IRENA
International Renewable Energy Agency

OFF-GRID RENEWABLE ENERGY SOLUTIONS

Global and regional status and trends

The 2030 Agenda for Sustainable Development positions access to affordable, reliable, sustainable and modern energy as a key pillar of Sustainable Development Goal 7 (SDG 7) (UN, 2018). This represents a growing recognition that modern energy is a key building block towards broader development goals associated with environmental sustainability, delivery of public services and poverty eradication. Access to reliable and affordable electricity, for example, can have an immediate and transformative impact on quality of life, access to basic services (*e.g.,* health, education) and livelihoods.

Off-grid renewable energy solutions have emerged as a mainstream solution to expand access to modern energy services in a timely and environmentally sustainable manner. Over the past five years, the deployment of stand-alone and mini-grid systems has witnessed tremendous progress as technology costs have plummeted, innovation in deployment and financing models has picked up, and a more diverse set of stakeholders, including local entrepreneurs, the international private sector and financing institutions, have become engaged in the sector. Besides providing energy for lighting and cooking, off-grid solutions are being deployed to support the delivery of public services (*e.g.,* education, water and primary health care), the development of livelihoods by powering productive end-uses (*e.g.,* agriculture) and other commercial and industrial needs.

The evidence base on the transformative socio-economic impact of off-grid solutions is expanding with the documentation of country- and project-level case studies. A more complete picture on the status and trends of off-grid renewable energy technologies requires addressing challenges associated with the availability of, and accessibility to, harmonised data at the national and regional levels. Efforts are also needed to address other methodological challenges such as the definition and categorisation of off-grid renewable energy systems.[1]

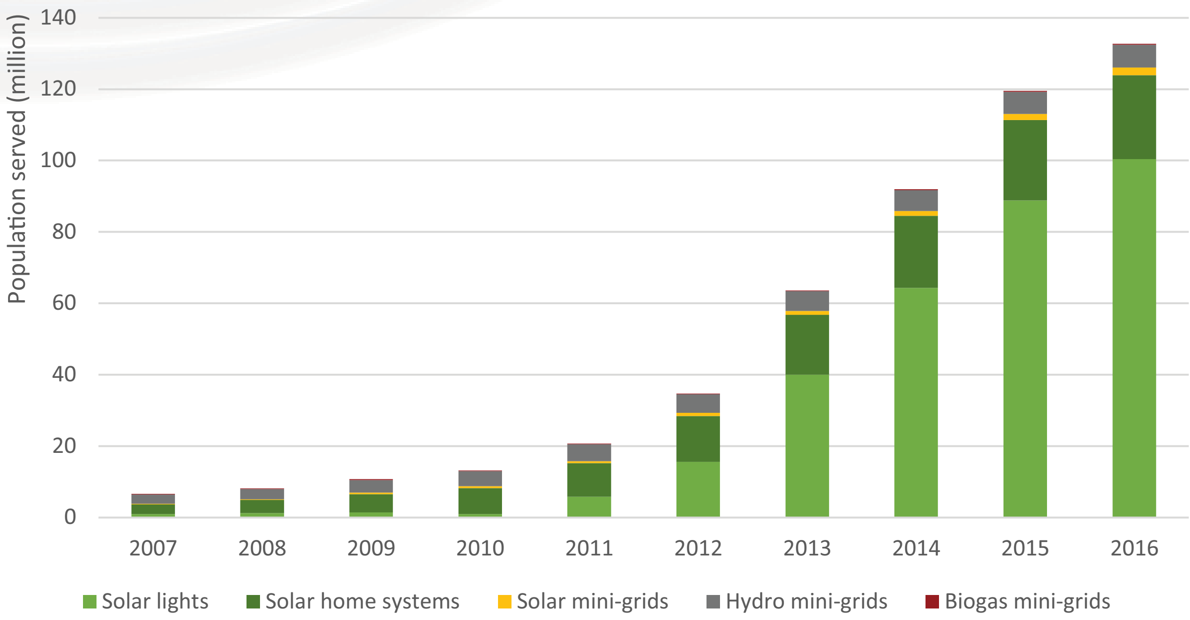
To contribute to filling this gap, IRENA has been collecting country-level capacity statistics for off-grid renewable energy applications (see Box 8 for the adopted methodology). These have been integrated into IRENA's annual *Renewable Energy Capacity Statistics* series and provide valuable insights on off-grid trends at the global, regional and national levels. This brief captures some of these trends and discusses the key components of an enabling environment to scale-up deployment.

