Technology Collaboration Programme
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International Energy Agency
Photovoltaic Power Systems Programme

Task 18 Off-Grid and Edge-of-Grid Photovoltaic Systems

PVPS

Digitalization in Off-Grid Systems
2025

Report IEA-PVPS T18-05:2025

What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, India, Israel, Italy, Japan, Korea, Malaysia, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, the United Kingdom and the United States of America. The European Commission, Solar Power Europe and the Solar Energy Research Institute of Singapore are also members.

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What is IEA PVPS Task 18?

The objective of Task 18 of the IEA Photovoltaic Power Systems Programme is to find the technical issues and barriers which affect the planning, financing, design, construction and operations and maintenance of off-grid and edge-of-grid systems, especially those which are common across nations, markets and system scale, and offer solutions, tools, guidelines and technical reports for free dissemination for those who might find benefit from them.

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INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Digitalization in Off-Grid Systems

IEA PVPS
Task 18
Off-Grid and Edge-of-Grid Photovoltaic Systems

Report IEA-PVPS T18-05:2025

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AUTHORS

Main Authors

Philipp Blechinger, Reiner Lemoine Institute, Germany
Narges Chinichian*, Reiner Lemoine Institute, Germany
Jad Mhanna, Asantys, Germany
Stefan Trittler, Asantys, Germany

Editor

Michael Müller, OFRES, Germany

* Non-Task 18 collaborating co-author

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LIST OF ABBREVIATIONS

AC	Alternating Current
AI	Artificial Intelligence
CAD	Computer-Aided Design
CRM	Customer Relationship Management
DC	Direct Current
GHG	Greenhouse Gas
GIS	Geographic Information System
IEA	International Energy Agency
ICT	Information and Communication Technology
IoT	Internet of Things
O&M	Operation and Maintenance
PV	Photovoltaic (used in the context of solar PV)
RFP	Request for Proposals
SDI	Spatial Data Infrastructure
SHS	Solar Home System

EXECUTIVE SUMMARY

This report is intended for professionals and stakeholders in the off-grid energy sector who are either seeking to integrate digital tools into their projects or evaluating existing tools to enhance their system's performance. As off-grid energy systems expand to meet the needs of remote and underserved communities, the role of digitalization has become increasingly critical in optimizing their development, implementation, operation, and long-term sustainability. This report systematically explores the various digital tools available across each phase of the off-grid energy project value chain, offering valuable insights for decision-makers and practitioners.

The report is organized around four key phases of the off-grid energy project value chain: **Development**, **Implementation**, **Operation and Maintenance**, and **Capacity Development**. Each phase is analyzed in detail, with a focus on how digital technologies can be effectively leveraged:

1. **Development**: Tools such as Geographic Information Systems (GIS) and remote sensing are highlighted for their ability to optimize site identification and planning. These tools allow for precise assessment of spatial factors and local energy needs, ensuring that projects are technically viable and economically sustainable.
2. **Implementation**: Digital project management platforms and real-time tracking systems are explored for their role in streamlining procurement, logistics, and installation. These tools enhance coordination, ensure adherence to timelines and budgets, and support remote troubleshooting, particularly in challenging environments.
3. **Operation and Maintenance**: The report discusses the impact of IoT devices, sensors, and cloud-based platforms in facilitating real-time monitoring, predictive maintenance, and customer management. Additionally, advanced algorithms for dispatch and control, as well as digital financial tools like electricity price algorithms, are analyzed for their role in optimizing system performance and ensuring financial sustainability.
4. **Capacity Development**: Recognizing the importance of human capital, the report emphasizes the need for digital literacy and technical training. Digital platforms that support knowledge sharing and capacity building are essential for empowering local communities and ensuring the long-term success of off-grid systems.

To support the practical application of these insights, the report includes an annex that details over 60 different digital tools applicable to off-grid energy systems. Each tool is described in terms of its functionality, target application within the project value chain, and potential benefits. This comprehensive resource aims to assist readers in identifying the most suitable tools for their specific needs and project contexts.

In conclusion, this report serves as a guide for off-grid energy practitioners who are looking to harness the power of digital technologies to enhance the effectiveness and sustainability of their projects. By providing detailed analyses and a curated list of digital tools, the report equips readers with the knowledge and resources needed to make informed decisions and drive successful off-grid energy initiatives.

1 INTRODUCTION

Stand-alone photovoltaic (PV) systems are historically the first photovoltaic applications to spread worldwide through a natural market [1]. From small pico-PV applications to solar home systems (SHS), PV hybrid systems to large PV diesel systems and mini-grids, a wide range of professional and also industrial applications exist today. Applications with a few watts up to several megawatts can be efficiently realized with off-grid and "edge-of-grid" photovoltaic systems. For this purpose, different topologies exist, which can be implemented with the help of professional products from the industry.

For this report we focus on so-called mini- or micro-grids [2] [3] which serve several consumers within one distribution grid via on-site power generation. These systems are usually not connected to the central power supply systems and thus framed as “off-grid” systems.

The rapid growth of digitalization in all fields of technology, including the PV off-grid sector, necessitates the development of efficient and user-friendly guides for practitioners to comprehensively choose a desired tool. It also signifies the necessity for developers to identify a well-thought set of features they need to assess in their product to make them more useful for practitioners.

This report aims to fill the gap in collecting, classifying, and assessing digital tools in the PV off-grid sector. It goes beyond a static format, which is not in line with the fast-paced changes of digitalization, and embraces the dynamic potential for the community to contribute to and shape further developments in an open environment.

Outlines

In this report, we begin with a comprehensive exploration of the background of digital technologies and the off-grid sector. We explain our methodology for categorizing digital technologies within the off-grid project value chain and introduce the 4 areas, Development, Implementation, Operation and Maintenance, and Capacity Development along with their categories, and subcategories to which we have assigned these digital tools. The report is complemented by an annex that brief details about some of the digital tools we have identified in each category.

Following the classification section, we shift our focus towards introducing the seven dimensions we have established for assessing the innovation potential of digital tools. These dimensions, briefly summarized as interlinkages with other digital tools, user interfaces, process assistance, flexibility, transparency, data protection, and the potential for integrating AI, can be evaluated for each digital tool. This evaluation serves as a valuable measure for developers seeking to enhance their digital products. Alongside this report, we have included an open-source survey designed for assessing these dimensions, which is intended to aid the community in evaluating digital tools effectively.

To fully harness the digital capabilities of this report, readers are encouraged to view it as a piece of a larger puzzle. Its completion is contingent upon the accompanying online infographics, the current static version of the annex, and its dynamic digital counterpart on Energypedia, designed to facilitate community-driven improvements and updates, and the survey source. This survey can be readily circulated, as we have done in a pilot run, to evaluate digital tools comprehensively.

2 BACKGROUND

2.1 What are digital technologies

Digital technologies refer to the utilization of digital information and communication tools, such as computers, smartphones, the internet, and software, to create, process, store, and share information. These technologies have had a profound impact on society, transforming the way we live and work, and revolutionizing how we communicate, access information, and conduct business [4].

The widespread adoption of digital technologies has enabled individuals and organizations to connect with others around the world in real-time, access vast amounts of information from almost anywhere, and automate tasks that were once performed manually. Additionally, digital technologies have facilitated the emergence of new business models and industries, such as e-commerce, social media, and cloud computing. These advancements have ushered in an era of unprecedented connectivity, efficiency, and innovation, shaping the modern world and driving the rapid evolution of technology.

Information and communication technologies (ICT) are a subset of digital technologies and encompass tools such as computers, smartphones, and the internet. They are utilized for communicating, processing, storing, and managing information. Both ICT and digital technologies have had a profound impact on society, transforming the way we live and work, and creating new opportunities for innovation and growth in various sectors, including healthcare, education, transportation, and energy. In the energy sector, digital technologies play a crucial role in monitoring and managing power generation and distribution, optimizing energy consumption, and facilitating the integration of renewable energy sources.

Effective use of digital technologies requires several prerequisites. Firstly, access to digital infrastructure: This includes availability of devices like computers, smartphones, and tablets, as well as access to high-speed internet connectivity. Ensuring reliable energy supply is essential to provide this digital infrastructure. Digital technologies in energy systems can enhance their performance, but they also rely on them. Other prerequisites include digital literacy and data security: Users must possess the knowledge and skills to effectively use digital technologies, including basic computer skills and proficiency in software applications. It is also crucial for users to understand how to safeguard their personal and business data from cybersecurity threats and take appropriate measures to ensure data privacy and security.

Lastly, supportive policies and regulations are necessary. Governments and regulatory bodies should establish policies and regulations that promote the development and adoption of digital technologies while safeguarding user rights and ensuring the safety and security of digital infrastructure.

Overall, these prerequisites are essential to ensure the effective and optimal use of digital technologies, and to ensure that they have a positive impact on society and the economy. In this report, we focus solely on the digital technologies for off-grid systems, while acknowledging the importance of the necessary infrastructure and framework conditions for their usage.

2.2 What are off-grid systems

Off-grid systems are standalone energy systems that are not connected to a centralized electricity grid. They are typically used in remote or rural areas where access to the grid is limited or non-existent and where households rely on expensive and polluting kerosene lamps or candles for lighting. Off-grid systems can be powered by a variety of energy sources, including solar, wind, hydro, and diesel generators. In recent years, solar PV has become the preferred energy source for off-grid systems due to its reliability, low maintenance requirements, and decreasing costs.

Mini-grids are off-grid energy systems that serve a small community or a cluster of households. They typically consist of a central power source, such as a solar PV array, diesel generators, battery storage and a distribution network that delivers electricity to individual homes or businesses. Mini-grids can be designed to meet the specific energy needs of the community they serve and can be expanded as the community grows and if more (productive) loads are developing.

Solar home systems are small off-grid energy systems that are designed to power individual households. They typically consist of a solar PV panel, a battery bank, and a controller that regulates the flow of electricity. Solar home systems are particularly useful in rural areas where settlements and households are very dispersed and the individual loads are very low.

In summary, off-grid systems are standalone energy systems that are not connected to a centralized electricity grid. Mini-grids are off-grid energy systems that serve a small community or a cluster of households connected with a distribution grid, while solar home systems are small off-grid energy systems that are designed to power individual households or small enterprises.

