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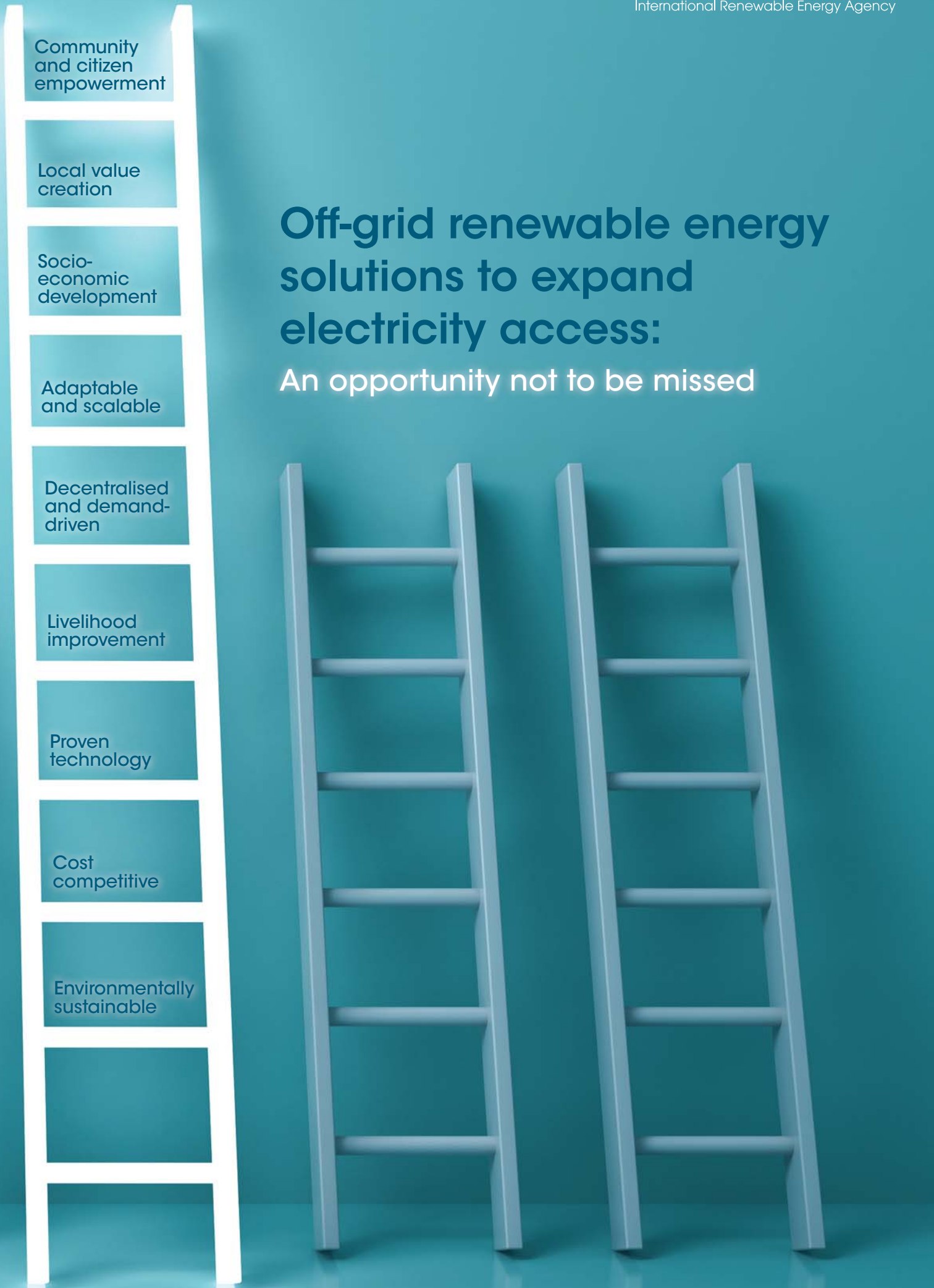
Off-grid renewable energy solutions to expand electricity access:

An opportunity not to be missed



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The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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"Off-grid renewable energy systems have transformed our ability to deliver secure, affordable electricity to rural communities all over the world, and are playing a vital role in breaking a cycle of energy poverty that has held back socio-economic progress for hundreds of millions of people."

Adnan Z. Amin, Director-General

International Renewable Energy Agency

Photo: Prashanth Vishwanathan

OFF-GRID RENEWABLE ENERGY SOLUTIONS TO EXPAND ELECTRICITY ACCESS:

AN OPPORTUNITY NOT TO BE MISSED

The number of people living without electricity access has, after several decades of dedicated effort, dipped below one billion in 2016. The world is steadily progressing towards universal access to electricity, with the global electrification rate reaching 87% in 2016. Access rates in rural areas – where most of those without access live – have been growing rapidly and now stand at about 76% (World Bank Group, 2018). Strong political commitment to the energy access agenda at the national and global level, combined with financing, local entrepreneurship and technological innovations, have set the stage for a final push towards universal electricity access by 2030 – a target within the Sustainable Development Goal 7 (SDG 7).

Today we have the technologies and the solutions that can dramatically accelerate the growth trajectory of electricity access. Off-grid renewable energy solutions, including stand-alone systems and mini-grids, have emerged as a mainstream, cost-competitive option to expand access to electricity. Tremendous progress has been made in recent years as technology costs have plummeted, innovation in delivery models and financing has picked up, and a more diverse set of stakeholders, including communities, local entrepreneurs and the private sector, have become engaged in the sector. The number of people benefiting from off-grid renewable energy solutions grew six-fold between 2011 and 2016, reaching more than 133 million (IRENA, 2018a). Besides providing electricity services for households, off-grid solutions are also increasingly supporting public services (*e.g.,* education, water and primary health care) and livelihoods (*e.g.,* in agriculture).

Off-grid renewable energy solutions represent a viable electrification solution that is rapidly scalable, environmentally sustainable, can be tailored to local conditions and, importantly, has the potential to empower rural communities, especially the youth and women. The next phase of expansion will require these solutions to play a fundamental role. It is estimated that by 2030, renewable energy sources will power over 60% of new electricity access, and stand-alone and mini-grid systems will provide the means for almost half of new access (IEA, 2017).

This brief takes stock of the opportunity at hand – detailing the dynamism and the innovations in the off-grid renewable energy sector. Building on IRENA's growing body of work on the topic (Figure 1), it highlights the latest trends and advancements, including innovations in delivery and financing models, and discusses the policy and regulatory measures governments are taking to harness the potential of off-grid renewables for meeting SDG 7 on energy, as well as several other SDGs.

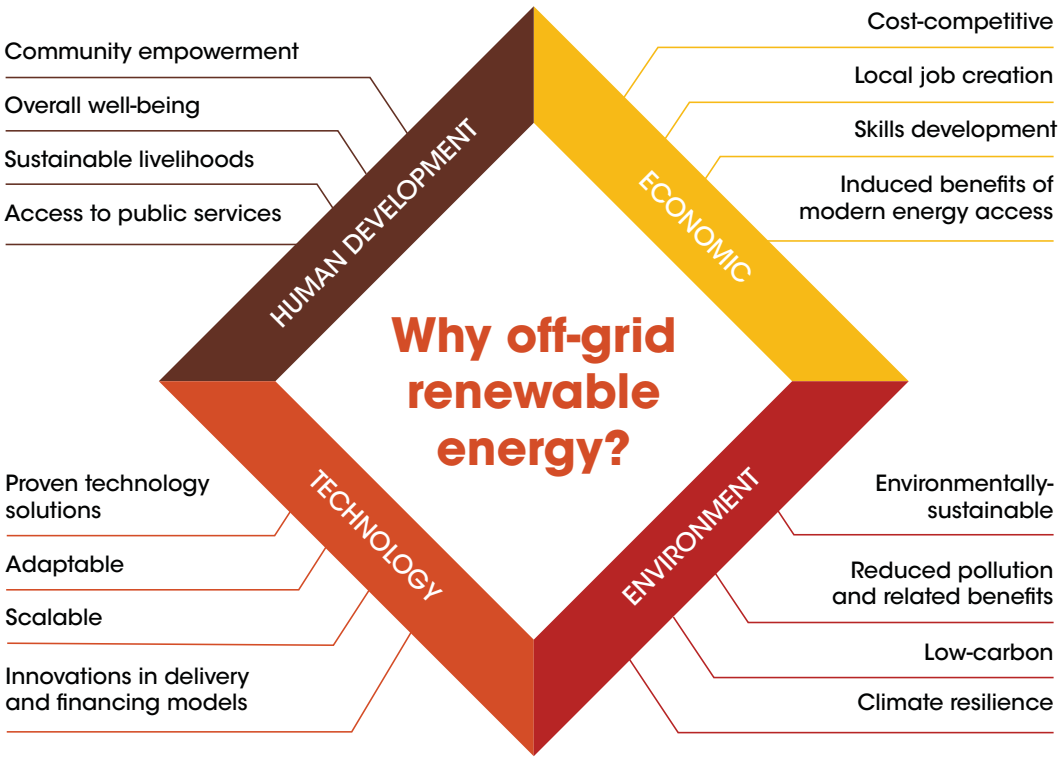
Figure 1: Overview of IRENA activities on off-grid renewable energy

The case for off-grid renewables

The convergence of several powerful factors has opened a window of opportunity for achieving universal access to electricity supported by off-grid solutions (Figure 2). Rapid decreases in technology costs have meant that off-grid renewable energy solutions are now the cost-competitive choice for expanding electricity access in many unelectrified areas. Since 2009, for instance, solar PV module costs have fallen by more than 80% while, globally, the cost of solar PV power declined by 73% from 2010 to 2017 (IRENA, 2018b).