THE NUMBER OF PEOPLE SERVED BY OFF-GRID RENEWABLES GLOBALLY HAS EXPANDED SIX-FOLD SINCE 2011, REACHING NEARLY 133 MILLION PEOPLE IN 2016

IRENA estimates that some 133 million people accessed lighting and other electricity services using off-grid renewable energy solutions in 2016. 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 (Figure 1). A large part of the growth in off-grid renewables has occurred over the last five years, driven by the rapidly decreasing costs of solar lighting solutions and by the establishment of local supply chains making these solutions accessible. The adoption of innovative delivery and tailored financing models, such as pay-as-you-go (PAYG) and micro-financing, has driven the growth of solar home systems that offer a wider range of electricity services. The population served by hydropower-based mini-grids has more than doubled since 2007, reaching 6.4 million in 2016 due mainly to growth in Asia.

1 IRENA's working paper *Off-grid Renewable Energy Systems: Status and Methodological Issues (2015)* proposed a number of concrete methodological improvements, including consistent categorisation of off-grid systems by uses, customers, system components and size.

Figure 1: **Population served by off-grid renewable energy solutions globally**

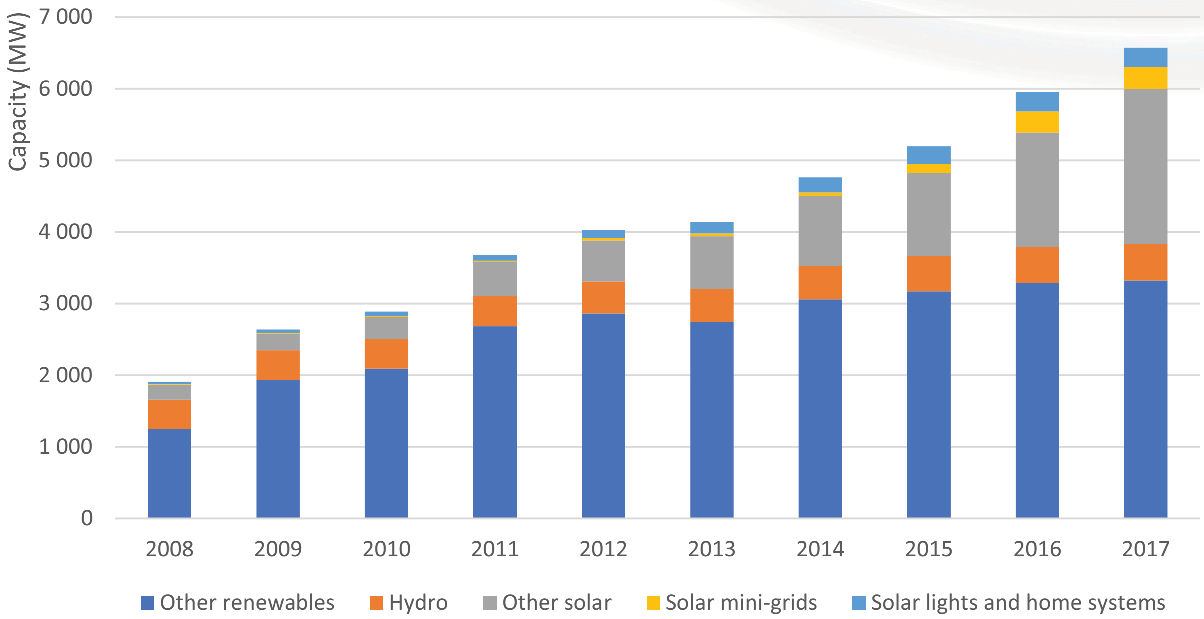


While solar lighting solutions and solar home systems serve a dominant share of the population served by off-grid renewable energy solutions, they account for a small fraction (4%) of the total installed capacity. Solar lights represent an initial first step in the energy ladder (often between Tier 0 and Tier 1 of the Multi-Tier Framework[2]) – one that is increasingly within the reach of millions of people globally. High-capacity solar home systems and mini-grids based on solar, hydropower and biomass have the potential to offer a wider range of electricity services (Tier 1 and higher), including for productive uses. Indeed, energy-efficient appliances enable off-grid systems to deliver a wider spectrum of electricity services at lower installed capacities.

Off-grid renewable energy capacity has witnessed a spectacular three-fold increase from under 2 gigawatts (GW) in 2008 to over 6.5 GW in 2017 (Figure 2). While a proportion of the deployed capacity is to support household electrification, a majority (83%) is dedicated for industrial (*e.g.,* co-generation), commercial (*e.g.,* powering telecommunication infrastructure) and public end-uses (*e.g.,* street lighting, water pumping). The status of off-grid capacity by end-use sector is discussed in detail later.

2 The Multi-Tier Framework (MTF) collects information on seven attributes of electricity service including capacity, service hours, reliability or service interruptions, quality or voltage fluctuations, affordability, legality and safety. On the basis of these seven attributes, the MTF assigns any given household to one of five tiers: Tier 0 (no meaningful access), Tier 1 (basic lighting and charging), Tier 2 (a few small appliances), Tier 3 (formal grid connection with limited service), Tier 4 (a service capable of supporting refrigeration) and ultimately Tier 5 (unrestricted continuous service) (Bhatia and Angelou, 2015).

Figure 2: **Capacity of off-grid renewable energy solutions globally**



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

Developments in off-grid renewable energy vary across regions. Countries in Africa and Asia account for most of the growth over the past years, with more than 53 million people in Africa and 76 million in Asia now using such power sources.