2.3 Value chain of PV off-grid projects

To better grasp how digitalization tools can contribute to off-grid projects, we recommend looking at these tools in terms of the different stages of an off-grid project's value chain. We have identified four key areas within this value chain that represent essential stages in the project's journey. These areas help us understand where digitalization tools can make a difference.

Figure 1 provides a visual representation of these four value chain areas, development, Implementation, operation and maintenance, and capacity development which serve as a roadmap for assessing how digitalization tools can be useful in specific aspects of off-grid projects. This practical approach allows us to see where these tools fit in, what they can improve, and how we can leverage them to tackle challenges and seize opportunities throughout the off-grid project's lifecycle. By aligning digital tools with each stage of the value chain, we can make the choice of tool easier for the project, leading to more effective and successful off-grid projects.

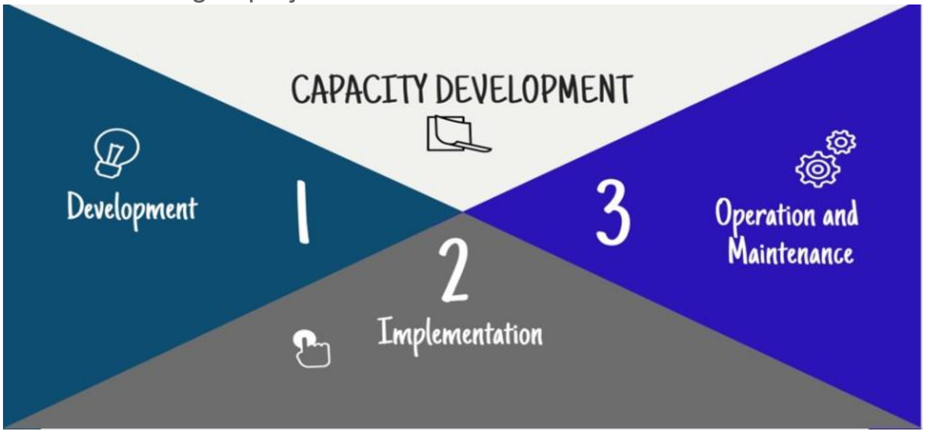

Figure 1: Projects value chain

3 IDENTIFICATION OF SPECIFIC DIGITAL TOOLS FOR OFF-GRID SYSTEMS

3.1 Methodology

In the subsequent subsections of this report, we will conduct an in-depth exploration of the following four areas in the value chain encompassed by digital technologies for off-grid systems:

1- Development

2- Implementation

3-Operation and Maintenance

4- Capacity Development

Each of these areas represents critical aspects identified by off-grid experts where digital technologies play a pivotal role in enhancing the sustainability, efficiency, and effectiveness of off-grid systems. Within these subsections, we will further divide and examine various categories and subcategories to gain a comprehensive and fine-grained understanding of the significant impact that digitalization can have in shaping the future of off-grid energy solutions.

3.2 Development

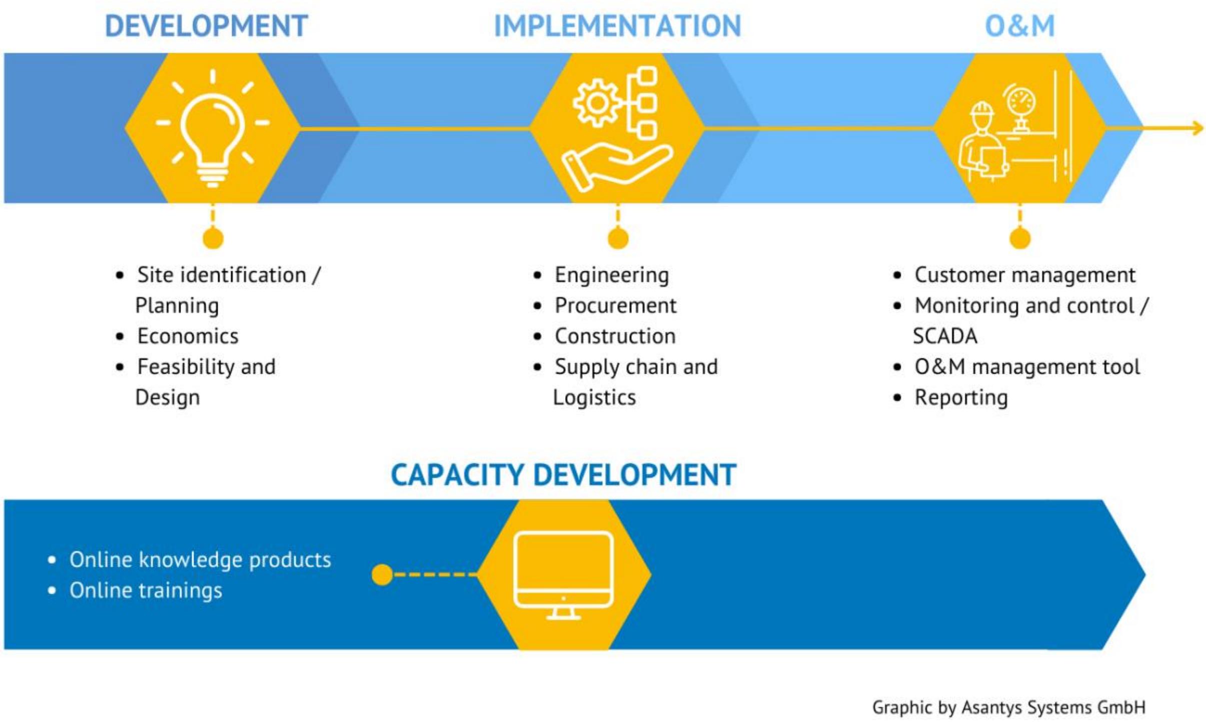

Figure 2: Areas and categories of project value chain

Development area is the first step in the value chain of off-grid PV projects. Projects need to be planned, evaluated and studied before implementation. We identified 3 main categories in which digital tools could come to the aid of project developers, these categories together with their subcategories are shown in figure. 3.

Three categories, “site identification / planning”, “economics” and “feasibility and design” are explained in more details below:

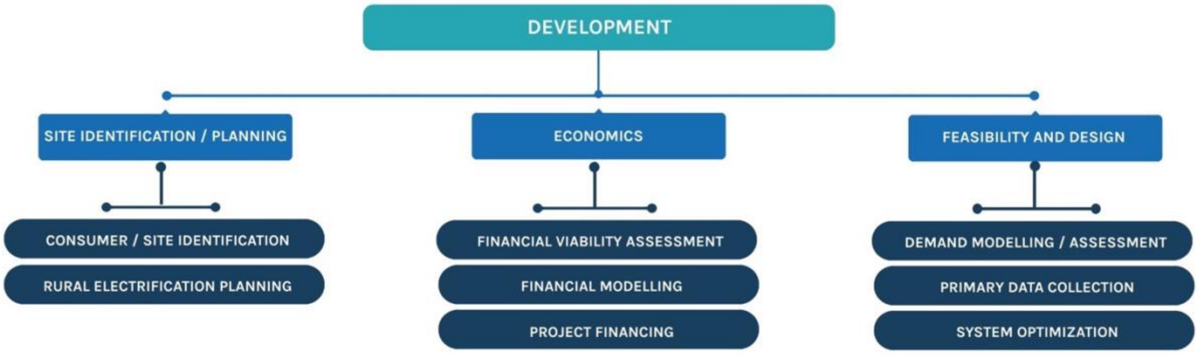

Figure 3: Development area, its categories and subcategories.

3.2.1 Site identification / Planning

This category includes digital tools that are instrumental in the initial stages of project development. These tools are used for identifying suitable locations for off-grid projects and planning the electrification strategies for remote regions. Within this category, two subcategories are highlighted below:

Consumer/Site Identification: Consumer/site identification involves utilizing spatial data and Geographic Information System (GIS) software to identify potential customers and their energy needs for off-grid projects. This process includes collecting and analyzing data on local energy demand, usage patterns, availability of alternative energy sources, as well as spatial data such as solar irradiation levels, topography, and proximity to potential customers. By comprehending the spatial characteristics of the community they serve, developers can utilize GIS software to identify suitable sites for off-grid systems and design energy solutions that cater to the specific needs of the community.

Rural Electrification Planning: Planning for rural electrification entails devising and implementing strategies to provide reliable and sustainable electricity to rural regions. This often involves harnessing renewable energy resources like solar and wind, alongside developing appropriate infrastructure and financing systems to facilitate electricity transmission to remote areas.

vidaGIS [5], ArcGIS [6], QGIS [7], Nigeria SE4ALL [8] and Renewable Ninjas [9] are a few examples of digital tools we identified in the “Site identification / Planning” category. More information on them can be found in the annex.

3.2.2 Economics

This category encapsulates a range of digital tools that revolve around the financial aspects of projects. These tools play a role in evaluating the economic feasibility and financial sustainability of projects, ultimately guiding investment decisions. Two identified subcategories of this category can be find below:

Financial Viability Assessment: The financial viability assessment procedure evaluates the sustainability of a project or investment. It helps investors and project sponsors determine if a project is financially feasible and has the potential to yield a favorable return on investment. This assessment involves analyzing the project's financial performance over time, considering factors such as income, costs, and cash flow. Additionally, financial modeling plays a crucial role in the assessment by developing mathematical models that allow investors and analysts to better understand the potential outcomes of various investment decisions, including cash-flow calculations.

Project Financing: Project financing is a financing mechanism used to fund small-scale or off-grid energy projects. This approach involves establishing a separate entity to finance and manage the project, with the project's revenue stream used to repay the debt over several years. In the context of small-scale or off-grid projects, project financing may involve smaller amounts of capital and may include a single investor or a group of investors. Project financing for such projects enables investors to participate in energy projects that may otherwise struggle to attract funding from traditional lenders due to their smaller scale. Additionally, this approach allows for the transfer of risk from the project sponsor to the lenders, as lenders typically conduct extensive due diligence on the project's financial viability before committing funds.

