to a number of barriers and challenges they experienced in their efforts to digitalise energy access. Table 2 summarizes these main barriers, together with the corresponding mitigation strategies and the "lessons learned" from the energy access projects' experience.

Table 2. Challenges and risks associated with digital tools for energy access.

Type of barrier/ challenge	Description	Mitigation strategy / lessons learned
Data security and data privacy	GDPR requirements Companies/partners have concerns of losing control of their data Cybersecurity concerns.	Develop plan for data governance and data security Pre-assessment of tools with regards to GDPR
Digital literacy	Limited capability of the user to operate the digital tools, especially in rural areas, older people, analphabetism	Trainings, workshops User guide (e.g. in local languages) Adapt solutions to the socio-economic context, user-friendly design.
Data availability	Reluctance of companies/partners to share or disclose data Unavailability of data, outdated data, dysfunctional APIs	Non-disclosure agreements Pre-assessment of data supply sources Work with institutions to improve public databases Apply open-data approach
Communication infrastructure	Mobile network coverage in rural areas Availability of internet Telecommunication outages.	Communication infrastructure assessment Develop communication alternatives.
Compatibility	Compatibility of the tool with different systems or APIs Lacking interoperability of platforms	Define technical specifications Use only tools/solutions that work with standardized protocols.
Affordability	High extra costs for the digital solution	Cost-benefit analysis Modular and scalable solutions Work with open-source technologies
Sustainability issues	Solution is not ecologically or socially sustainable Digital divide. The solution does not address the gender, poverty and age gap.	Impact assessment prior to project implementation
Adequacy	Solution is not adapted to the specific socio-economic context of the project	Prototype testing Use of user-centric technologies

One of the most common barriers mentioned by practitioners is **data security and privacy**. Although energy access projects are certainly not a typical target for cyber-crime, data security and data protection have to be addressed when using or developing digital tools in this context. A recurring challenge, often mentioned by experts concerned with RBF-monitoring platforms, is the reluctance of local companies to share data or to automatize data exchange from their databases for fear of losing control over their data. Another common issue is complying with information privacy regulations, such as the EU's General Data Protection Regulation (GDPR), which must be adhered to in the global development context and which, according to certain practitioners, puts additional strain on energy access initiatives. Strategies for mitigating data security and privacy challenges include developing a plan for data governance and data security prior to project implementation, and evaluating digital solutions for their compliance with GDPR regulations.

By the very nature of energy access work, target populations often reside in rural areas where there is not only a lack of energy but also a lack of access to education. In this environment, it is often difficult to bring digital solution to the attention of potential user groups. In addition, elderly individuals may face difficulties with new digital technologies entering their daily lives. To overcome these barriers of **digital literacy**, several solutions can be proposed: user-friendly design, training programs, community workshops, user guides, and generally an emphasis on developing solutions adapted to the socio-economic context of the beneficiary groups.

A further barrier for implementing digital solutions in the energy access sector is lacking **data availability**. As mentioned above, there is the frequently-mentioned challenge of data availability from companies participating in RBF support schemes. But also, public data needed to implement energy access programs, such as census data, socio-economic indicators, geo-located information on infrastructure assets, etc., may be limited, especially in developing countries that lack the resources and infrastructure to effectively collect, manage, and disseminate data. One potential barrier removal approach would be to work with public institutions in order to improve data availability (creating databases, improving data access via APIs, etc.) and to conduct a pre-assessment of data sources. Non-disclosure agreements or open-data strategies could be a solution to the challenge of obtaining data from private sector partners.

Closely linked to the data availability challenge is the challenge of flawed or lacking **communication infrastructure**, which is often an issue in rural areas where mobile phone coverage is weak and internet access not available. A thorough examination of the conditions and possibly the search for alternative communication options could be ways of meeting this challenge.

The missing **compatibility** of digital tools can give rise to several concerns, hindering effective communication, collaboration, and efficiency of energy access projects. Practitioners have noted compatibility issues in particular with management platforms, which are often not interoperable and do not allow integration of different APIs from different data sources. Generally, addressing compatibility barriers involves careful planning, selecting interoperable tools, and prioritizing compatibility and standardized communication protocols when defining technical specifications for new digital tools.