Steeply declining costs of the most important components of off-grid systems, combined with an equally remarkable increase in efficiency of end-use appliances, have further lowered prices and increased affordability. Between 2010 and 2016, for instance, the prices of main components of stand-alone solar home systems – LED lights and batteries (Li-ion) – dropped by 80% and 73%, respectively (IFC, 2018).

Figure 2: Case for off-grid renewable energy solutions



Although the cost of delivering technology to certain areas can be prohibitively high, the cost competitiveness of off-grid solutions is likely to further strengthen as deployment grows, technology improves, supply channels are established, and key components improve (*e.g.,* batteries, appliances).

Other factors contributing to the appeal of off-grid solutions include rising incomes, expansions of infrastructure and rural connectivity, and wider availability of consumer finance (IFC, 2018). Decreases in technology costs have already unlocked new markets and innovations in delivery and financing models. The pay-as-you-go model in East Africa (Box 1), and the micro-finance ecosystem in Bangladesh, for example, transformed market potential into actual deployment.

Illustrating the **scalability** of off-grid solutions, between 2011 and 2016, the number of people benefiting from such solutions increased six-fold, reaching more than 133 million. This includes about 100 million using solar lights (<11 watts), 24 million using solar home systems (>11 watts) and at least 9 million connected to a mini-grid. Concurrently, off-grid renewables capacity witnessed a spectacular three-fold increase from under 2 gigawatts (GW) in 2008 to over 6.5 GW in 2017 (IRENA, 2018a) (Figure 3).

While a proportion of the deployed capacity is to support household electrification, a majority (83%) is dedicated to end-uses in industry (*e.g.,* co-generation), commercial (*e.g.,* powering telecommunication infrastructure) and public services (*e.g.,* street lighting, healthcare centres, water pumping). This demonstrates the adaptability of off-grid solutions and the opportunity to **tailor** them to local conditions and the services demanded.

Box 1: Leveraging the digital ecosystem: Rise of pay-as-you-go (PAYG) solar systems in East Africa

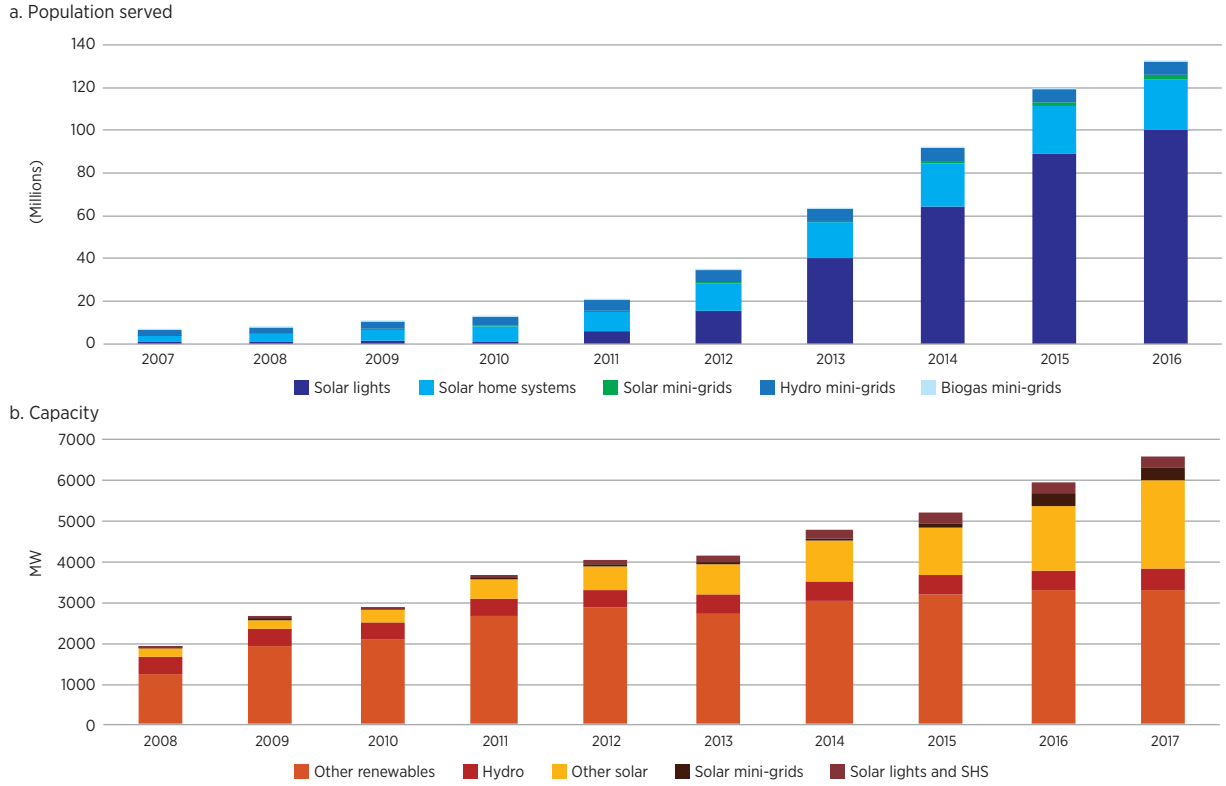
The number of people benefiting from stand-alone solar lighting and home systems has grown twelve-fold since 2010, exceeding 120 million by 2016. PAYG-based plug-and-play solar solutions, wherein consumers pay tailored, periodic instalments often towards eventual ownership of the systems, spread at an average annual growth rate of 140% between 2013 and 2016. East Africa has accounted for most of this growth, thanks to the existence of a strong mobile money ecosystem.

Combining PAYG financing with digital payments has been a boon for the sector, enabling rural households to access larger solar home systems that provide other electricity services in addition to lighting. The digitisation process has also enabled financial inclusion, access to energy efficient appliances (including for productive end-uses), the development of credit worthiness and the use of data as a powerful management tool for both suppliers and end-users.

The PAYG sector attracted a cumulative USD 773 million in investments between 2012 and 2017, equivalent to 85% of all investments in the off-grid solar sector. The sector is estimated to exceed USD 20 million in annual sales and to generate USD 6-7 billion in annual revenue by 2022.

Source: IRENA, 2018a; IFC, 2018.

Figure 3: Population served by, and capacity of, off-grid renewable energy solutions



Source: IRENA, 2018a.

Note: Other renewables: primarily industrial bioenergy. Other solar comprises off-grid power capacity in end-use sectors as industry and commercial/public. For about 1.5 GW of reported off-grid solar capacity, the end-use is unknown and, therefore, recorded in this category.

Growing deployment has expanded the knowledge base on the transformative effect that off-grid renewable energy solutions can have on **socio-economic development**. Even access to basic electricity services, such as lighting and mobile charging, has substantial positive socio-economic outcomes in terms of reduced spending on traditional fuels, improved lighting (*e.g.,* for cooking, studying, income-generating tasks) and enhanced connectivity (GOGLA, 2018a).

Experience further shows that the expectations of rural communities grow with time, stimulating demand for appliances that use the newly available electricity, often at grid-like service levels. In rural Kenya, for example, the desire for appliances such as TVs, radios, mobile phones and income-generating appliances is consistent between households that primarily use off-grid electricity and those that use kerosene. From an electrification planning perspective, stand-alone systems play an important role in **unlocking latent demand** and improving the viability of larger systems (mini-grids or grid extension, where feasible).

The **distributed** and **decentralised** nature of off-grid technologies offers the opportunity to maximise the socio-economic benefits of energy access by engaging local capacities along different segments of the value chain. Many of the skills needed to install, operate and maintain off-grid systems can be developed locally, providing access to training and employment opportunities, especially for youth and women. Examples around the world demonstrate that the value of actively engaging communities at all stages of project development can improve sustainability and maximise benefits by promoting local ownership and establishing links with end-uses, including income-generating activities.

Recent advancements in off-grid solutions present an excellent opportunity to accelerate progress towards the SDG 7 target on universal access to modern energy services. No one off-grid solution will suit every local context, but enough has been learned in recent years to conclude that a judicious selection among tested approaches will yield good results in all cases.

Key drivers for growth in off-grid renewable energy

Advances have come in the areas of delivery and financing models, policies and regulations, institutional frameworks, capacity building, technology, and cross-sector linkages (IRENA, 2017), as illustrated in Figure 4.