Odyssey [10] and Ecoligo [11] represent two noteworthy digital tools that we have specifically identified within the "Economics" category. Please refer to the detailed information provided in the enclosed annex for more information.

3.2.3 Feasibility and Design

The 'Feasibility and Design' category revolves around a suite of digital tools that shape the preliminary stages of projects. This category includes tools that are instrumental in enhancing the feasibility assessment and design processes. They facilitate the understanding of consumer demand, collection of primary data through surveys and optimization of the system to enhance the performance and streamline operations. The following subcategories are suggested for this category:

Demand Modeling / Assessment: Demand modeling is the process of determining consumer demand for a product or service. It involves analyzing previous data, identifying trends and patterns, and using mathematical and statistical models to forecast future demand. These generated models play a vital role in planning production and inventory levels, as well as devising effective marketing and pricing strategies.

Primary Data Collection: Surveys are a research technique utilized to gather information on the opinions, attitudes, and behaviors of a sample of individuals. The collected data is then analyzed in various sectors, including market research, public opinion polls, and social sciences, to identify trends and patterns and assist decision-makers in making informed choices.

System Optimization: System optimization employs engineering and mathematical concepts to enhance the performance of complex systems. This process involves evaluating the system's effectiveness, identifying potential areas for improvement, and implementing solutions to optimize the system. By improving procedures, systems, and workflows, system optimization aims to increase efficiency, reduce costs, and enhance overall quality.

Odyssey [10], RAMP [12], HOMER [13] and Sunny Design [14] are among the digital tools that have been discerned within the "Feasibility and Design" category. For more extensive details about these tools, please consult the additional information contained in the attached annex.

3.3 Implementation

After development, comes the implementation phase. The main four categories within this area are shown in figure 4. Digital tools that belong to one of “construction”, “engineering”, “supply chain and logistics”, and “procurement” categories are classified as implementation phase assisting tools. Below, you will find a more detailed explanation of each category and its subcategories.

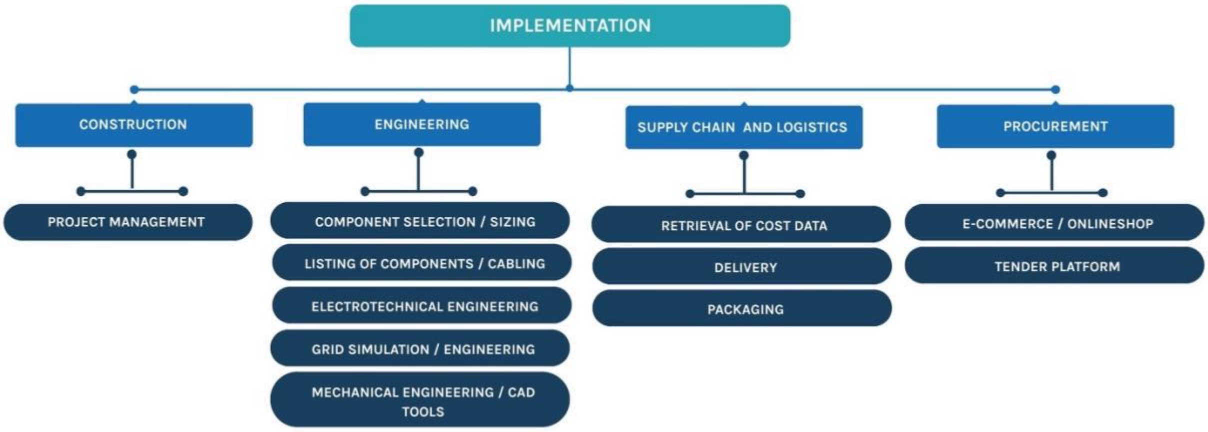

Figure 4: Implementation area, its categories and subcategories.

3.3.1 Construction

The 'Construction' category centers on digital tools that play a pivotal role in orchestrating the execution of projects. The identified subcategory of this category is:

Project Management: Project management is the process of planning, organizing, and coordinating resources and activities to achieve specific goals within defined scope, budget, and timeline. Key elements of project management include defining project scope, creating a project plan, allocating resources, setting timelines and milestones, monitoring progress, and making adjustments as needed to ensure the project's timely and successful completion to the satisfaction of stakeholders.

MS Project [15] is a notable digital tool that we have identified under the "Construction" category. For further information about this tool, please refer to the detailed content provided in the attached annex.

3.3.2 Engineering

This category encompasses a range of digital tools that collectively contribute to off-grid projects. Tools in this category are instrumental in optimizing component selection, facilitating precise inventory management, advancing electrotechnical engineering, simulating grid scenarios, and refining mechanical design. By leveraging these tools, the engineering aspects of off-grid systems benefit from increased efficiency, accuracy, and innovation, leading to more effective and sustainable outcomes. The subcategories in this category are:

Component Selection / Sizing: Component selection involves assessing the technical requirements and constraints of the system and choosing specific components that meet those criteria. Considerations may include cost, availability, materials, size, capacities, and compatibility of the components.

Listing of Components / Cabling: A comprehensive inventory of all individual parts and cables needed to construct and connect a large system or product. This list typically includes the name and model number of each component, the required quantity, and specific cabling and wiring specifications for each component.

Electrotechnical Engineering: Electrotechnical engineering encompasses a wide range of operations, from fundamental research and development of new technologies to designing and constructing complex systems and equipment. Key areas of focus include designing electrical and electronic circuits, developing power generation and distribution systems, creating control systems for automation and robotics, and developing communication systems for data and voice transmission.

Grid Simulation / Engineering: Grid simulation software is used to model and simulate electrical power systems, including transmission networks and distribution systems. It helps test the system's responsiveness and reliability under various scenarios and assess the effects of system updates or modifications. Grid modeling software often includes advanced analytical techniques like fault analysis, transient stability analysis, and load flow analysis. This part is often already conducted in the feasibility and design phase, but then repeated during the implementation phase by the implementing company.

Mechanical Engineering / CAD Tools: CAD (Computer-Aided Design) software is used to design electrical and electronic circuits, devices, and systems. Engineers can create simulations and 2D and 3D models, perform performance analysis, and utilize component libraries, automated design tools, and simulation capabilities. Mechanical engineering professionals also use CAD technologies to design, model, and simulate mechanical systems and components, allowing for the construction and visualization of complex designs while testing their functionality.

PVsyst [16], HOMER [13], Sunny Design [14], and Odyssey [10], and are exemplary digital tools that have been recognized within the "Engineering" category. To access comprehensive information about these tools, consult the detailed materials available in the annex.

3.3.3 Supply Chain and Logistics

This category comprises an array of digital tools that collaboratively enhance the efficiency of off-grid projects by streamlining supply chain and logistics processes. These tools are pivotal in elevating the retrieval of cost data, fine-tuning delivery methods, and perfecting packaging strategies. They guarantee the smooth and effective functioning of operations within the logistics and supply chain domain. The three identified subcategories of Supply Chain and Logistics are listed below:

Retrieval of cost data: Cost data in logistics and supply chains refers to the cost incurred to the many stages of the procedure, from procurement through delivery. This comprises the price of raw materials, along with labor, transportation, and other expenditures. Cost data analysis is essential for supply chain optimization and cost reduction since it enables businesses to pinpoint areas where they can cut costs and boost productivity.

Delivery: Delivery is the process of moving products from one place to another, and it is essential to the logistics and supply chain processes. To guarantee that things are delivered on time and in acceptable condition, effective delivery systems include careful planning, scheduling, and tracking. This sometimes entails managing complicated logistics networks and coordinating several delivery methods, including trucks, ships, and airplanes.

Packaging: The process of packing involves choosing the right packaging materials and creating packages that are durable and simple to carry. Packaging is the process of preparing items for shipment. To minimize damage and lower the danger of loss or theft during shipment, good packaging techniques are crucial.

Flexport [17] is an example of a digital tool we identified in the "Supply Chain and Logistics" category. More information on it can be found in the annex.

3.3.4 Procurement

In this category, a range of digital tools which enhance the procurement procedures within off-grid projects are classified. These tools are essential for optimizing the acquisition process, enabling efficient transactions, and streamlining the selection of vendors. Their pivotal role lies in boosting the overall efficiency and effectiveness of procurement operations, resulting in smoother workflows and achieving improved outcomes within the two following subcategories:

E-Commerce / Onlineshop: E-commerce platforms are online marketplaces that let companies conduct online transactions for the purchase and sale of products and services. These platforms often offer a central area for buyers and sellers to transact as well as tools for controlling the buying process, with the goal of streamlining the procurement process. Platforms for e-commerce may also have features like integrated payment systems, electronic invoicing, and automated workflows.

Tender platform: Tender platforms are online platforms that enable companies to issue and react to requests for proposals (RFPs) and tenders electronically. These platforms are aimed to simplify the procurement process by offering a single site for managing the bidding process, as well as tools for analyzing offers and selecting vendors. In off-grid projects developed by multilateral organisations (e.g. WorldBank, UN, etc), the tendering often takes place at the last stage of development as the entire project is tendered out. In our described case tendering includes the tendering and procurement of individual components is included in the phase and therefore put at a later stage of the project value chain.

Odyssey [10] is a notable digital tool we've identified within the "Procurement" category. For a deeper understanding of this tool, please refer to the more detailed information provided in the attached annex.