Affordability. High additional costs associated with new digital tools in energy access projects require a strategic approach and a reflection on whether these solutions are actually effective in achieving the project objectives. Often it is useful – before starting a project - to conduct a thorough cost-benefit analysis to evaluate the potential benefits of integrating digital features. There are also other ways to reduce costs, for instance by choosing modular and scalable digital solutions or by working with open-source solutions (e.g., open-source planning software etc.).

Addressing **sustainability** barriers in digital solutions for energy access projects is crucial for ensuring long-term success and positive environmental, social, and economic impacts. It has to be carefully assessed whether the implementation of a digital tool actually provides sustainable benefits for the targeted communities (see here also the "Guiding Principles" for digital development, mentioned in Section 1.1. New digital solutions should also be assessed for their ability to bridge the "digital divide" and overcome gender, poverty and age gaps in achieving energy access. Finally, in terms of environmental sustainability, it should not be forgotten that many digital solutions (e.g. smart meters, data loggers, sensors, smartphones, ...) also generate electronic waste, the disposal of which is often a challenge in developing countries.

Sometimes, digital solutions, especially those designed and developed by foreign suppliers, are not adequately designed for the energy access challenges in a particular country or for a particular community. Solutions that worked in other areas, might not be applicable in the context of energy access. The block chain technology, for example, has yet to prove its usefulness in the field of rural electrification. **Adequacy** challenges can be avoided by conducting a thorough needs assessment to understand the specific requirements and challenges of the target communities, testing prototypes at a smaller scale, and consistently using user-centred technologies.

4 Conclusion and Recommendations

In conclusion, our extensive analysis of over 50 digital planning tools, supported by interviews with 20 experts and three workshops, has provided a comprehensive understanding of the potential of digital tools in scaling up energy access. As depicted in Figure 6, we have identified a structured approach to categorise these tools and evaluate their scaling potential.

Figure 5. Digital tools and their potential for scaling up energy access

	Planning and Development	Financing and Payments	Learning, Analysis and Capacity Building	Demand Stimulation and Consumers	Market Platforms and Matchmaking	Operation and Management
High Scaling Potential	Geospatial Planning	Loan Eligibility Platform	Exchange and Learning Platforms		QR Codes Market Overview	Remote Monitoring Platforms
	GISI AI Demand Estimation		Progress Monitoring / Dashboards			RBF Management Platforms
	Forecasting Algorithm		Impact Measurement			QR Codes, Value Chain Tracking
			Training Platforms			Pay-as-you-go
Medium Scaling Potential	Survey Tools	Mobile Loan System		Product Comparison Platforms	Digital Marketplaces	Field Verifications Tools
		Digital Scoring System		DigitalCustomer Service	Web Portals	
		Crowdfunding				
		Carbon Trading Platforms				
Low Scaling Potential	Design Tools	Digital Tokens		Smart Appliances/ Productive Use	Smart Contracts	
	Drone Imaging					
Scaling Potential not Determined		Digital Payments	E-Learning Services	User-centred Digital Innovations		Tender Management
			Data Research Centre	Demand Side Management		AI in RBF Verification
			Data Analytics			

The figure summarizes the main findings of the project, first the structure of the digital tools and their specific applications and second the ranking of the scaling potential. Within the categories “operation and management” and “Learning, Analysis, Capacity building” we found the most specific applications of digital tools with high scaling potential for energy access. Both include platform-based solutions which can be especially interesting for international development initiatives such as EnDev. Further scaling potential lies in planning and finance, while market development and design for the user look less promising.

Despite this categorization, it is important to see digital solutions not in isolation but as integral components of broader project value chains. The findings highlight that while individual tools may offer specific functionalities, the true potential for disruptive change lies in the strategic combination of these tools, tailored to the unique context of each project. This approach, which leverages the diversity of digital tools’ functional properties, is crucial for enhancing the scalability of energy access initiatives. The insights gained from this research underscore the necessity of a nuanced, context-specific approach to digital planning, emphasizing the importance of collaboration, adaptability, and continuous improvement in the pursuit of scalable and impactful solutions within the energy sector.