Delivery models tuned to technology and adapted to end-users' needs

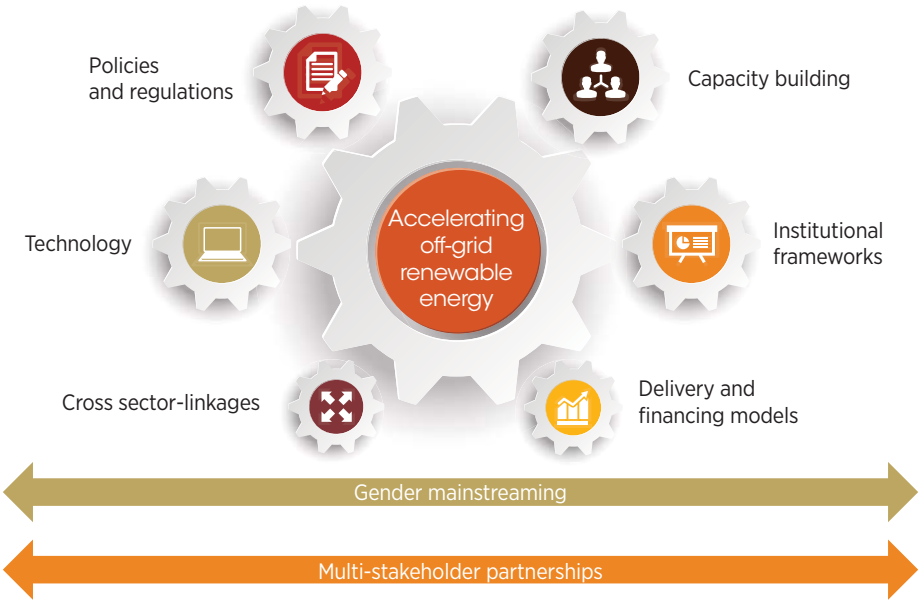
A remarkable feature of the off-grid renewables revolution has been the innovation in delivery models to make technologies and modern energy services accessible, affordable and sustainable over the long-term. Delivery models need to be adapted to local socio-economic conditions, the specific technologies (*e.g.,* stand-alone systems or mini-grids) and current and projected demand for electricity services. This adaptation is evident in the diversity of delivery approaches seen globally and has played a key role in the accelerated deployment recently observed.

For **stand-alone systems**, Bangladesh stands out as a key solar home system market where over 4 million systems have been deployed to date, providing electricity services to over 11% of the population. Key success factors for the programme have been the existence of a microfinance ecosystem, the design of tailored financing schemes for end-users, a focus on long-term sustainability and market development, and, importantly, the existence of a sector "champion" in the form of the Infrastructure Development Company, Ltd (IDCOL).

In East Africa, especially Kenya, which has emerged as a hub for innovation and adoption in stand-alone systems, the private sector has devised different delivery models to reach unelectrified communities. Smaller systems, such as solar lights, are dominantly based on direct cash sales, given the relatively lower upfront capital cost, while larger systems have been deployed through lease-to-own or fee-for-service approach.

The private sector has leveraged opportunities offered by expanding mobile phone coverage and growing digitisation (*e.g.,* mobile money, smart metering). The emergence of pay-as-you-go financing, wherein consumers pay periodic instalments through mobile money, has transformed the landscape for stand-alone solar systems by integrating consumer financing into the delivery model and enabling distributors and suppliers to reduce operational expenditures in physical collection of fees (IRENA, 2017). Coupled with smart metering and data analytics, a digital ecosystem has emerged to support the off-grid renewables sector.

Figure 4: Components of an enabling environment for off-grid renewable energy solutions



Source: IRENA, 2018a.

Photo: Martin Wright/Ashden

Delivery models for household biodigesters have also undergone major innovations. Large programmes in sub-Saharan Africa and South/Southeast Asia now deploy these solutions at scale, utilising locally available feedstock (*e.g.,* agricultural residues, food waste, livestock waste) to generate renewable cooking fuels, electricity and organic farm fertilisers. In Viet Nam, for instance, over 250 000 domestic biogas digesters have been deployed, benefitting over 1.2 million people (IRENA, 2018c). The delivery and financing model has been designed to support long-term market development. Initially, households received a flat-rate subsidy per digester, accounting for on average 10% of total investment costs. Recently, this subsidy is being replaced with a results-based financing scheme that offers suppliers incentives to take additional risks and to transition towards a self-sustaining market.

Delivery model innovations in the **renewable energy mini-grid** sector have aimed to improve long-term viability so as to attract investments, boost local demand for energy services and improve the sustainability of projects from a technical, economic, social and environmental stand-point. Many approaches are used, ranging from community-led micro-hydro systems in Southeast Asia, to private sector-driven solar-battery mini-grids across sub-Saharan Africa, and hybrid systems on islands. The public sector plays, a crucial role in supporting innovation in mini-grid delivery models by crowding in investments from the private sector.

Several countries have introduced dedicated policies and regulations for the sector (discussed later) to provide entry points for the private sector to develop mini-grids. Tanzania's Small Power Producers framework, for instance, has, since 2008, offered the private sector opportunities to generate, distribute and retail electricity in unelectrified areas (IRENA, 2018d).

Unique public-private partnership models are also being introduced. In some, the public sector takes ownership of distribution assets, while the private sector invests in the generating asset. Actively engaging communities in the design, construction, operation and maintenance of projects can increase community buy-in, enhance sustainability and increase opportunities for rural employment. Countries like Nepal have built community ownership into the delivery model for micro-hydro projects to maximise socio-economic benefits. A large potential market (on a scale of hundreds of gigawatts) also exists to replace or hybridise existing off-grid diesel generators with renewable energy (IRENA, 2015).

The delivery models for off-grid renewable energy solutions are closely tied to access to affordable, long-term financing for both enterprises and end-users. In fact, a number of delivery model innovations in the sector, including pay-as-you-go, have come about to compensate for poor access to consumer financing. To further scale up off-grid deployment of renewables, the financing gap in the sector needs to be addressed, as discussed in the next section.

Catalysing financing through innovative instruments

Investment in the off-grid renewables sector has grown strongly as deployment has accelerated. In the stand-alone solar sector, estimated annual investments have risen nearly four-fold since 2014, reaching USD 284 million by 2017 (IFC, 2018). Investments in the mini-grid sector have grown from USD 16 million in 2015 to USD 81 million in 2018 (BNEF, 2018). Despite the impressive growth, the investment gap in the off-grid sector and in energy access broadly remains large. Off-grid solutions, for instance, attracted no more than 1% of the USD 30 billion committed in 2015-16 for expanding electricity access (SEforALL and CPI, 2018).

Both public and private sources of financing have an important role to play in bridging the financing gap. **Public finance** can close the funding gap through: i) direct financing for public services, rural enterprises and households that are unable to access available solutions and are at risk of being left-behind (Practical Action, 2018); and ii) financing instruments that de-risk investments and, thereby, attract private capital for enterprises and projects (*e.g.,* high-risk innovation funds, funds for initial feasibility study).

To scale-up off-grid renewables, there is a need to **access commercial debt financing** in large volumes. Increasingly, the pay-as-you-go solar segment is accessing debt often on favourable terms, but the renewable energy mini-grid sector is still largely financed through grants and non-commercial, patient equity (UNDP and ETH Zurich, 2018). New financing approaches are also being introduced to the sector, including **securitisation** opening new debt markets for off-grid energy companies (Aidun and Muench, 2016) and **crowdfunding** (Box 2).

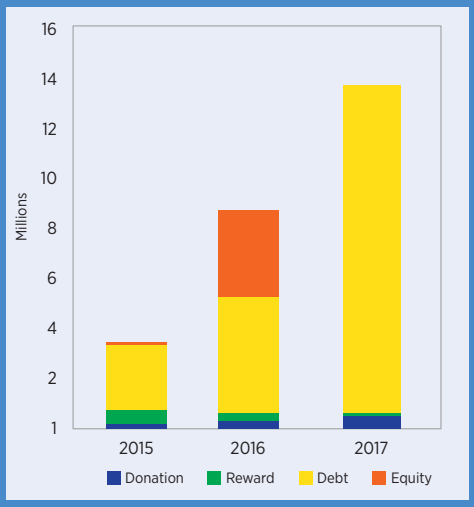
Box 2: Complementary financing instruments: The case of crowdfunding

Crowdfunding offers an opportunity for enterprises, entrepreneurs, communities, aid agencies and consumers to raise financing for off-grid renewable energy projects, especially in countries with underdeveloped financial markets or where traditional financing is not easily accessible. It is estimated that in 2017, at least USD 13.7 million was raised through crowdfunding platforms for energy access, up nearly 60% from 2016 levels (Figure 5) (Cogan and Weston, 2018). Crowdfunding can raise financing quickly, at relatively low cost and risk (UNDP, 2018; Ottinger and Bowie, 2015; MIF, 2015). It also allows project developers to widen their pool of investors, both in terms of geographical reach and risk appetite (Baeck, Bone and Mitchell, 2017).