3.4 Operation and Maintenance

Figure 5 shows the categories and subcategories of area operation and maintenance. Digital tools in this area can play a pivotal role in smooth control, management and decision making regarding the functioning of already implemented projects. Read more on identified categories and subcategories below:

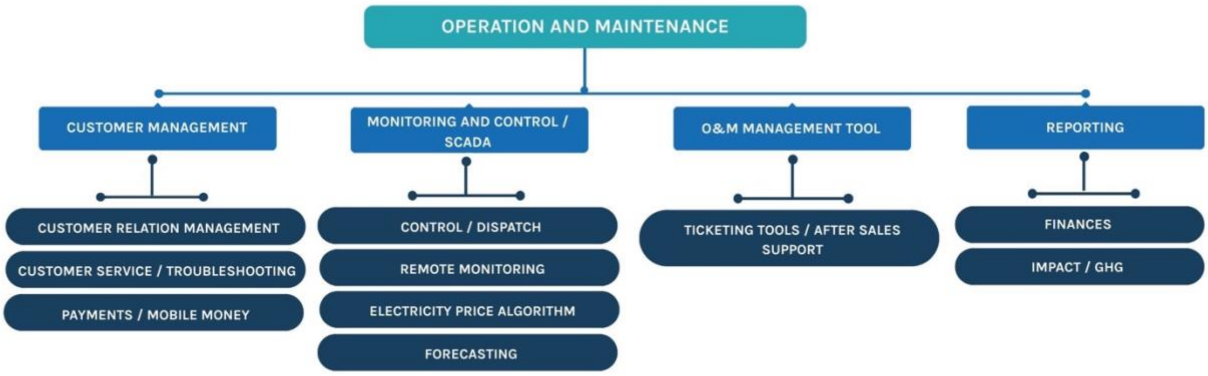

Figure 5: Operation and Maintenance area, its categories and subcategories.

3.4.1 Customer management

Within this category, an array of digital tools contributes to refining customer management processes in off-grid projects. These tools are utilized in nurturing robust customer relationships, boosting contentment, and fostering trust. The category includes tools for maintaining effective communication, delivering customer service, resolving issues, and facilitating payments via mobile money systems. The identified subcategories are:

Customer Relationship Management (CRM): Customer relationship management is the process of overseeing communications and connections with clients to enhance customer engagement, satisfaction, and trust. In the context of operations and maintenance (O&M) services, CRM involves maintaining strong relationships with clients who utilize or rely on services like maintenance, repair, and support. CRM in O&M encompasses managing client contacts, improving customer satisfaction, fostering customer loyalty, and analyzing customer data.

Customer Service / Troubleshooting: Customer service in O&M refers to the process of providing support and assistance to clients who use or depend on O&M services. This includes addressing inquiries, handling complaints, and offering guidance and advice to clients. Troubleshooting in O&M involves identifying and resolving issues that may arise during the provision of maintenance, repair, or support services.

Payments / Mobile Money: Payments through mobile money involve using mobile devices to simplify payment and invoicing procedures related to maintenance, repair, and support services. Instead of traditional payment methods like cash or credit cards, users can utilize their mobile devices, such as smartphones or tablets, to pay for services. Mobile payments offer features like convenience, security, and cost savings.

PineBerry [18], New Sun Road [19], Meter Supplier Tools Sparkmeter [20], and MicroPowerManager [21] represent some of the digital tools we've identified in the "Customer Management" category. For further details about these tools, please refer to the comprehensive information provided in the attached annex.

3.4.2 Monitoring and control

This category introduces digital tools that contribute to monitoring and control in off-grid projects. These tools are employed for managing and enhancing the performance of energy generation, storage, and distribution within off-grid energy systems. Tools that help with real-time control and dispatch, remote monitoring for distant assessment, computation of electricity prices through algorithms, and the practice of energy forecasting. By leveraging these tools strategically, off-grid projects can ensure reliable, efficient, and optimized energy operations while providing valuable insights for future planning and expansion. The following subcategories can be named in this category:

Control / Dispatch: Dispatch and control refer to the management and coordination of energy generation, storage, and distribution in off-grid energy systems. It involves real-time monitoring, control, and optimization of various components, such as renewable energy sources, energy storage systems, and power converters, to ensure reliable and efficient operation. Remote control enables O&M providers to modify the operation of the systems or devices under observation and take appropriate actions in response to problems or failures. Load shedding is a strategy used to reduce power demand during high-demand periods or when there is a lack of electrical supply.

Remote Monitoring: Remote monitoring is the process of using technology to inspect the functionality and performance of systems, equipment, or other devices from a distance. Through sensors or monitoring equipment installed on the system, data is collected and sent to a dashboard or centralized monitoring center for real-time evaluation and interpretation.

Electricity Price Algorithm: An electricity price algorithm is a computational method used to determine the cost of electricity in off-grid energy systems. It considers factors such as energy production costs, storage costs, maintenance expenses, and overall demand and supply dynamics of the system. The algorithm calculates the appropriate price of electricity that reflects the system's operational costs while ensuring affordability for consumers. The objective is to strike a balance between the financial sustainability of the off-grid system and providing affordable and reliable electricity services to end-users. Additionally, the algorithm can enable peer-to-peer trading within the off-grid system among different consumers.

Forecasting: Forecasting in off-grid energy systems involves predicting energy generation, demand, and other relevant factors to optimize system operation. Short-term forecasting predicts energy generation and load patterns on a daily or hourly basis, allowing real-time adjustments and energy dispatch optimization. Long-term forecasting predicts energy trends, seasonal variations, and future load growth to inform system planning and expansion. Forecasting techniques utilize historical data, statistical models, and advanced algorithms to provide accurate predictions, enabling off-grid energy systems to operate efficiently, minimize costs, and conduct predictive maintenance to ensure reliable energy supply.

AMMP [22], Odyssey [10] and New Sun Road [19] are a few examples of digital tools we identified in the “Monitoring and Control” category. For additional information about these tools, please refer to the detailed materials provided in the attached annex.

3.4.3 O&M management tool

In the category of operation and maintenance management, a distinct digital tool category emerges, this category includes tools tailored to after-sales support, primarily ticketing tools. Such tools provide a platform for clients to submit and track support requests, enabling effective issue resolution. With widespread applications in sectors like customer service and technical support, these tools streamline communication and contribute to smooth after-sales operations. Our subcategory identified in this category is:

Ticketing Tools / After Sales Support: In the context of after sales support, a ticketing tool is a software platform that allows clients to submit support requests or issues to a company's support staff, and enables the team to organize and track these requests until they are resolved. This versatile tool finds applications across various sectors, including customer service, technical support, and after sales support.

Illu [23] is an example of a digital tool we identified in the “O&M management tool” category. More information on it can be found in the annex.

3.4.4 Reporting

In the reporting category, digital tools can help provide insights and information for informed decision-making. This category contains tools that facilitate the evaluation of financial performance, offering opportunities for cost optimization and revenue generation. Furthermore, these tools enable organizations to analyze their impact on various aspects, including environmental sustainability and greenhouse gas emissions. Through these reports, businesses gain valuable perspectives to guide their efforts in promoting sustainability and making well-informed choices.

Finances: Reporting finances is a process that involves tracking the financial performance of O&M operations and identifying opportunities for cost reduction or revenue generation. Standard components of financial reporting in the O&M industry include tracking and evaluating various financial measures, such as revenue, costs, profitability, and cash flow. This process involves collecting, organizing, and analyzing financial data to generate comprehensive reports.

Impact / GHG: An impact report is a specific type of report that analyzes the effects of an organization's operations or initiatives on the environment, society, and economy. It assesses the organization's overall impact, including its contribution to greenhouse gas (GHG) emissions and environmental sustainability. The report provides valuable insights into the organization's environmental and social responsibility efforts and helps in making informed decisions to promote sustainability and reduce carbon footprint.

3.5 Capacity development

Parallel to all above-mentioned areas, the area capacity development can greatly benefit from digital tools that facilitate the transfer of knowledge in the PV off-grid sector. In addition to classical training, initiatives that focus on expanding the general public knowledge about the energy sector and help reduce energy poverty can rely on financially feasible options that digital tools have to offer. Online free encyclopedias like energypedia enable collecting the crowd knowledge and experiences of experts for further development of off-grid projects informed by the outcomes and pitfalls of the previous similar projects. Figure 6 shows our 2 categories in capacity development.

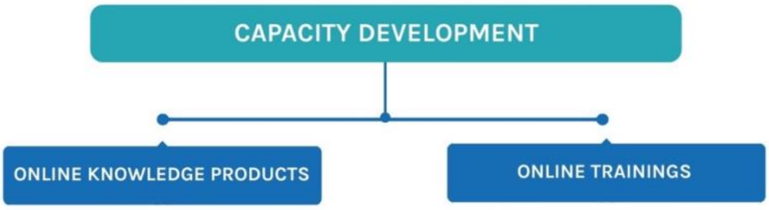

Figure 6: Capacity development area, its categories and subcategories.

3.5.1 Online knowledge products

Online knowledge products refer to any digital sources that provide guidance or information on a specific subject. This category includes online encyclopedias, courses, podcasts, e-books, webinars, videos, and other types of content. Online knowledge products are designed to be user-friendly and accessible, allowing learners to access them at any time and from any location.

SMA Solar Academy [24] and Victron Energy [25] are a few examples of digital tools we identified in the "Online knowledge products" category. More information on them can be found in the annex.

3.5.2 Online trainings

Online training involves delivering education or instruction over the internet using tools such as webinars, e-learning platforms, and virtual classrooms. It is a convenient and cost-effective approach to provide training to a large audience. Online training can be tailored to meet specific learning goals and often includes interactive elements, such as quizzes and discussion forums, to enhance engagement and retention among learners.

Green Mini-Grid Help Desk [26] is an example of a digital tool we identified in "Online Trainings" category. More information on them can be found in the annex.

4 ASSESSMENT OF “INNOVATION POTENTIAL” FOR DIGITAL TOOLS

After introducing the classification strategy for digital tools along the value chain, we propose seven dimensions along which a digital tool can be evaluated. In the following section, we explain each of these dimensions and present an open survey with which the digital tools can be evaluated. We then present the results of a pilot circulation of the survey to compare two example tools.