Scaling up energy access through digitalisation is a multifaceted endeavour driven by the need to reduce costs, minimize risks, and enhance sustainability. By leveraging digital platforms to aggregate data, streamline operations, and improve customer service, energy access can be made more efficient and affordable. This approach not only addresses immediate challenges in energy distribution but also lays the groundwork for a more sustainable future. As digitalisation continues to evolve, it will be crucial to balance the benefits of increased efficiency and accessibility with the need to protect the environment and ensure data security. This balance will be key to realizing the full potential of digitalisation in the energy sector. A summary of the determined key drivers for scaling up energy access through digitalisation is depicted Figure 6.

Figure 6. Key drivers for scaling up energy access

Key drivers for scale	Digital approach to support scaling
Cost reduction	• Reduce maintenance costs • Reduce planning costs. • Reduce cost of payment collection
Risk minimization	• Reduce planning risks. • Reduce proJect roll-out risks • Reduce finance risks
Aggregation	• Platforms to increase efficiency by aggregating large amounts of data, customers, financial flows.
Capacity building	• Increase technical skills • Strenghthen networks • Building/ strengthening awareness on sustainability
Demand simulation	• Market transparency, make information available for the user • Increase user convenience • Improve customer service quality • Increase affordability for the user • Customer empowerment
Support decision making	• Measure and evaluate social and environmental outcomes • Improve data availability for informed decision making • Build • Improve data availability for informed decision making • Build credibility and trust with partners and stakeholders • Credibility and trust with partners and stakeholders

However, along with the numerous benefits, there are also risks and challenges that need to be addressed to fully realize the potential of digital solutions in energy access initiatives. To overcome those, we conclude with the following recommendations to enable digital tools for scaling energy access in a safe and user-friendly way:

1. *Enhancing Data Quality and Security:* Addressing the risks associated with data quality and security is crucial for the successful implementation of digital tools. Ensuring reliable data sources, protecting sensitive information, and implementing robust cybersecurity measures are essential steps to mitigate these risks.

2. *Promoting Digital Literacy:* Improving digital literacy among stakeholders, especially in rural areas, is vital for maximizing the impact of digital financial solutions, market platforms, and user-centred innovations. Training programs and awareness campaigns can help bridge the digital divide and empower communities to leverage digital tools effectively.

3. *Ensuring Contextual Relevance:* It is important to carefully assess the appropriateness of digital solutions in specific project contexts. Tailoring tools to meet the unique needs and socio-economic conditions of target populations will enhance their effectiveness and scalability.

4. *Fostering Collaboration:* Encouraging collaboration among stakeholders, including government institutions, international organizations, local partners, and communities, is essential for promoting the adoption and sustainability of digital tools. Shared ownership and participation can drive innovation and ensure the long-term success of energy access projects.

5. *Continuous Monitoring and Evaluation:* Implementing robust monitoring platforms for impact measurement and progress tracking is essential for evaluating the effectiveness of energy access initiatives. Regular assessments can provide valuable insights for optimizing strategies, improving outcomes, and building trust among stakeholders.

6. *Investing in Capacity Building:* Supporting digital learning platforms for capacity building can empower diverse audiences to acquire knowledge and skills related to energy access. Investing in training programs that cater to different demographic groups will foster inclusivity and promote sustainable development in the sector.

By addressing these recommendations and overcoming the identified challenges, stakeholders in the energy access sector can harness the full potential of digital tools to accelerate progress towards universal energy access and sustainable development goals.