Crowdfunding can also provide a range of additional, often non-monetary, benefits for project proponents, investors and recipient countries. It allows entrepreneurs to assess market demand and validate their products or services before turning to traditional investors (MIF, 2015). For recipient countries, crowdfunding can help attract additional direct aid flows from other regions, *e.g.,* by channelling diaspora investments. Several platforms have already been set up to capture remittance flows, among them Homestrings for African countries, Zafen for Haiti and ISupportJamaica (AlliedCrowds, 2015).

With a growing population of young enterprises and the rising adoption of internet technologies, the potential of crowdfunding in developing countries is still largely untapped.

Figure 5: Crowdfunding for energy access



Source: (Cogan and Weston, 2018)

Mobilising sufficient capital for investments in the sector is as important as establishing inclusive channels for delivering tailored financing for end-users and enterprises. Investments in the sector show substantial disparity. East Africa accounted for over half of the total investments in off-grid solar in 2017. Furthermore, between 2012 and 2017, pay-as-you-go enterprises raised over USD 770 million with just four companies accounting for 67% of all investments (IFC, 2018).

The financing needs of enterprises in the off-grid energy sector vary widely, depending on the maturity of the enterprise, its product and service portfolio, and the stage of the projects in which it is involved. Viewed from the consumer side, access to long-term financing at affordable rates can bring off-grid products (*e.g.,* solar home systems) and services (*e.g.,* mini-grid connections) within the reach of millions of end-users who otherwise might not be able to acquire them. Designing financing mechanisms in a manner that engages local financial institutions can help unlock local currency lending over the long-term and widen the range of financial services available to projects and end-users.

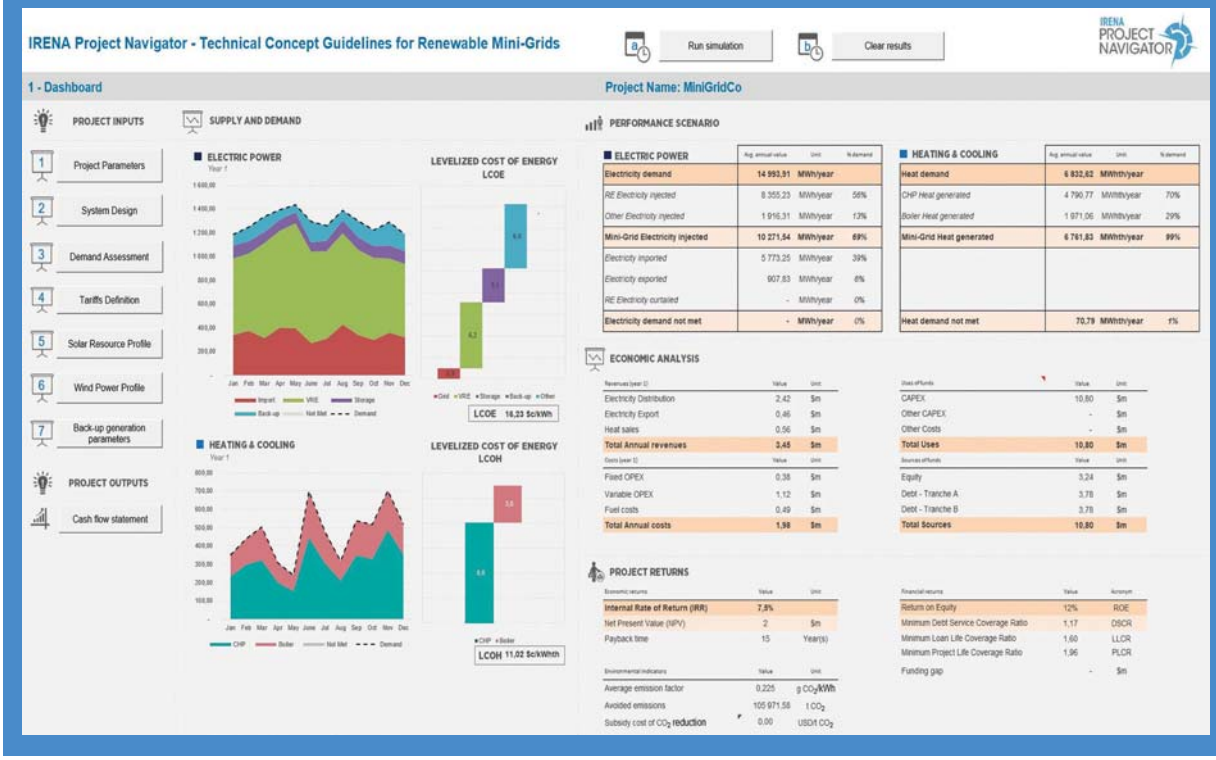
Meeting SDG 7 on modern energy access will require financial instruments tailored to local conditions, as well as efforts to support the development of a pipeline of projects and enterprises. Dedicated project facilitation tools can help project developers secure financing. IRENA's online platform, Project Navigator (https://navigator.irena.org), for instance, provides the tools and guidance to assist in developing renewable mini-grid projects, and introduces best practices to assist project developers in preparing, developing, and operating bankable projects (Box 3). The Sustainable Energy Marketplace (www.irena.org/marketplace) connects renewable energy project owners, financiers/investors, service providers and technology suppliers.

Box 3: Tools to support project preparation: IRENA's Project Navigator

Project developers often have trouble securing funding for renewable off-grid projects owing to limited awareness and technical expertise. To address some of these issues, IRENA has developed the Technical Concept Guideline on Renewable Mini-grid Projects. The guideline offers project developers case studies and practical tools (Figure 6) for application to their own projects.

Project developers can learn how to develop bankable project proposals following the IRENA Project Navigator's nine-step process. In the past two years, more than 1 000 project developers worldwide have participated in the on-site training workshops and more than 3 000 people have been trained online on the development of bankable renewable mini-grid projects.

Figure 6: IRENA Project Navigator: Mini-grid project evaluation model



Policy and regulatory frameworks that build a conducive environment for growth

Countries are increasingly mainstreaming off-grid renewable energy solutions within national energy access strategies (Box 4). This provides a strong foundation for market development and incentivises stakeholders to devise tailored solutions to provide energy services. Electrification planning and strategies should clearly identify those areas of the country that will be reached by grid extension within a reasonable time frame, as well as those suitable for off-grid solutions. Holistic and integrated energy access strategies must be backed by dedicated policies and regulations designed for different off-grid solutions, such as mini-grids and stand-alone systems.

Box 4: Mainstreaming off-grid solutions: Kenya's national rural electrification strategy

In December 2018, the Kenya National Electrification Strategy was launched to provide a roadmap to universal access to electricity by 2022. Based on a geospatial analysis, the strategy identifies least-cost options to expand electricity access to the remaining 14 unelectrified counties. In this effort, off-grid renewable energy solutions will play an important role, leveraging in part the pay-as-you-go revolution that is underway in Kenya for the deployment of stand-alone solar home systems.

Universal access to electricity is a key requirement to meet Kenya's goal, expressed in Vision 2030, to become an industrialised middle-income country. Kenyan households and businesses will need competitively-priced, reliable, safe and sustainable energy to deliver on the four priorities of affordable housing, manufacturing, food security, and universal healthcare.

Source: Willuhn, 2018.

In the specific case of **stand-alone systems,** policies can strongly influence the accessibility and sustainability of such solutions for rural communities. Fiscal incentives, such as import duty and value-added-tax exemptions, are often introduced to incentivise market development; these directly improve the affordability of stand-alone systems. Other supportive measures include levelling the playing field (*e.g.,* evaluating fossil fuel subsidies, raising public awareness), introducing quality standards and establishing dedicated consumer/enterprise financing channels as part of a broader programme (discussed further on).

Scaling up **renewable energy mini-grids** requires dedicated policies and regulations to address key areas such as licensing and permitting requirements, tariff setting frameworks, the implications of arrival of the main grid and the distinctive aspects of mini-grid financing (IRENA, 2016a). Responding to the growing competitiveness of renewable energy mini-grid solutions, countries are taking steps to create a conducive environment for attracting private sector participation and scaling up deployment. Box 5 discusses the case of Nigeria where dedicated mini-grid regulations were introduced in 2017 (IRENA, 2018d).

Policies and regulations for off-grid renewables should take a **holistic approach** in order to create an enabling ecosystem for deployment and maximise socio-economic development. Moving beyond key investment risks, policies also need to address aspects related to **capacity building and linkages between the sector and productive** end-uses. All of these have a strong bearing on the scalability of off-grid solutions and the socio-economic outcomes of deployment policies.