4.1 Methodology

To assess the innovation potentials of every digital tool along the value chain, we have identified seven dimensions with which we can evaluate the functionality of the tool. These dimensions are as follows:

- Interlinkages to other digital tools
- User interfaces
- Process assistance
- Flexibility
- Transparency
- Data Protection
- Potential of including AI

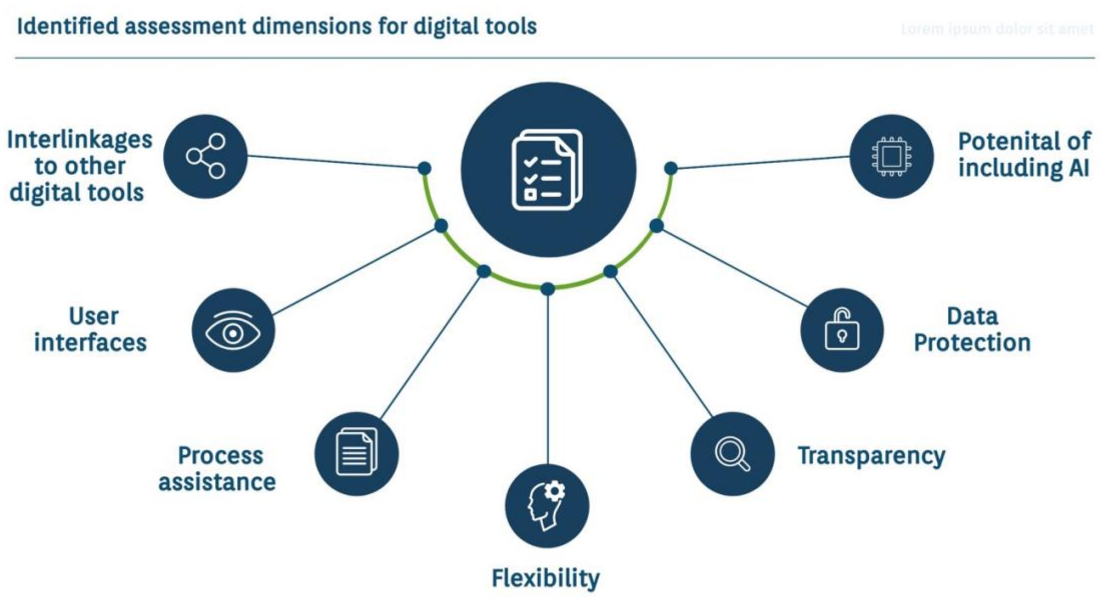

Figure 7: Assessment dimensions identified to evaluate existing digital tools

Below you will find the definition of all dimensions and a question designed to address and assess each individual dimension. We recommend tool developers to evaluate their tools along all proposed dimensions to contribute further to the digital space of off-grid electrification.

4.2 Assessment Dimensions

Interlinkages to other digital tools:

This dimension assesses the digital tool's capability to seamlessly integrate with other tools within the off-grid system's ecosystem. Efficient interlinkages enable smooth data exchange and information sharing, enhancing system coordination and decision-making. A well-connected digital infrastructure promotes a collaborative approach among stakeholders and optimizes overall system performance.

We approach the evaluation of this dimension by asking this short question:

“Are there input / output interfaces to other tools established?”

User interfaces:

The second dimension evaluates the digital tool's user interface for its ease of use and accessibility. A user-friendly graphical interface enhances the tool's usability, making it intuitive and straightforward for users to interact with the system. A well-designed interface streamlines user interactions, reducing the learning curve and improving overall user experience. This fosters better engagement and encourages users to make the most of the tool's functionalities, ultimately contributing to the effectiveness of the digitalization efforts within off-grid systems.

We approach the evaluation of this dimension by asking this short question:

“Is a user-friendly graphical interface implemented?”

Process assistance:

The third dimension focuses on the extent to which the digital tool provides process guidance to its users. A user-friendly tool should offer clear instructions, step-by-step guidance, or prompts that assist users in navigating through various processes effectively. This guidance not only helps users maximize the tool's capabilities but also minimizes the chances of errors or misunderstandings during system operation. A digital tool that offers process assistance contributes to improved efficiency, productivity, and overall user satisfaction in utilizing the tool for off-grid system use cases. This also includes training and capacity development for the users – but this could be defined as additional dimension as well.

We approach the evaluation of this dimension by asking this short question:

“Does the digital tool guide the user through the process?”

Flexibility:

The fourth dimension examines the degree of flexibility the digital tool offers to users in customizing configurations or functions. A flexible tool allows users to adapt its settings and functionalities to align with specific requirements and preferences. This adaptability is particularly valuable in the context of diverse off-grid systems with varying needs and conditions. When users can tailor the tool to suit their unique circumstances, it enhances the tool's relevance and effectiveness in addressing specific challenges and optimizing system performance. A highly flexible digital tool empowers users to tailor it to their operational preferences, making it a valuable asset in the digitalization of off-grid systems.

We approach the evaluation of this dimension by asking this short question:

“Can the user customize certain configurations / functions of the digital tool?”

Transparency:

The fifth dimension focuses on the transparency of the digital tool's operations. A transparent tool allows users to comprehend the relationship between input data and the resulting outputs or outcomes. When users have clear visibility into how the tool processes information and generates results, they can trust the tool's reliability and make well-informed decisions based on the provided insights. Transparent input-output relations also enable users to identify potential issues or discrepancies, enhancing the tool's credibility and facilitating effective troubleshooting. In the context of off-grid systems, transparency in the digital tool's operations fosters confidence among users, encouraging broader adoption and ensuring the accuracy of data-driven decisions.

We approach the evaluation of this dimension by asking this short question:

“Can the user understand the input-output relations?”

Data protection:

The sixth dimension addresses the critical aspect of data protection within the digital tool. It assesses the measures in place to safeguard sensitive and confidential information from unauthorized access, use, or manipulation. A robust data protection system ensures that critical data related to off-grid systems, such as customer information, operational data, and financial records, remains secure and private. By implementing appropriate encryption, access controls, and data storage protocols, the digital tool can minimize the risk of data breaches and cyberattacks. Data protection not only enhances the integrity and trustworthiness of the tool but also safeguards the overall security of the off-grid systems it supports.

We approach the evaluation of this dimension by asking this short question:

“Is critical data properly protected within the digital tool?”

Potential of including AI:

The seventh dimension explores the potential of integrating artificial intelligence (AI) capabilities into the digital tool. AI offers the possibility of enhancing the tool's functionalities by enabling intelligent automation, data analysis, and decision-making support. By leveraging AI algorithms, the digital tool can identify patterns, optimize processes, and generate valuable insights from vast amounts of data. AI-powered tools can adapt and learn from user interactions, continuously improving their performance and relevance over time. The inclusion of AI in the digital tool can lead to more sophisticated and efficient off-grid systems management, providing opportunities for greater automation, predictive maintenance, and energy optimization. Evaluating the potential of including AI allows us to envision the future scalability and adaptability of the digital tool to address emerging challenges and opportunities in off-grid systems.

We approach the evaluation of this dimension by asking this short question: “Can AI be included into the digital tool to improve its functions?”

4.3 Evaluation Survey for Digital Tools

In the previous subsection, we introduced seven dimensions to evaluate the functionality and capacities of a digital tool. We designed an online open-access survey using freely available KoboToolbox[1] that could be used to evaluate a tool along these 7 dimensions. The survey is openly accessible for further use of the community[2]. We then invited PV Off-Grid Systems experts to pilot entering the digital tools they utilize in their job in our survey and evaluate it.

Participants are provided with six different options to rate each dimension:

- Very bad
- Fairly bad
- Fairly good
- Very good
- Does not apply
- I don't know

To quantify answers, we assigned values 1 to 4 respectively to "Very bad", "Fairly bad, "Fairly good" and "Very good".

Figure 8 shows an example visualization of ratings for two digital tools each evaluated by 3 experts. A total of thirteen experts filled out the survey during July/August 2023 and their non-overlapping evaluated tools were added to the tools annex provided as a supplementary material to this report.

One noteworthy highlight of responses to the survey was that the majority of answers [79%] to data protection question was "I don't know", this can suggest a lack of interest from users' side to keep their data confident or a lack of transparency/user-friendliness of data protection information from developers' side in explaining well how the user data is handled.

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[1] https://www.kobotoolbox.org/

[2] Use this link to access the preview of the survey along with downloadable XLS and XML versions of it. Please click on the three dots in the upper right corner to download the files which then can be integrated into a new Kobotoolbox survey.

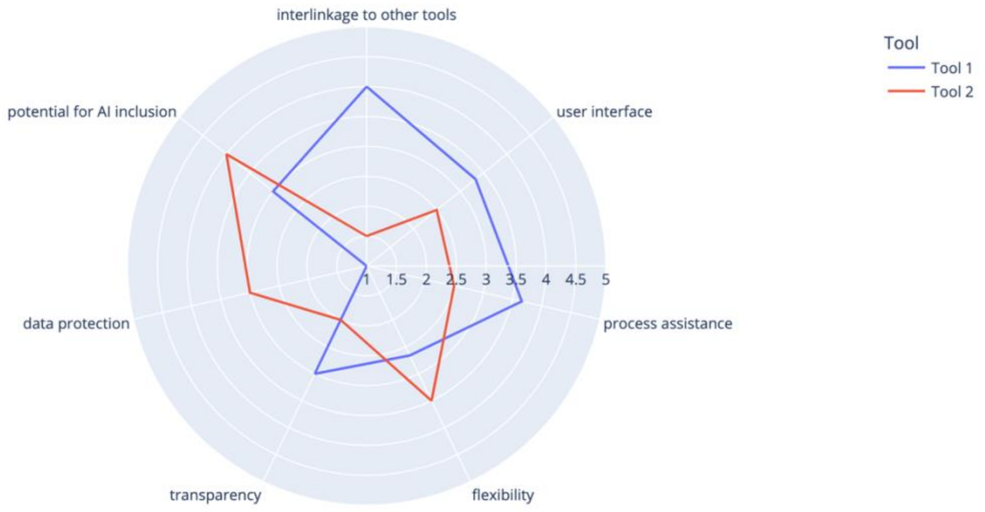

Figure 8: Evaluation results for two example tools. Each tool is evaluated by 3 experts. The bigger values are associated with better reported performance of the tool along that axis.

4.4 Prioritization of Subcategories for Digitalization

While digital tools are increasingly embedded throughout the off-grid energy value chain, not all areas benefit equally. Some project steps stand out as having greater potential for impact, easier integration of digital tools, and more mature solutions available. Recognizing this, we developed a prioritization framework to help project managers and decision-makers focus their digitalization efforts where they are likely to generate the most value.

To evaluate the 31 subcategories (the "dark blue boxes" in our diagrams), we assessed each one against the following three dimensions:

- **Impact Potential**: How significantly can digital tools enhance cost-effectiveness, system reliability, efficiency, accuracy, or scalability in this area?
- **Ease of Adoption**: How easily can digital tools be implemented, considering digital infrastructure, required skills, and usability?
- **Maturity of Digital Tools**: Are there proven, widely used, and context-appropriate tools already available for this step?