5 Annex

Mapping of Digital Tools / Endev & Partners

Country	Digital application (short title)	Project context	Type of digital application	Description	Project phase	Weblink / Contact (for further information)
Kenya	USSD customer service management.	SEE Clean Cooking – Biogas Sector Kenya	User-centric innovation	Unstructured Supplementary Service Data (USSD) platform that links bio digester enterprises and end users seeking using the USSD code. Feature available on both smartphones and mobile phones.	Operation and Management, Market Development	https://www.kplc.co.ke/content/item/3671/kenya-power%E2%80%99s-977 jimmy.kyalo@giz.de
Bangladesh	Smart charging management of electric Tuk-Tuks	Demonstration project with SREDA	User-centric innovation	Demand side management. Solar battery charging of E-rickshaws including grid connected net metering systems. Intelligent management of the charging process, remote monitoring of charging and solar feed-in, can be monitored from Endev's office.	Operation and Management	https://sreda.portal.gov.bd/sites/default/files/files/sreda.portal.gov.bd/page/2f04d85f_e1bb_4596_b37f_89cd63d91567/2023-01-08-04-07-5f99fb7e7a4c24fd0c70ec16f9436b04.pdf sen.sajib@giz.de

Sierra Leone	Business to consumer marketplace	IT4RE (IT for Renewables)	Marketplace Platform	This platform allows individuals, businesses, and experts to highlight their products and services (Business to consumer). Used for quality control and certification and awareness building. For clean cooking as well as electricity access. Applied in 3 regions (Sierra Leone, Liberia, Guinea) (part of IT4Renewables). EnDev works with RE association to get sellers into the market place.	Market Development	https://new.renewables-salone.info mohamed.harding@giz.de
Bénin	Remote monitoring of data from public health centres	Collaboration with Agency of Health Facilities, Equipment and Maintenance (AISEM), Access to Energy Institute (A2EI) and GBE	Remote monitoring	Solar systems with Smart meters for health centres. The Prospect platform allows relevant stakeholders to access, analyse and visualize key data on the status of power systems installed health centre power systems. Applied in 3 regions (Sierra Leone, Liberia, Guinea) (part of IT4Renewables). EnDev works with RE association to get sellers into the market place	Operation and Management, Planning	macaire.adjagba@giz.de
Rwanda	RBF Eligibility Tool	Pro Poor RBF	RBF management platform	Tool allows to check eligibility of customer by checking location, product and national ID (to cross check with socio-economic status of customer, OMIS and Government data	Operation and Management	https://www.gogla.org/wp-content/uploads/2022/12/case_study-_endevs_pro-poor_results_based_financing_in_rwanda_.pdf sarah.leitner@giz.de
Kenya	CaVex Platform for carbon credit trading.	Smart biogas & digital carbon trading pilot project (GIZ + SNV)	Finance Platform	Integrate smart biogas meters into the CaVex platform (cloud-based digital marketplace for carbon credit trading) to capture data and sell carbon credits.	Finance	https://fsdafrica.org/projects/carbon-value-exchange-platform-cavex/ jimmy.kyalo@giz.de

Kenya	RBF management platform for biogas sector	ABC project / Sofy Platform	RBF management platform	Information management and online verification platform for sales of Biogas enterprises, used for RBF. Implementation by KPMG. Also in Uganda, Burkina Faso, Niger and Mali.	Operation and Management	jimmy.kyalo@giz.de
Bénin	Odyssee for RBF management	GBE Benin Productive Use	RBF management platform	To receive applications online, give feedback and approve application, companies submit results, data validation / sanity check via verification dashboard; information can be sent to field / phone surveyors; Management and dashboard of entire program	Operation and Management	https://odysseyenergysolutions.com/financing-programs/gbe-benin-productive-use-rbf
Bénin	Kobo Toolbox	GBE Benin Productive Use	Field survey tool	Integrated into Odyssee; is used for surveys for field verification; verifiers go with tablets to clients to monitor implementation progress. Results are sent back via Odyssee	Operation and Management	https://www.kobotoolbox.org/ razvan.sandru@giz.de
Bénin	Prospects platform for monitoring of smart meters	GBE Benin Productive Use	Remote monitoring	Remote monitoring of RBF financed connections; direct integration of APIs of smart meters. Is also used as SDG 7 tracking platform, ideally directly connected with meters	Operation and Management	https://assets.website-files.com/64215dde2dcac-ceaa70d7bd9/645d1bc-2208687cd1785c5d4_Re-mote%20monitoring%20EN%20(March%202023).pdf razvan.sandru@giz.de
Sierra Leone	Online Learning Platform	IT4RE (IT for Renewables)	Learning Platform	Trains engineers and non-engineers, learn about renewables, production techniques and clean cooking, especially for technicians really useful, module-based platform (RE, clean cooking, etc.), collaboration with ECREEE to develop courses.	Learning, Analysis and Capacity Development	https://new.renewables-salone.info mohamed.harding@giz.de
Senegal	QR code for clean cooking stoves	EnDev Senegal	Management tool	Value chain verification of distribution of clean cook stoves. By scanning the QR code, the tracking of the cook stove until the end-user can be tracked	Operation and Management	https://endev.info/wp-content/uploads/2020/11/ESA-and-ESMP_Climate-Friendly-Cooking-in-Kenya-and-Senegal_EnDev_GIZ-FP-to-GCF_Englisch.pdf