Box 5: Establishing dedicated mini-grid policy and regulatory frameworks: The case of Nigeria

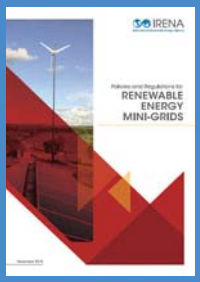
More than half the population in rural Nigeria lacks access to electricity. The Rural Electrification Strategy and Implementation Plan released in 2016 aims to utilise both on- and off-grid solutions to redress this situation. The plan highlights the importance of community and privately owned mini-grids for expanding electrification. In 2017, a set of regulations for mini-grids was released by the Nigeria Electricity Regulatory Commission (NERC), providing tailored regulatory guidance for systems under 100 kW, between 100 kW and 1 MW, and interconnected mini-grids. Some key design features of the regulation are as follows:

Licensing and legal provisions. For mini-grids with a distributed capacity above 100 kW and an installed capacity of less than 1 MW, obtaining a permit is mandatory. For mini-grids with a distributed capacity below 100 kW, registration with NERC is sufficient, although developers may apply for a permit voluntarily. Meanwhile, interconnected mini-grids (up to 1 MW generation capacity) are eligible for permits in underserved areas.

Tariff setting. Registered mini-grid companies with a distribution capacity under 100 kW are allowed to set their own tariffs. Mini-grid operators that apply for a permit must use a standardised tariff calculation tool approved by the NERC. For interconnected mini-grids, the developer, distribution company and the community must reach agreement on the retail tariff, rights to use the network infrastructure and the tariff for electricity generated by the mini grid and fed into the distribution companies' network.

Arrival of the main grid. Mini-grid operators holding a permit are guaranteed compensation on arrival of the main grid. They may either convert to an interconnected mini-grid or sell their assets at the depreciated price, plus 12 months of revenue.

Nigeria was one of the eight jurisdictions analysed in IRENA's Policies and Regulations for Renewable Energy Mini-grids (November 2018). Others include Cambodia, Indonesia, Peru, Rwanda, Sierra Leone, the United Republic of Tanzania and Uttar Pradesh (India). The report captures the evolution of the mini-grid policy and regulatory landscape, highlights emerging trends and draws lessons.



Source: IRENA (2018d); NERC (2016).

An appropriate institutional framework is crucial to ensure the effective implementation of national energy access strategies and related policies. Some countries (notably in sub-Saharan Africa) have created new institutions to support rural electrification activities, while others have placed the responsibility for rural electrification within existing ministries or agencies. In several countries, financial institutions have been empowered to champion the development of the off-grid sector (*e.g.,* IDCOL in Bangladesh).

Although approaches differ according to country contexts, successful strategies share some traits, such as simplified and streamlined administrative procedures, clearly defined roles and responsibilities, and cooperation among diverse national and international institutions and agencies.

Technology innovations reducing costs, enhancing reliability and improving livelihoods

Technology innovation has played a key role in an ongoing process of reducing costs, improving reliability and making solutions accessible. The innovation process covers generation technologies (*e.g.,* solar modules, micro-hydro turbines), balance-of-system components (*e.g.,* inverters, electronic load controllers, smart meters), control systems and appliances. To support a further scale-up in off-grid renewables, the innovation process needs to be strengthened through a focus on **adaptation to local conditions and end-uses,** and through the **establishment of quality infrastructure.**

Linking technology innovation with livelihood development has emerged as an important frontier for off-grid renewables to support income-generating activities. This synergy requires tailoring technology solutions to different productive end-uses (current and potential) and integrating off-grid renewables along different segments of the value chain in relevant sectors (*e.g.,* textiles, agriculture, animal husbandry, cottage industries, etc.). Box 6 shares some examples of grassroots research and development focused on livelihood solutions.

Box 6: Linking technology innovation with livelihoods: Experience of the SELCO Foundation

Technology innovation is one of the key pillars to support livelihoods through off-grid renewable energy solutions. SELCO Foundation has developed over 50 livelihood technologies and worked with more than 1 500 entrepreneurs over the past five years to improve access to livelihood solutions driven by sustainable energy. Some examples include:

- A solar powered, hand-held cotton-picking machine to improve productivity and reduce drudgery, coupled with a solar-based, energy-efficient, direct-current machine for ginning, spinning, weaving and sewing, resulting in value addition and higher incomes
- Solar powered processing equipment for pulses, millet, cereals, spices and fruits, resulting in reduced costs, greater productivity and higher incomes
- Sustainable energy solutions for the dairy sector, including milking machines and butter churners, and for poultry, such as coop lighting and egg incubators
- Solutions for blacksmiths to reduce labour costs, inputs and drudgery – in particular, solar-powered angle grinders for cutting metal strips, fan blowers for heating iron and a power hammer for shaping metal.

Innovation must extend beyond technology to focus on ownership models, financial models, and supply and service-delivery models that allow for sustained impacts from the design and deployment of the technological solutions.

Source: SELCO Foundation, 2018.

Beyond generation technologies, **innovations in enabling components** – including smart control systems that take advantage of the internet of things; artificial intelligence; energy storage; and low-voltage, direct-current mini-grids – are also underway. Through these technologies, opportunities have arisen to better integrate large shares of solar and wind in isolated power systems. Cloud-based monitoring solutions for mini-grids in Haiti, for instance, integrate the communications hardware in meters and transmit consumption data to a central gateway. These applications reduce electricity cost and increase the reliability of electricity supply by optimizing consumption, thus reducing generation and storage (*e.g.* battery size) costs (IRENA, 2016b; EarthSpark, 2016).

Remote islands are also becoming a great showcase for digital technologies, as they leap-frog over older systems deployed elsewhere and implement state-of-the-art solutions tailored to their context. For example, in 2016 the island of Ta'u in American Samoa demonstrated, through a mini-grid with 1.4 MW solar PV and a 6 MWh energy storage system, that transforming a 100 per cent diesel system to a solar PV system with battery storage is feasible (Lambert, 2016).

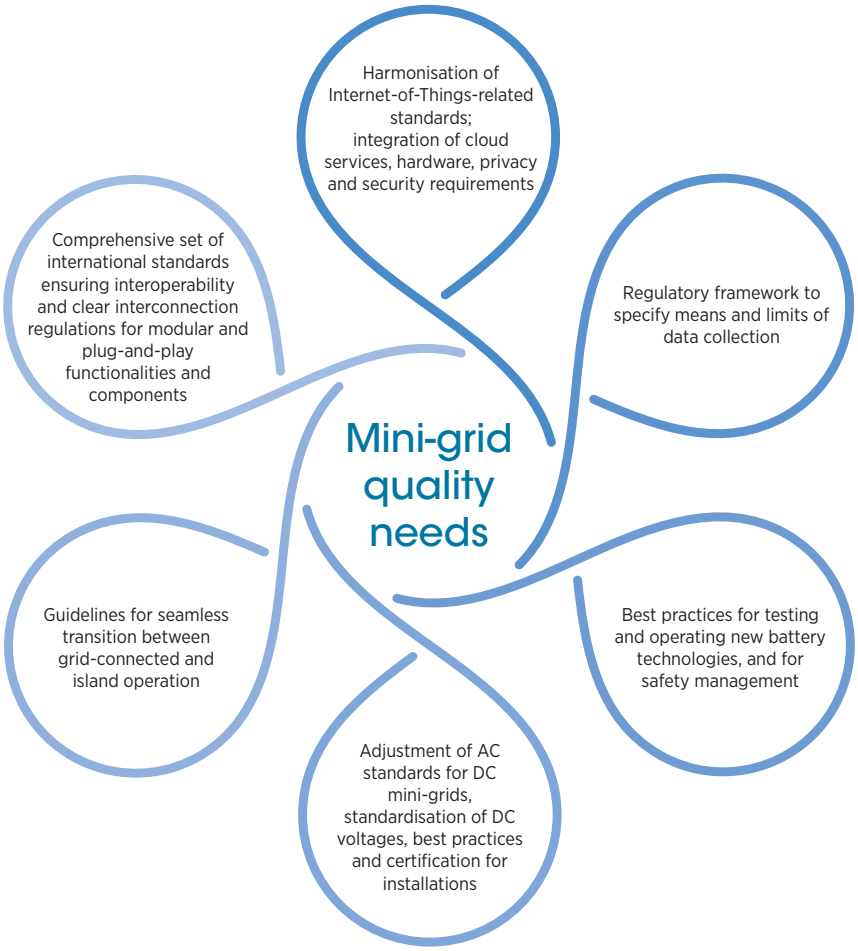
As discussed earlier, digital technologies for off-grid applications are enabling new business models. Recently, models such as pay-as-you-go, peer-to-peer energy trading and energy communities have grown in popularity in off-grid energy markets. In Bangladesh, for instance, SOLshare utilises peer-to-peer solar energy trading platforms to leverage excess generation from solar home systems by selling it to neighbouring households (SOLshare, 2017).

To leverage the benefits of these innovations, it is crucial to ensure that the systems deliver the expected services and benefits over the long term. **Quality infrastructure** for off-grid technologies reduces technical risk, leading in turn to better financial opportunities, improved operation and maintenance, and assured performance across the technology lifespan. Quality infrastructure comprises the entire institutional network and legal framework necessary to formulate and implement standards and regulations for products and services. It extends to evidence of the fulfilment of those standards and regulations through testing, certification and accreditation.