Using these dimensions, we ranked each subcategory as **high**, **medium**, or **lower priority** for digitalization. This prioritization does not imply that some areas are unimportant, but instead offers a practical roadmap for where digital tools can deliver the greatest immediate benefits with relatively low implementation barriers.
The table below presents the **subcategories with the highest overall digitalization potential**, based on strong performance across all three dimensions. These "low-hanging fruit" offer a valuable starting point for practitioners seeking to optimize their operations through digitalization.

Table 1: Digitalization Prioritization Table with Justifications

Value Chain Area	Sub-category	Priority Level	Impact Potential	Ease of Adoption	Maturity of Digital Tools
Development	Consumer / Site Identification	High	High – Improves targeting, speeds up planning, increases viability of site choices.	High – Most tools are intuitive, cloud-based, and GIS-trained users are common.	High – Mature tools like ArcGIS, QGIS, Energy Access Explorer widely used.
Development	System Optimization	High	High – Enhances cost-effectiveness, sizing, and long-term performance.	Medium – Requires technical understanding but tools are well-documented.	High – HOMER, PVsyst, and Sunny Design are proven and established.
Implementation	Project Management	High	High – Prevents delays, tracks tasks/resources	High – Tools like MS Project are familiar across sectors.	High – Widely adopted in and beyond energy sectors.

			, improves coordination.		
Operation & Maintenance	Remote Monitoring	High	High – Enables proactive maintenance and improves uptime.	Medium – Needs IoT infrastructure and internet access.	High – Tools like AMMP, Victron VRM, and Odyssey are in active use.
Operation & Maintenance	Customer Relationship Management (CRM)	High	High – Strengthens billing, retention, and service quality.	High – Mobile-first platforms with low user training needs.	High – Sector-specific CRMs like MicroPowerManager, SparkMeter exist.
Operation & Maintenance	Payments / Mobile Money	High	High – Improves collection rates and user convenience.	High – Popular in many regions; tools integrate with mobile money services.	High – Integration standard in tools like SteamaCo, PineBerry.
Operation & Maintenance	Control / Dispatch	High	High – Automates load balancing, reduces fuel use, improves energy availability.	Medium – Requires training and reliable communication systems.	High – Supported by SCADA-capable tools (Odyssey, New Sun Road).
Operation & Maintenance	Ticketing Tools / After Sales Support	High	Medium – Streamlines O&M workflows and responsiveness.	High – Lightweight, intuitive tools like Illu are plug-and-play.	Medium – Emerging but increasingly tailored to off-grid needs.
Capacity Development	Online Trainings	High	High – Scales knowledge transfer at low cost; essential for sustainability.	High – Accessible via mobile/web platforms even in remote areas.	High – Platforms from SMA, Victron, and others are widely available.

5 DISCUSSION & CONCLUSION

The integration of digital technologies across the value chain of off-grid energy systems has proven to be a transformative force, enhancing the efficiency, reliability, and scalability of these systems. By incorporating digital tools at every stage—from development to capacity building—off-grid projects can address the complex challenges associated with energy access in remote and underserved regions. However, this digital transformation also presents a set of challenges and opportunities that need to be carefully navigated. This is in line with findings from other similar reports, stating “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."[3] or “digital innovations can address other challenges by for instance optimising project development processes, improving the design and planning of mini-grids as well as improving maintenance, management and customer related processes.”[4] We can therefore contribute to accelerating off-grid systems via digital tools or technologies. Our report shows that along four main categories of the project value chain:

1. Development:

In the development phase, digital technologies such as Geographic Information Systems (GIS), remote sensing, and data analytics play a crucial role in site identification and planning. These tools allow developers to analyze spatial data, including solar irradiation, topography, and demographic information, to identify optimal locations for off-grid systems. Moreover, advanced data collection methods enable a deeper understanding of local energy needs and consumption patterns, ensuring that the system design is both technically sound and economically viable. The use of digital simulations and modeling tools during the development phase further helps in predicting system performance and optimizing the design, reducing risks and ensuring better alignment with community needs.

2. Implementation:

During the implementation phase, digital project management tools and platforms streamline the procurement, logistics, and installation processes. Additionally, digital tools can facilitate the detailed engineering process in terms of component selection and sizing as well as grid design and electrotechnical and mechanical engineering. Supply chain and logistics as well as procurement can also be supported by a wide range of digital tools.

3. Operation and Maintenance:

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[3] https://endev.info/wp-content/uploads/2024/07/Scaling-Up-Energy-Access-with-Digital-Solutions.pdf

[4] https://www.rifs-potsdam.de/sites/default/files/2019-08/2019_Mini-grids%20and%20digital%20technologies_IASS_Study.pdf

The operation and maintenance phase benefits significantly from digitalization through the use of remote monitoring and control systems. Internet of Things (IoT) devices, sensors, and cloud-based platforms enable continuous data collection on system performance, allowing for real-time monitoring and predictive maintenance. These technologies help identify potential issues before they lead to system failures, reducing downtime and maintenance costs. Advanced algorithms for dispatch and control optimize energy generation, storage, and distribution, ensuring a reliable and efficient energy supply that meets fluctuating demand. Additionally, digital customer management systems facilitate efficient billing, payment processing, and customer support, enhancing user experience and ensuring timely revenue collection. Furthermore, digital financial tools, including electricity price algorithms, ensure the system's financial sustainability by dynamically adjusting pricing to reflect operational costs and market conditions.

4. Capacity Development:

Capacity development is a critical, yet often overlooked, aspect of digitalization in off-grid energy systems. For digital tools to be effectively utilized, it is essential to invest in building the digital literacy and technical skills of local communities, system operators, and stakeholders. Training programs that focus on the use and maintenance of digital tools, data interpretation, and cybersecurity practices are crucial for empowering local actors and ensuring the long-term sustainability of off-grid systems. Furthermore, digital platforms can facilitate knowledge sharing, offering access to educational resources, best practices, and real-time support to build local capacities and foster community ownership of the systems.

However, the implementation of digital technologies in off-grid systems is not without its challenges. A major concern is the availability of reliable digital infrastructure, such as internet connectivity, which is often lacking in the very regions that off-grid systems aim to serve. Additionally, the successful deployment of digital solutions requires a certain level of digital literacy among both system operators and end-users, which may necessitate investments in training and capacity-building initiatives. Cybersecurity is another critical issue, as the increasing digitalization of energy systems exposes them to potential cyber threats that could disrupt operations.

In conclusion, while digitalization holds immense potential to transform off-grid energy systems by improving efficiency, reliability, and customer service, it also presents a set of challenges that must be addressed to ensure successful implementation. As digital technologies continue to evolve, it will be important for stakeholders in the off-grid energy sector to remain adaptive and proactive in addressing these challenges, while harnessing the opportunities that digitalization offers to achieve universal energy access.

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ANNEX

This table has a digital counterpart that could be found here:

https://energypedia.info/wiki/Digital_Tools_for_PV_Off-Grid_Systems

Please feel free to add more tools to the Energypedia editable page.

Planning & Site Identification

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
Global Electrification Platform	Explore least cost electrification strategies around the world, interacting with country contextual data and different investment scenarios.	Consumer / Site Identification: yes Rural Electrification Planning: yes		https://electrifynow.energydata.info/
OpeN Source Spatial Electrification Toolkit (ONSSET)	ONSSET is an open source, spatial electrification tool estimating, analyzing and visualizing the most cost effective electrification option (grid, mini grid & stand-alone) for the achievement of electricity access goals.	Consumer / Site Identification: yes Rural Electrification Planning: yes		https://www.energy.kth.se/energy-systems/completed-projects/open-source-spatial-electrification-

				toolkit-onsset-1.940024
Renewable Ninjas	Renewables.ninja allows you to run simulations of the hourly power output from wind and solar power plants located anywhere in the world. We have built this tool to help make scientific-quality weather and energy data available to a wider community.	Consumer / Site Identification: partially Rural Electrification Planning: no	Mini-grid site selection	https://www.renewables.ninja/
OpenPlan	A open source GUI that offers the ability to model and optimize energy systems.	Consumer / Site Identification: yes Rural Electrification Planning: partially	Easy to use GUI	https://open-plan.rl-institut.de/en/
Nessi	A free tool that allows users to make sustainable energy system decision for buildings or neighborhoods by simulating different impacts.	Consumer / Site Identification: yes Rural Electrification Planning: partially	Free online web tool	https://nessi.iwi.uni-hannover.de/en/
Energy Access Explorer	An interactive online platform mapping the state of energy access in underserved areas across Africa and Asia.	Consumer / Site Identification: yes Rural Electrification Planning: yes	Easy to use and free browser based data map.	https://www.energyaccessexplorer.org/
GeoSIM	GEOSIM is a tool dedicated to decision support for planning rural electrification aimed at decision-makers and planners. It aims at preparing rural electrification scenarios including grid extension projects, decentralized energy	Consumer / Site Identification: yes Rural Electrification Planning: yes	Spatial Analyst Demand Analyst Network Options Distributed Energy	http://www.geosim.fr/index.php?page=home

	projects (hydro, biomass and PV/ Wind hybrid mini grids) and other distributed energy projects.			
VidaGIS	Working with and creating geographical and spatial data, such as maps, satellite-images, multidimensional models and infrastructure management.	Consumer / Site Identification: yes Rural Electrification Planning: partially	Map & GIS Database Satellite Image GIS Software and Services Aktivmap (manage, track, and analyze your infrastructure assets, machines and equipment) Spatial Data Infrastructure (SDI) Software and Services	https://www.vidagis.com/
SWARM	SWARM quickly and efficiently analyzes sites based on financial, technical, and geospatial data, and calculates optimal mini-grid locations, reticulation design, and estimated system size, resulting in a prioritized list of the most viable sites.	Consumer / Site Identification: yes Rural Electrification Planning: yes	Products: Honeycomb Asali SWARM	https://www.powerhive.com/our-technology/
Development Maps	An initiative of Village Infrastructure Angels to offer useful GIS, business intelligence and software services and tools to the global industry, particularly those interested in poverty alleviation and international development.	Consumer / Site Identification: yes Rural Electrification Planning: partially	GIS, Business intelligence and software services	https://www.developmentmaps.org/
ArcGis	Mapping and spatial analytics. Creating digital representations of environments, both indoor and outdoor on different scales. Used for	Consumer / Site Identification: yes Rural Electrification Planning: partially	ArcGIS Platform (building mapping and analysis applications) ArcGIS Online (create, manage, and share geospatial content in the cloud)	https://www.esri.com/en-us/arcgis

	infrastructure management and analysis.		ArcGIS Pro ArcGIS Enterprise (powering mapping and visualization, analytics, and data management)	
Qgis	Can be used to create, edit and publish Geographic Information Systems.	Consumer / Site Identification: yes Rural Electrification Planning: partially	QGIS Desktop (Create, edit, visualize, analyse and publish geospatial information) QGIS Server (Publish your QGIS projects and layers as OGC compatible WMS, WMTS, WFS and WCS services) QGIS Web Client (powerful symbology, labeling and blending features) QField (QGIS on mobiles and tablets) Merging Maps Input app IntraMaps Roam	https://www.qgis.org/en/site/index.html