Sierra Leone	EnDev Collect Application for SHS and mini-grids	Renewables Liberia	Field survey tool	App to collect data and to provide reporting on solar installations, mainly SHS and stand-alone systems. Helps government with data collection for energy access mapping, monitoring of power generation in country, track investment.	Learning and Capacity Development	https://collect.renewables-liberia.info/ mohamed.harding@giz.de
Rwanda	SHS and minigrid progress monitoring platform	Off-grid Monitoring and Information System (OMIS)	Progress monitoring	Developed by EnDev, funded by Power Africa. Online information system to consolidate electrification data from solar companies and mini-grid developers in Rwanda and provides analysis through a dashboard. The tool has a link to an RBF management component (ProPoor RBF).	Learning, Analysis and Capacity Development	https://www.gfa-bis.de/projects/BIS_Project_2018_3920103.html Yvette.ingabire@giz.de
Bangladesh	PAYGO for electric cook stoves	Clean cooking project	PAYGO	Developed by Endev's innovative partner. ATEC. Digital interface, monitor consumption per time, payment monitoring, give sound signal if instalment is not paid / disable cooking.	Operation and Management	https://www.ecookstove.com/bangladesh/bd-double-upfront-vs-monthly sen.sajib@giz.de
Bangladesh	Improved e-cooker with digital features	Clean cooking project	User-centric innovation	Improved rice cooker, developed with the support of Endev. The device has some digital features, like the metering of power consumption and a digital tool to control cooking time.	Design for the User, Market Development	https://waltonbd.com/kitchen-appliances/multi-cooker-electric sen.sajib@giz.de
Bangladesh	EnDev Surveys App	Clean cooking project	Field survey tool	EnDev Bangladesh uses this tool for the RBF verification for clean cooking.	Operation and Management	https://surveys.endev.info sen.sajib@giz.de
Bangladesh	ME Solshare, P2P electricity sharing	Nano-grid electrification	User-centric innovation	EnDev Bangladesh has supported peer-to-peer electricity sharing concept for household connection of ME Solshare	Design for the User	https://solshare.com/ sen.sajib@giz.de
Mali	EnDev Surveys App	Electrification of health centres	Field survey tool	EnDev Mali uses the EnDev Survey App monitor PV electrification at health centres	Operation and Management	https://surveys.endev.info

All Countries	EnDev ODM	Monitoring and Evaluation of EnDev projects	Monitoring	Fully web-based Online Data Management (ODM) platform covering the whole monitoring system to further improve efficiency of processes, increase transparency of methodologies and flexibility of data analysis	Progress Monitoring and Evaluation	
Mozambique	RBF dashboard	Off-grid energy project	RBF Management	Results based finance dashboard for off- grid energy expansion	Progress Monitoring, Operation and Management	https://www.faser.co.mz/
Nepal	Performance monitoring for Water Pumping	GRM Project	Monitoring	Remote monitoring system for water pumping stations	Operation and Management	https://endev.info/impact-stories/sanad-rai-shared-solutions-for-renewable-energy/
Indonesia	Remote monitoring	REMOS Project	Remote monitoring	Remote monitoring system for PV-minigrids	Operation and Management	https://endev.info/rural-electrification/
Indonesia	Smart payment system	EnDev, Start-up company - Newlight	Digital payment	Smart payment systems with a server, smart meter, and LoRA (low range network) technology for PV-minigrids	Finance	https://endev.info/rural-electrification/

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