The adoption of international technical specifications for rural electrification – notably a methodology for the implementation and management of systems – will be essential in ensuring and sustaining quality. However, with rapid innovations in off-grid solutions, new quality gaps are arising. As shown in Figure 7 for renewable energy mini-grids, most of the emerging needs relate to the use of digital technologies and interoperability of components, including frameworks for big data management, interconnection to the main-grid, elaboration of DC mini-grid standards and comprehensive standards for the internet of things.

Some countries, such as India and the United Republic of Tanzania, have begun to address these gaps. The Tanzania Energy and Water Utilities Regulatory Agency has developed "Guidelines for Grid Interconnection of Small Power Projects", which includes standards and engineering recommendations to be considered when designing a system capable of being connected to the grid (EWURA, 2011). A forthcoming IRENA report, *Quality Infrastructure for Mini-grids* (IRENA, 2019a), studies the current status of and gaps in mini-grid quality assurance and offers recommendations to policy makers and energy stakeholders on how to ease the adaptation and operation of mini-grids.

Figure 7: Future quality needs for renewable energy mini-grids



Source: Forthcoming IRENA, 2019a

Building capacity across the off-grid value chain and fostering entrepreneurship

If off-grid renewables are to be scaled up to meet potential demand, adequate capacity must be developed across the sector. Skills development and training must be tailored for different stakeholders, including end-users, financing institutions, local entrepreneurs, standardisation agencies and the private sector. Many of the skills needed along the off-grid value chain can be developed locally, thus creating local job creation opportunities (see Box 7 for the case of the stand-alone solar value chain) (IRENA, 2012).

Box 7: Job creation in the stand-alone solar value chain

Rapid growth in the deployment of stand-alone solar solutions, including solar lights and home systems, has created employment opportunities along the value chain. Direct job creation is generally higher in the downstream segment, particularly in the distribution, sales, installation, operation and servicing of systems. As delivery models evolve, the employment opportunities also change in scale and in nature. The pay-as-you-go model, for instance, employs more people in after-sale customer relations, as well as technical, skilled jobs such as software design and logistics. In contrast, cash-based models create a higher proportion of jobs in sales.

An estimated 1.5 million full-time-equivalent jobs could be created in the off-grid solar value chain by 2022 (excluding manufacturing). Most are likely to be in installation and maintenance. Besides skilled positions for technicians, sales and after-sale services, job opportunities also arise in management and finance.

A far greater number of indirect and induced jobs can be created from economic activities enabled through improved access to electricity. The job creation potential is considerably increased when energy solutions are integrated with local economic activities. A better understanding of the employment effects of different energy access approaches (*e.g.,* the number, type, skill level and wage level of the jobs created by various technologies) can guide policy making and skills development efforts. In 2018, for instance, a multi-stakeholder global campaign – Powering Jobs – was launched (www.powerforall.org/campaigns/poweringjobs) to raise awareness and develop equitable, diverse, and inclusive training and employment opportunities, particularly for women and youth.

Source: (GOGLA, 2018b.)

Certification programmes, integration in training curricula and a focus on **building local skills** in operation and maintenance, while providing employment opportunities, would also support wider socio-economic development. The ECOWAS Certification for Sustainable Energy Skills Programme, for instance, has been established by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in partnership with IRENA and GIZ, the German development agency (ECREEE, n.d.).

The aim is to improve the technical competency of various renewable energy professions across the ECOWAS member states. The scheme is being piloted in Ghana and Senegal for certification of stand-alone solar PV technicians who will be required to clear a written and practical examination based on a regionally harmonised job-task analysis that details competencies for installation, maintenance, safety and basic design of off-grid solar. Subsequently the certification will be expanded to other solar PV technician profiles such as on-grid solar PV and mini-grids.

A key focus of skills-development programmes should be to ensure equal access for both men and women. However, the active participation of women in the sector is often hindered by social structures, traditions, mobility, access to training, and the perception that technology is something better left to men (IRENA, 2012). Designing training programmes in which women can participate fully is important if the benefits of access to energy, including employment opportunities, are to be equitably distributed (IRENA, 2019b).

Local renewable energy entrepreneurs have a crucial role to play in adapting delivery models and off-grid technological solutions to meet diverse energy needs. Entrepreneurship support schemes that are accessible by the local private sector could support the development of a sustainable market for off-grid solutions. Dedicated platforms and support facilities are needed through which small and medium-sized enterprises can access advisory services (Box 8). Specifically, women-led businesses need to be fostered that often face additional barriers related to access to financing, mentorship, training, and tailored support.

Box 8: Renewable Energy Entrepreneurship Support Facility

The ECOWAS Renewable Energy Entrepreneurship Support Facility was established in 2015 by IRENA in partnership with the ECOWAS Centre for Renewable Energy and Energy Efficiency and the International Institute for Water and Environmental Engineering (2ie). The facility has supported over 80 enterprises through training courses, advisory assistance, networking and match-making with financial institutions. Approximately USD 1 million in debt financing was accessed through facility-assisted proposals submitted to funding institutions.The facility also contributed to the creation of the Regional Solar PV Professionals Association for ECOWAS. Its successful pilot implementation set a precedent.

A similar facility in southern Africa was established in 2017 together with the SADC Centre for Renewable Energy and Energy Efficiency. Since the launch, nine partners – funding institutions, business incubation centres and technical training centres – have joined the facility. With a particular focus on gender and youth development, the preliminary call for applications launched in 2018 will be followed by additional calls in 2019.

Harnessing the cross-sector linkages of off-grid renewables to meet the SDGs

The innovations in technology, delivery and financing described above are being leveraged to provide affordable and reliable electricity for cross-sector applications and to maximise socio-economic and environmental outcomes. In this way, renewable energy contributes directly or indirectly to all of the SDGs, many of which are interconnected across the three dimensions of environmental sustainability, human development and sustainable growth (Figure 8).

Figure 8: Affordable and clean energy supports all the Sustainable Development Goals

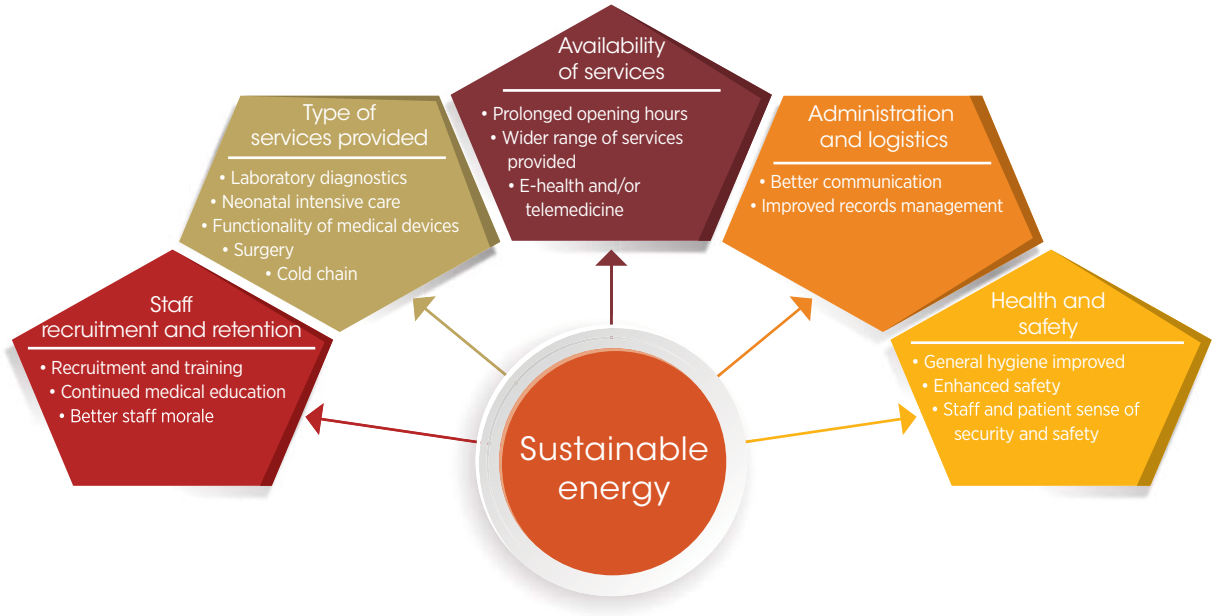
Source: IRENA (2017).

There is a growing evidence of the tremendous potential of off-grid renewable energy to advance several SDGs. For instance, with over a billion people globally served by health facilities without access to electricity (Practical Action, 2013), off-grid renewables can deliver reliable, affordable and sustainable energy to power medical devices (*e.g.,* vaccine refrigeration; surgical, laboratory and diagnostic equipment) and to support the provision of basic amenities (*e.g.,* light, communications, water). Deploying off-grid solutions can advance SDG 3 (on health and well-being) by enabling crucial, and often lifesaving, health services (Figure 9).

In the Indian state of Chhattisgarh, over 900 health centres and district hospitals have been electrified using solar power. In the process, several health-related benefits have been realised: 50 percent more patients admitted; twice the number of successful childbirths per month in solar-powered health-centres compared to those without; and improved day-to-day care (Severi, 2018).