Economics

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
Odyssey	Helps connect renewable energy projects with financiers and equipment suppliers.	Financial Viability Assessment: yes Project Financing: yes	Finance Procurement Remote Management Deal Origination Due Diligence Monitoring and analytics Feasibility Analysis Tenders/RBFs Monitoring and Evaluation	https://odysseyenergysolutions.com/
RETScreen	Clean Energy Management Software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis.	Financial Viability Assessment: yes Project Financing: partially	RETScreen® Clean Energy Management Software	http://www.retscreen.net/
Minigrid Policy Toolkit	This Policy Toolkit shall improve understanding about mini-grids, stakeholders, and options for supportive and regulatory frameworks with the aim to make investments into mini-grids more attractive.	Financial Viability Assessment: partially Project Financing: partially	policy-makers, project developers, investors, development banks and donor agencies, primarily in Africa.	http://minigridpolicytoolkit.euei-pdf.org/support-tools
Nessi	A free tool that allows users to make sustainable energy system decision for buildings or neighborhoods by simulating different impacts.	Financial Viability Assessment: yes Project Financing: partially	Free online web tool	https://nessi.iwi.uni-hannover.de/en/

Feasibility & Design

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
Odyssey	Helps connect renewable energy projects with financiers and equipment suppliers.	Demand Modeling / Assessment: yes Primary Data Collection: partially System Optimization: yes	Finance Procurement Remote Management Deal Origination Due Diligence Monitoring and analytics Feasibility Analysis Tenders/RBFs Monitoring and Evaluation	https://odysseyenergysolutions.com/
RAMP	OpenSource Demand Modelling Tool	Demand Modeling / Assessment: yes Primary Data Collection: no System Optimization: no	create demand profiles based on appliance ownership and usage times	https://rampdemand.org/
HOMER	Offers software for optimized hybrid power grid modeling of different sizes and scales	Demand Modeling / Assessment: yes Primary Data Collection: no System Optimization: yes	Combined engineering and economics Determine least-cost options Systems Simulations Energy Savings Integrate EV Charging Project Screening Site Selection	https://www.homerenergy.com/index.html
Sunny Design	A tool to model and plan PV systems offering a variety of options.	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	Design Recommendation Optimization Visual Planning Integrate E-mobility Energy-related system assessment Financial system assessment Self-consumption forecast	https://www.sma.de/en/products/apps-software/sunny-design#c439

PVsyst	A tool that can be used either educational of professionally to model solar systems and estimate different metrics like shading, economic evaluation and ageing.	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	System Design System Sizing Simulation Grid Storage Meteo Database Optimization Economic Evaluation	https://www.pvsyst.com/
Valentine Software	Products to simulate, design and forecast different types of renewable energy systems.	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	PV*SOL Premium PV*SOL T*SOL GeoT*SOL	https://valentin-software.com/en/
Kobo Toolbox	A tool used to create, distribute and evaluate detailed surveys.	Demand Modeling / Assessment: no Primary Data Collection: yes System Optimization: no	Powerful form development Data collection & analysis Project & team management	https://www.kobotoolbox.org/
DC System Analysis	The DC System Analysis includes Battery Sizing, DC Load Flow, DC Short Circuit (ANSI), and DC Short Circuit (IEC). The module complies with various industry standards and includes both a DC equipment library as well as DC component types.	Demand Modeling / Assessment: no Primary Data Collection: no System Optimization: yes	Industry standard complient, Large equipment library	https://www.skm.com/dcSystemAnalysis.html
CYME	Designed for planning studies and simulating the behavior of electrical distribution networks under different operating conditions and scenarios.	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	Modelling, Planning, Distributed Energy Resources, Operation, Protection, Power Quality, Optimization, Time-Series, Scripting	https://www.cyme.com/software/cymdist/
PV sol	Design and simulation software for PV Systems.	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	A product by Valentin-software [see Valentin Software row for more information].	https://valentin-software.com/en/products/pvsol-premium/

OEMOF	A modular open source framework to model energy supply models	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	System Design System Sizing Simulation Grid Storage Meteo Database Optimization Economic Evaluation	https://oemof.org/
OpenPlan	A open source GUI that offers the ability to model and optimize energy systems.	Demand Modeling / Assessment: yes Primary Data Collection: no System Optimization: yes	Easy to use GUI	https://open-plan.rl-institut.de/en/
Nessi	A free tool that allows users to make sustainable energy system decision for buildings or neighborhoods by simulating different impacts.	Demand Modeling / Assessment: partially Primary Data Collection: partially System Optimization: partially	Free online web tool	https://nessi.iwi.uni-hannover.de/en/
HEDERA Impact Toolkit	Helps to create mobile and web-based surveys.	Demand Modeling / Assessment: partially Primary Data Collection: yes System Optimization: no	Impact data management	https://hedera.online/en/hit/surveys.html
Offgridders	Open Source Software to model and optimize energy systems for off-grid use.	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	Github Repository	https://github.com/rl-institut/offgridders
iHOGA	The software can model systems with electrical energy consumption load (DC and/or AC) and/or Hydrogen, as well as consumption of water from tank or reservoir previously pumped.	Demand Modeling / Assessment: partially Primary Data Collection: no System Optimization: yes	Easy to use GUI	https://ihoga.unizar.es/en/

Construction

Digital Tool	Description	Sub-Category addressed	Features	Website [accessed on 8.24]
MS Project	Cloud based tool to manage task, work packages and projects within groups.	Project Management: yes	Project Management Portfolio Management Resource Management	https://www.microsoft.com/en-us/microsoft-365/project/proje
sPlan	You need a software to design your schematic circuit diagrams easy and fast? Then there is no way around sPlan! No matter if you only want to sketch a little circuit diagram or if you need to design a big project with several pages.	Project Management: no	Compact software at a relatively low price	https://www.electronic-software-shop.com/elektronik-software/splan-80.html?language=de

Engineering

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
HOMER	Offers software for optimized hybrid power grid modeling of different sizes and scales	Component Selection / Sizing: yes Listing of Components / Cabling: no Electrotechnical Engineering: partially Grid Simulation / Engineering: partially Mechanical Engineering / CAD Tools: no	Combined engineering and economics Determine least-cost options Systems Simulations Energy Savings Integrate EV Charging Project Screening Site Selection	https://www.homerenergy.com/index.html
Sunny Design	A tool to model and plan PV systems offering a variety of options.	Component Selection / Sizing: yes Listing of Components / Cabling: no Electrotechnical Engineering: yes Grid Simulation / Engineering: yes Mechanical Engineering / CAD Tools: no	Design Recommendation Optimization Visual Planning Integrate E-mobility Energy-related system assessment Financial system assessment Self-consumption forecast	https://www.sma.de/en/products/apps-software/sunny-design#c439
PVsyst	A tool that can be used either educational of professionally to model solar systems and estimate different metrics like shading, economic evaluation and ageing.	Component Selection / Sizing: yes Listing of Components / Cabling: no Electrotechnical Engineering: yes Grid Simulation / Engineering: yes Mechanical Engineering / CAD Tools: no	System Design System Sizing Simulation Grid Storage Meteo Database Optimization Economic Evaluation	https://www.pvsyst.com/
Valentine Software	Products to simulate, design and forecast different types of	Component Selection / Sizing: yes Listing of Components / Cabling: no Electrotechnical Engineering: yes	PV*SOL Premium PV*SOL	https://valentin-software.com/en/

	renewable energy systems.	Grid Simulation / Engineering: partially Mechanical Engineering / CAD Tools: no	T*SOL GeoT*SOL	
PandaPower	Similar application field like PowerFactory; Open Source Based in Python	Component Selection / Sizing: no Listing of Components / Cabling: no Electrotechnical Engineering: yes Grid Simulation / Engineering: yes Mechanical Engineering / CAD Tools: no	Analysing generation Transmission Distribution Industrial systems	http://www.pandapower.org/
PowerFactory	Optimize the value of your hybrid power system—from utility-scale and distributed generation to standalone microgrids	Component Selection / Sizing: no Listing of Components / Cabling: no Electrotechnical Engineering: yes Grid Simulation / Engineering: yes Mechanical Engineering / CAD Tools: no	Analysing generation Transmission Distribution Industrial systems	https://www.digsilent.de/en/powerfactory.html
SOLIDWORKS	A powerful CAD tool used in industry for modeling, simulations and machining. Can be expanded with plugins	Component Selection / Sizing: no Listing of Components / Cabling: partially Electrotechnical Engineering: partially Grid Simulation / Engineering: no Mechanical Engineering / CAD Tools: yes	SOLIDWORKS Simulation SOLIDWORKS Electrical 3D SOLIDWORKS 3D CAD	https://www.solidworks.com/
AutoCAD	A CAD system that can be used for mechanical, electrical and architectural modeling. Includes advanced features for cooperation.	Component Selection / Sizing: no Listing of Components / Cabling: yes Electrotechnical Engineering: partially Grid Simulation / Engineering: no Mechanical Engineering / CAD Tools: yes	Design and annotate Automate tasks Create a customized workspace	https://www.autodesk.com/products/autocad/overview
Splan	Drawing of electronic circuit diagrams	Component Selection / Sizing: no Listing of Components / Cabling: yes Electrotechnical Engineering: yes	Design of electrical plans	https://splan.de.softonic.com/