Scaling-up adoption requires cross-sector action and innovation involving multiple stakeholders (Box 9).

Figure 9: Importance of energy to health services



Source: Adapted from WHO, 2016.

Box 9: Platforms for cross-sector dialogue and collaboration: First International Conference on Renewable Energy Solutions for Healthcare Facilities

Off-grid renewable energy solutions present a key opportunity to transform the quality of healthcare services provided to rural communities. To facilitate action, IRENA organised the first International Conference on Renewable Energy Solutions for Healthcare Facilities in November 2018, bringing together policy makers, practitioners, financial institutions, development partners and non-governmental organisations from both sectors..

Among the conference's key findings:

- Electrification of health facilities should be a key priority for national governments and development partners, reflected in electrification strategies and plans. Electrification is central to enhancing the quality of healthcare services in rural areas and for staff retention.
- Greater cooperation between the energy and health sectors (including the respective ministries) is needed in the areas of planning, policy formulation, budgeting, procurement and implementation.
- Capital and recurring expenses related to electricity should be budgeted as part of healthcare facilities' operations from the outset. Budgeting should account for costs related to operation and maintenance, as well as replacement (*e.g.,* of batteries).
- Strong collaboration and partnerships between private, public and non-governmental institutions should be facilitated to leverage existing experiences with electrifying healthcare facilities.
- Innovation in delivery and financing models is needed to scale up deployment. Dedicated financing schemes from financial institutions and energy service contracts (including operation and maintenance) were highlighted as particularly important.
- Innovation should be supported across the value chain, including in the design of medical devices suitable for rural areas (robust, efficient, low-maintenance, user-friendly).
- Aggregation models, with contracts that serve multiple health facilities in proximity, may bring down costs by aggregating demand and facilitating operation and maintenance. Use of district/first-referral hospitals as hubs (and also as a locus for trained energy technicians) could be considered.
- Energy-efficient medical devices, off-grid energy solutions and digital technologies can together improve access to, and the quality of, medical services for under-served communities, while reducing the cost incurred in travelling to district/first referral hospitals to seek medical assistance.
- The development of a local ecosystem is key to assuring the long-term sustainability of off-grid renewable energy solutions, including training of staff and reliable technical support.

Note: Conference presentations are available at *http://iorec.irena.org/Home/Healthcare*

In the agriculture sector, integrating off-grid renewable energy solutions into the segments of the agri-food chain can bring substantial benefits for farmers. Increasing access to affordable, reliable modern energy can improve productivity, increase incomes, enhance resilience to shocks and catalyse socio-economic development (IRENA, 2016c). These considerations are particularly relevant, as 78 percent of the world's poor people live in rural areas and rely on farming, livestock, aquaculture and other agricultural work (World Bank Group, 2014).

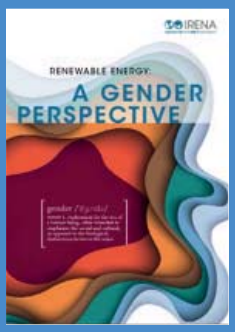
Innovations in end-use appliances have unlocked several new applications of off-grid renewable energy technologies, ranging from agricultural-processing equipment, water pumps and milking machines, to the production of clean cooking gas from farm and livestock waste. Interestingly, financing approaches devised to support off-grid renewables deployment are also being adapted to cross-sector applications.

In Kenya, for instance, pay-as-you-go for stand-alone systems has adapted into "pay-as-you-grow" for solar irrigation systems linking farmer payments to crop cycles (FAO, 2018; IRENA, 2016d).

The transition towards modern energy services brings substantial socio-economic and environmental co-benefits contributing to several SDGs. It is estimated that about 840 million people, or 13% of the global population, are engaged in the part-time collection of wood fuel for subsistence use. Almost 85% of this work is done by women and girls, who each spend an average of 100 hours a year in this activity (FAO, 2014; Whiteman *et al,* 2018). Switching to modern fuels or using improved cookstoves can reduce the amount of time spent collecting wood, free up time for other economic activities and reduce indoor air pollution, with the benefits accruing mostly to women.

In fact, off-grid renewable energy solutions can contribute to gender equality in a variety of ways. Integrating a gender perspective in the design of policies, products and services relevant to energy access is essential if energy access initiatives are to succeed given women's role as primary end-users and their critical role in delivering off-grid solutions. The organisation Solar Sister has trained 1 200 women entrepreneurs who are marketing and selling off-grid solutions benefiting more than 200 000 people so far. Even as cultural and social norms evolve, engaging women as active agents within the off-grid energy value chain is known to improve self-perceptions and raise empowerment within the community (IRENA, 2019b; Practical Action, 2018) (Box 10).

Box 10: Renewable energy: A gender perspective



The distributed nature of off-grid renewable energy solutions offer tremendous opportunities for women's active engagement along different segments of the value chain, with co-benefits for gender equality and empowerment.

IRENA's Renewable Energy: A Gender Perspective (2019) analyses the gender dimension of renewable energy in the modern and access contexts. It draws on the literature and presents insights from an online survey conducted by IRENA to gather insights from individuals and organisations working in the renewable energy sector.

Over 800 respondents (out of a total of 1 500) took the energy access segment of the survey and shared valuable insights on the key barriers faced by women in the sector and offered potential solutions. Cultural and social norms were cited as the most common barrier, followed by a lack of gender-sensitive policies and training opportunities. In the realm of solutions, respondents highlighted the importance of access to training and skills development. Over half of the respondents also agreed that improving access to finance and mainstreaming the gender perspective in energy access programmes are likely to improve women's engagement.

Source: IRENA, 2019b.

Harnessing the complete spectrum of opportunities offered by off-grid renewable energy solutions to advance the SDGs requires an inclusive approach. This means greater collaboration among stakeholders in the energy sector, as well as across sectors like health, education, agriculture and water.

Photo: Solar Sister

Accelerating off-grid renewable solutions to reach universal electricity access

In 2016, the number of the world's people living without electricity globally fell below one billion. Today, the technologies exist to build on the present momentum and reach still-unconnected populations well before the target year of 2030. Off-grid renewable energy solutions (stand-alone systems and mini-grids) are now cost-competitive with grid extension for expanding access in many areas. Beyond economic viability, these solutions have the added advantage of being rapidly deployable, easily customisable to local conditions, readily integrated with emerging digital technologies and useful as a tool for community empowerment and engagement.

With the number of the world's people benefiting from off-grid electricity solutions increasing six-fold between 2011 and 2016, leaders have a unique opportunity to embrace this proven electrification solution in their efforts to transform the socio-economic landscape in rural areas and island settings.

As outlined in this brief, several key dynamics have converged to drive growth in the sector. Tailored delivery models, innovative financing instruments and a new digital ecosystem to support sector development have been particularly important. As the off-grid renewables sector advances, targeted policies and regulations, coupled with programmes to develop the local skills and capacities, of community-based solutions and women-led enterprises, will help ensure that growth is equitable and inclusive.

As countries embark on efforts to realise the full potential of off-grid solutions to meet the SDGs, multi-stakeholder partnerships and cross-sector dialogue will be crucial. IRENA's International Off-grid Renewable Energy Conference (IOREC) is now the principal platform for convening key stakeholders and facilitating dialogue on solutions to scale up off-grid renewable energy deployment.

The fourth IOREC conference and exhibition took place in Singapore in October 2018; its key messages are summarised in Box 11.

Box 11: Key messages from the fourth International Off-grid Renewable Energy Conference and Exhibition

IOREC is a global collaborative platform convened biennially by IRENA to share experience and best practices in the deployment of off-grid renewable energy solutions, both stand-alone and mini-grids. The fourth edition convened in Singapore on 31 October and 1 November 2018 during the Singapore International Energy Week 2018, in conjunction with the meeting of ASEAN energy ministers. Key messages from the discussion are summarised below:

- Modern energy access is central to achieving the SDGs. Governments should consider the entire spectrum of opportunities offered by off-grid renewable energy solutions to expand access to affordable, reliable and sustainable energy; support livelihoods; enhance delivery of essential services; and strengthen gender equality.
- National electrification strategies and plans should mainstream off-grid renewable energy solutions and facilitate cooperation among actors.
- To ensure effective implementation of energy-access plans, institutional and legal frameworks at the national level should clearly define the roles and responsibilities of public sector institutions, streamline administrative procedures and ensure adequate capacities.
- To ensure private sector involvement in energy access, the policy and regulatory framework should provide the right set of incentives and risk coverage to private investors and alleviate barriers to unlock financing.
- Regulations are particularly important for renewable energy mini-grids in areas where governments have the dual role of ensuring economic viability while ensuring that tariffs are not too high for underserved communities. With the right set of regulations in place, the arrival of the main grid, which is often seen as a major risk for mini-grid developers, can become an opportunity for developers and utilities alike.
- The financial instruments and products on offer from banks and other financing institutions do not always match the sector demands. To foster innovation in the sector and accelerate deployment, financing instruments need to be tailored to the requirements of end-users and small enterprises.
- Putting in place the right ecosystem for accelerating off-grid renewable energy deployment requires efforts to develop the human capital by building capacities across the off-grid value chain and supporting local job creation and entrepreneurship.
- Off-grid renewable energy should be viewed as a job-creating opportunity, as it has the potential to create millions of jobs across the value chain.
- Efficient end-use appliances should be included in the off-grid ecosystem to ensure affordability and long-term sustainability.
- Ground-breaking improvements in off-grid renewable energy solutions are under way, particularly in digital technology and small-scale energy storage. These are expected to lower system costs dramatically over the next two decades.

Note: Conference presentations are available at *http://iorec.irena.org*

IOREC
International Off-Grid Renewable Energy Conference & Exhibition

REFERENCES

Aidun, C. and D. Muench (2016), "Securitization: Unnecessary complexity or key to financing the DESCO sector?" www.gogla.org/sites/default/files/recource_docs/securitization_-_unnecessary_complexity_or_key_to_financing_the_desco_sector.pdf.

AlliedCrowds (2015), Developing World Crowdfunding Diaspora Crowdfunding, AlliedCrowds, London, https://cdn.filestackcontent.com/LW8v7hifQ0aMhIKeEdx8.

Baeck, P., J. Bone, and S. Mitchell (2017), Matching the Crowd: Combining Crowdfunding and Institutional Funding to Get Great Ideas Off the Ground, Nesta, London, https://media.nesta.org.uk/documents/matching_the_crowd_main_report_0.pdf.

BNEF (Bloomberg New Energy Finance) (2018), 4Q 2018 Off-Grid AND Mini-Grid Market Outlook, https://medium.com/climatescope/4q-2018-off-grid-and-mini-grid-market-outlook-1dace7fc9087.

Cogan, D. and P. Weston (2018), Powering the Crowd into the Future: Key Learnings and Recommendations, Energy4Impact, www.energy4impact.org/file/2067/download?token=N0BdMcEu.

EarthSpark (2016), "Real-time data from a smart grid with smart meters", www.earthsparkinternational.org/blog/real-time-data-from-the-sparkmeter-thundercloud.

ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (n.d.), "Regional Certification Scheme for Sustainable Energy Skills", www.ecreee.org/page/regional-certification-scheme-sustainable-energy-skills.

EWURA (Energy and Water Utilities Regulatory Agency) (2011), Guidelines for Grid Interconnection of Small Power Projects in Tanzania, Energy and Water Utilities Regulatory Agency, Dodoma, TZ.

FAO (Food and Agriculture Organization of the United Nations) (2018), The Benefits and Risks of Solar-Powered Irrigation – A Global Overview, FAO, Rome, www.fao.org/3/I9047EN/i9047en.pdf.

GOGLA (Global Off-Grid Lighting Association) (2018a), "Powering opportunity: The economic impact of off-grid solar", www.gogla.org/sites/default/files/resource_docs/gogla_powering_opportunity_es.pdf.

GOGLA (2018b), "Employment opportunities in an evolving market: Off-grid solar: creating high-value employment in key markets", www.gogla.org/sites/default/files/resource_docs/job_creation_in_the_og_sector_-_policy_note_1.pdf.

IEA (2017), Energy Access Outlook 2017. World Energy Outlook Special Report. www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf.

IFC (International Finance Corporation) (2018), Off-Grid Solar Market Trends Report 2018, International Finance Corporation, Washington, DC, www.gogla.org/sites/default/files/resource_docs/2018_mtr_full_report_low-res_2018.01.15_final.pdf.

IRENA (International Renewable Energy Agency) (2019a), Quality Infrastructure for Renewable Mini-Grids, IRENA, Abu Dhabi.

IRENA (2019b), Renewable Energy: A Gender Perspective, IRENA, Abu Dhabi.

IRENA (2018a), Off-grid Renewable Energy Solutions: Global and Regional Status and Trends, IRENA, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jul/IRENA_Off-grid_RE_Solutions_2018.pdf.

IRENA (2018b), Renewable Power Generation Costs in 2017, IRENA, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf.

IRENA (2018c), Renewable Energy Market Analysis: Southeast Asia, IRENA, Abu Dhabi, http://irena.org/publications/2018/Jan/Renewable-Energy-Market-Analysis-Southeast-Asia.

IRENA (2018d), Policies and Regulations for Renewable Energy Mini-grids, IRENA, Abu Dhabi.

IRENA (2017), REthinking Energy 2017: Accelerating the Global Energy Transformation, IRENA, Abu Dhabi.

IRENA (2016a), Policies and Regulations for Private Sector Renewable Energy Mini-grids, IRENA, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Policies_Regulations_minigrids_2016.pdf.

IRENA (2016b), Innovation Outlook: Renewable Mini-grids, IRENA, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Innovation_Outlook_Minigrids_2016.pdf.

IRENA (2016c), Renewable Energy Benefits: Decentralised Solutions in the Agri-Food Chain, IRENA, Abu Dhabi, www.irena.org/publications/2016/Sep/Renewable-Energy-Benefits-Decentralised-solutions-in-agri-food-chain.

IRENA (2016d), Solar Pumping for Irrigation: Improving Livelihoods and Sustainability, IRENA, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Solar__Pumping_for_Irrigation_2016.pdf.

IRENA (2015), Off-grid Renewable Energy Systems: Status and Methodological Issues, IRENA, Abu Dhabi.

IRENA (2012), Renewable Energy Jobs & Access, IRENA, Abu Dhabi, www.irena.org/DocumentDownloads/Publications/Renewable_Energy_Jobs_and_Access.pdf.

Lambert, F. (2016), "Tesla converted an entire island to solar with new microgrid product developed by SolarCity", https://electrek.co/2016/11/22/tesla-island-microgrid-battery-solar/.

MIF (Multilateral Investment Fund) (2015), Creating a Crowdfunding Ecosystem in Chile, Inter-American Development Bank, Washington, DC, http://idbdocs.iadb.org/wsdocs/getDocument.aspx?DOCNUM=39725763.

NERC (Nigerian Electricity Regulatory Commission) (2016), NERC Mini Grid Regulation, Nigerian Electricity Regulatory Commission, Abuja, www.nercng.org/index.php/library/documents/Regulations/NERC-Mini-Grid- Regulation/.

Ottinger, R. L. and J. Bowie (2015), "Innovative financing for renewable energy", Pace Environmental Law Review, Vol. 32/3, pp. 701, https://digitalcommons.pace.edu/cgi/viewcontent.cgi?article=1778&context=pelr.

Practical Action (2018) Poor people's energy outlook 2018: Achieving inclusive energy access at scale, Practical Action Publishing, Rugby.

Practical Action (2013) Poor people's energy outlook 2013: Energy for community services, Practical Action Publishing, Rugby.

SEforALL (Sustainable Energy for All) and CPI (Climate Policy Initiative) (2018), Energizing Finance: Understanding the Landscape 2018, Sustainable Energy for All, Washington, DC, and Vienna, https://climatepolicyinitiative.org/wp-content/uploads/2018/11/Energizing-Finance-_-2018.pdf.

SELCO Foundation (2018), Sustainable Energy and Livelihoods: A Collection of 50 Livelihood Applications, https://selcofoundation.org/wp-content/uploads/2018/10/SF_SELivelihoods-compressed.pdf.

Severi, L. (2018), "In conversation with: Chhattisgarh State Renewable Energy Development Agency (CREDA)", http://poweringhc.org/in-conversation-with-chhattisgarh-state-renewable-energy-development-agency-creda/.

SOLshare (2017), https://www.me-solshare.com/.

UNDP (United Nations Development Programme) (2018), "Financing solutions for sustainable development", http://www.undp.org/content/sdfinance/en/home/solutions/template-fiche12.html.

UNDP and ETH Zurich (2018), Derisking Renewable Energy Investment: Off-Grid Electrification, United Nations Development Programme, New York, NY; and ETH Zurich, Energy Politics Group, Zurich, Switzerland.

Whiteman, A., Y. Li, E. Fornari, and I. Animon (2018), "The potential for improved cookstoves to reduce carbon dioxide emissions", International Forestry Review, Vol. 20/4, pp. 559 570.

Willuhn, M. (2018), "Kenya's 2022 universal electrification goal bets on off-grid solar", www.pv-magazine.com/2018/12/07/kenyas-2022-universal-electrification-goal-bets-on-off-grid-solar/.

World Health Organisation (WHO) (2016), Working beyond SDG3 for health: the example of health facility electrification and SDG7, https://iorec.irena.org/-/media/Files/IRENA/IOREC/2016/Presentations/Working_beyond_SDG3_for_health_Michaela_Pfeiffer.pdf.

World Bank Group (2018), Tracking SDG7: The Energy Progress Report 2018, https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg7-the_energy_progress_report_full_report.pdf.

World Bank Group (2014), "For up to 800 million rural poor, a strong World Bank commitment to agriculture", www.worldbank.org/en/news/feature/2014/11/12/for-up-to-800-million-rural-poor-a-strong-world-bank-commitment-to-agriculture.

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