		Grid Simulation / Engineering: no Mechanical Engineering / CAD Tools: no		
OEMOF	A modular open source framework to model energy supply models	Component Selection / Sizing: yes Listing of Components / Cabling: no Electrotechnical Engineering: yes Grid Simulation / Engineering: partially Mechanical Engineering / CAD Tools: no	System Design System Sizing Simulation Grid Storage Meteo Database Optimization Economic Evaluation	https://oemof.org/
CYME	Designed for planning studies and simulating the behavior of electrical distribution networks under different operating conditions and scenarios.	Component Selection / Sizing: partially Listing of Components / Cabling: partially Electrotechnical Engineering: yes Grid Simulation / Engineering: yes Mechanical Engineering / CAD Tools: no	Modelling, Planning, Distributed Energy Resources, Operation, Protection, Power Quality, Optimization, Time-Series, Scripting	https://www.cyme.com/software/cymdist/

Supply Chain & Logistics

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
Flex port	Flexport offers tools for every aspect of the supply chain, from transportation, over inventory management to financial aspects	Retrieval of Cost Data: yes Delivery: yes Packaging: yes	Digital Advertising eCommerce Payments Cloud Computing Global Logistics	https://www.flexport.com/

Procurement

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
Odyssey	Helps connect renewable energy projects with financiers and equipment suppliers.	E-Commerce / Online Shop: no Tender Platform: yes	Finance Procurement Remote Management Deal Origination Due Diligence Monitoring and analytics Feasibility Analysis Tenders/RBFs Monitoring and Evaluation	https://odysseyenergysolutions.com/

Customer Management

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 4.23]
PineBerry	Offers everything needed for scaling of clean energy services on a “as a service” basis	Customer Relationship Management (CRM): yes Customer Service / Troubleshooting: yes Payments / Mobile Money: yes	Minigrid Last Mile Water Cooling E-mobility	https://pineberry.services/
MicroPowerManager	Open-Source platform for decentralized utility management	Customer Relationship Management (CRM): yes Customer Service /	Integrated prepayment metering Sales of goods through deferred payment schemes Real-time asset monitoring	https://micropowermanager.com/

	including customers, revenues and assets	Troubleshooting: yes Payments / Mobile Money: yes	Two-way SMS messaging Built-in ticketing system Centralized CRM database	
New Sun Road	Hardware and Software for Real-Time management of power systems using IoT	Customer Relationship Management (CRM): partially Customer Service / Troubleshooting: yes Payments / Mobile Money: partially	Power Asset Management in Underserved Communities Optimize Renewable Energy, Reduce Emissions Increase Tower Availability While Minimizing Costs Remotely Operate Islandable Hybrid Microgrids	https://newsunroad.com/
Meter Supplier Tools Sparkmeter	Offers utility management tools and hardware for different grid systems.	Customer Relationship Management (CRM): yes Customer Service / Troubleshooting: yes Payments / Mobile Money: yes	Stronger Asset Management Reduce distribution network costs Reduce wholesale energy costs Avoid or defer capital expenses for distribution network upgrades to meet growing peak demand Minimize the need for asset replacement due to reduced lifetime from transformer overloading	https://www.sparkmeter.io/
Meter Supplier Tools SteamaCo	Smart metering software and hardware for energy infrastructure	Customer Relationship Management (CRM): yes Customer Service / Troubleshooting: yes Payments / Mobile Money: yes	Advanced energy theft detection technology for utilities Overhaul your revenue protection methods Resolve Aggregated Technical Commercial and Collection (ATC&C) losses	https://steama.co/

Monitoring & Control

Digital Tool	Description	Sub-categories addressed	Features	Website [accessed on 8.24]
MicroPowerManager	Open-Source platform for decentralized utility management including customers, revenues and assets	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: yes Forecasting: partially	Integrated prepayment metering Sales of goods through deferred payment schemes Real-time asset monitoring Two-way SMS messaging Built-in ticketing system Centralized CRM database	https://micropowermanager.com/
Odyssey	Helps connect renewable energy projects with financiers and equipment suppliers.	Control / Dispatch: no Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: partially	Finance Procurement Remote Management Deal Origination Due Diligence Monitoring and analytics Feasibility Analysis Tenders/RBFs Monitoring and Evaluation	https://odysseyenergysolutions.com/
New Sun Road	Hardware and Software for Real-Time management of power systems using IoT	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: partially Forecasting: yes	Power Asset Management in Underserved Communities Optimize Renewable Energy, Reduce Emissions Increase Tower Availability While Minimizing Costs Remotely Operate Islandable Hybrid Microgrids	https://newsunroad.com/
AMMP	Service that allows to collect data from different sources, build dashboards and helps to monitor and control	Control / Dispatch: partially Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: partially	Data acquisition Vendor-agnostic integrations of different manufacturers and service providers Performance tracking and reporting	https://www.ammp.io/

	renewable energy investments			
EcoPhi Renewables Engineering GmbH	All-in-one monitoring and control solutions for solar, water and agriculture.	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: partially	Reports Analytics Alarms Remote Control API Integrations	https://ecophi.io/
New Sun Road	Real-time visibility and remote control to manage and optimize your power systems operations	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: partially	Power Asset Management in Underserved Communities Optimize Renewable Energy, Reduce Emissions Increase Tower Availability While Minimizing Costs Remotely Operate Islandable Hybrid Microgrids	https://newsunroad.com/
Inverter Supplier Tools SMA	Professional management, monitoring and presentation of PV plants	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: yes	Sunny Portal Live system status data Information about current energy flow (purchased electricity, battery charging) Monitors communication to the portal Monitors inverter performance Weather information for location Visualized energy yields	https://www.sma.de/en/products/monitoring-control/sunny-portal
Inverter Supplier Tools Victron	System that allows to monitore, manage and optimize renewable energy systems remotely.	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: yes	VRM Remote Monitoring works with a GX-device such as the Cerbo GX with internet connection or the GlobalLink 520 for smaller systems Monitor Manage Optimize Proactive maintenance services	https://www.victronenergy.com/panel-systems-remote-monitoring/vrm#technical-information
Inverter Supplier	FusionSolar Smart PV Management System	Control / Dispatch: yes Remote Monitoring: yes Electricity Price	One APP for all access procedure KPI Dashboard, centralized management of	https://solar.huawei.com

Tools Huawei		Algorithm: no Forecasting: yes	multiple plants Module-level monitoring Report subscription and real-time alarm push Online Smart I-V Curve Diagnosis, 15mins required for a 100MW plant diagnosis	
Fronius Solar.web	Solar.web monitors electricity consumption. It can notify of any critical events and give access to all of the information required at any time and from any location.	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: partially	Use Fronius Solar.web to keep an eye on your product at all times Identify consumption patterns Optimize consumption Store surplus energy	https://www.solarweb.com
Inverter Supplier Tools Schneider	The solution provides local system configuration and management, as well as live system monitoring for the residential and commercial range of solar and battery applications.	Control / Dispatch: no Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: yes	Control of energy management decisions Built-in wireless station mode Optimize energy consumption based on time Monitor system's performance from anywhere at any time Remotely upgrade Schneider Electric solar & storage devices' firmware	https://www.se.com/us/en/product-range/66298-insight-energy-management/?parent-subcategory-id=7030&filter=business-7-solar-and-energy-storage#documents
SolarView	SolarView for SolarEdge provides proactive monitoring and notifications for	Control / Dispatch: yes Remote Monitoring: yes Electricity Price	Provides regular production reports Notifies of any detected system faults	https://solarviewtech.com

	SolarEdge users and installers	Algorithm: no Forecasting: yes	Tracks actual energy production versus the estimated production Takes into consideration the degradation of solar panels over time	
SolarSCADA	SolarSCADA is a fully integrated SCADA system specifically designed for solar PV asset monitoring	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: partially	Plug and play solution- one input to all devices Pre-commissioned SCADA system ready to install Simplified sensor install, calibration & maintenance for monitoring-instruments	https://www.solarscada.com
Mana Monitoring Platform	The Mana Monitoring Platform was built for Solar Company and Asset Managers to centralize their portfolio of Solar installations	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: no Forecasting: no	KPIs and performance ratio Monthly targets vs actual performance Notify on faults Connect via API/FTP/HTTP/MQTT Templates for daily/monthly reports User management Additional data sources (weather, satellite, sensors)	https://manamonitoring.com
SOLARMAN	Solar Monitoring and Management Platform for Device Manufacturers, PV Professionals, Investors	Control / Dispatch: yes Remote Monitoring: yes Electricity Price Algorithm: yes Forecasting: partially	Acquiring and supervising multiple device types Compatible with all major inverters on the market Centralized display of massive quantities of plant data information Customized authorization Role management Alerts settings Intelligent AI Diagnosis	https://www.solarmanpv.com/products/solarman-business

O&M Management Tool

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
Illu	Making deploying, operating, and maintaining distributed renewable energy in the field as easy as possible	Ticketing Tools / After Sales Support: yes	Preventative Maintenance Incident Management Site Survey and Onboarding Commissioning and QC	https://www.illu.works/

Online Knowledge Products

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
Green Mini-Grid Help Desk	Practical information on mini grids	Online Knowledge Products: yes Online Trainings: no		https://greenminigrid.afdb.org/

Online Trainings

Digital Tool	Description	Sub-Categories addressed	Features	Website [accessed on 8.24]
SMA Solar Academy	Provides product, system, solution and service training related to PV systems	Online Knowledge Products: yes Online Trainings: yes	Online training In-person training Tech tips videos	https://solaracademy.sma.de/en.html
Victron Energy	Basic-to-Pro training courses for system installers	Online Knowledge Products: partially Online Trainings: yes	Digital Training	https://www.victronenergy.com/blog/2021/06/08/victron-training-videos/

Technology Collaboration Programme

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