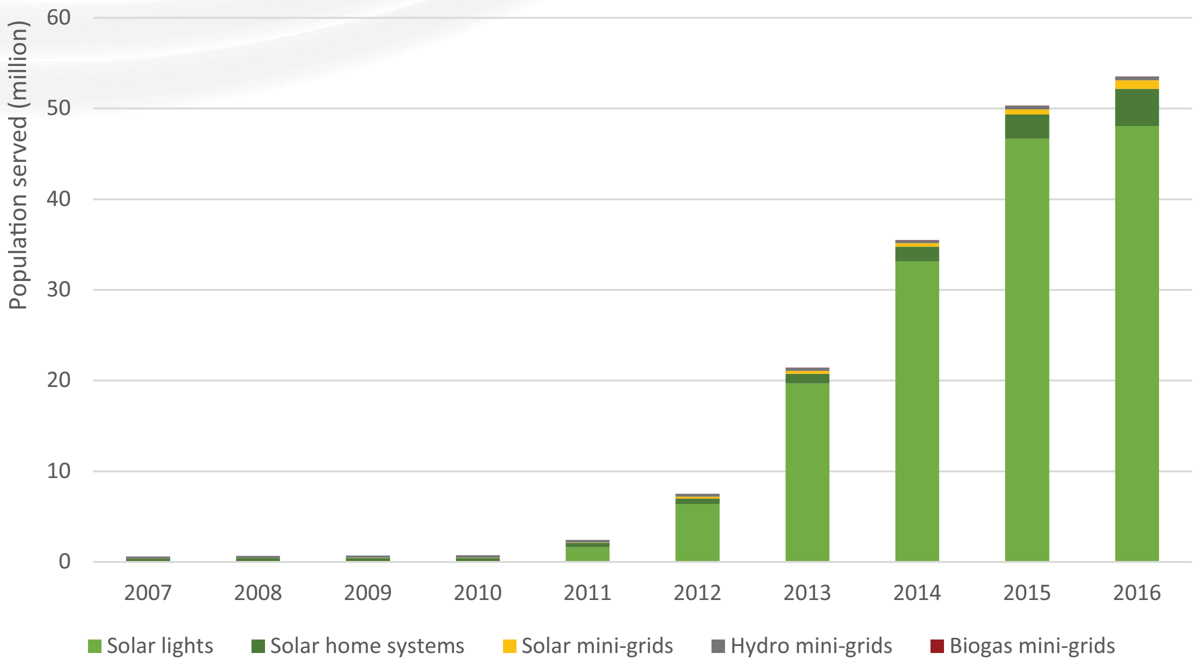
AFRICA HAS EMERGED AS A DYNAMIC, FAST-MOVING HUB FOR OFF-GRID RENEWABLES

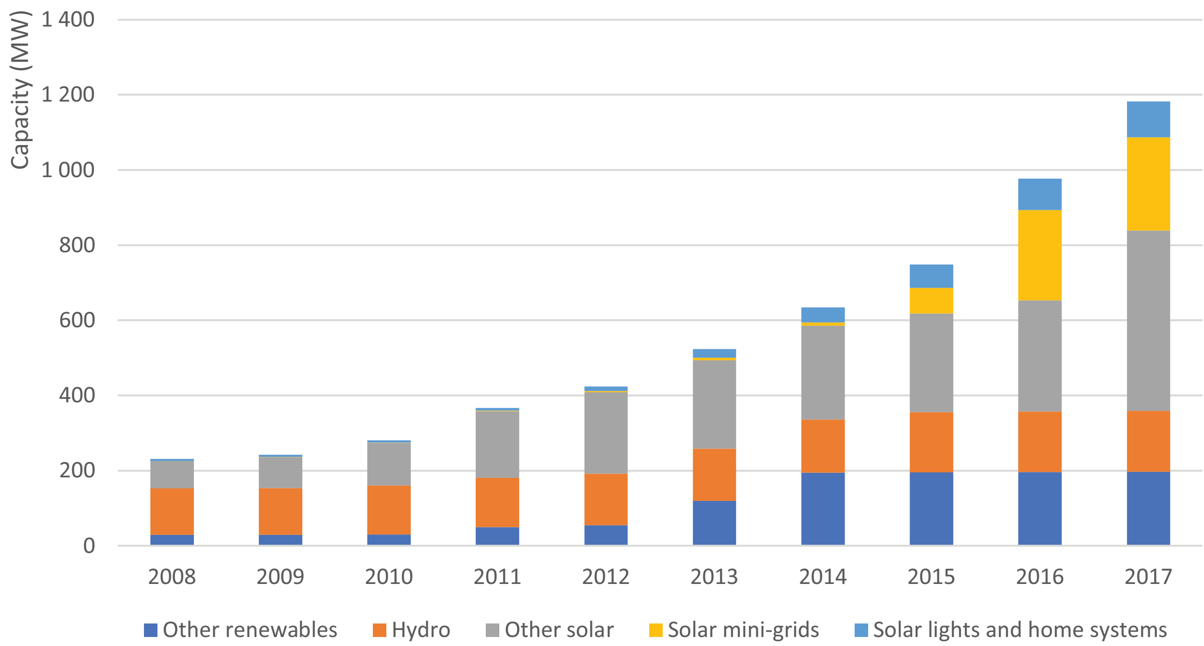
The African continent has seen rapid developments in off-grid renewable energy over the past five years. The population served by off-grid solutions in Africa grew rapidly from just over 2 million people in 2011 to over 53 million in 2016 (Figure 3). Solar lights have driven this rapid growth, but about 10% of the population served in Africa (5.4 million) obtained a higher level of electricity services from off-grid solar (Tier 1 access or more). Solar home systems reached over 4 million people in 2017 thanks in part to innovations in technology design and financing (*e.g.,* PAYG) and to coupling with mobile payment platforms, mainly in East Africa (Box 1).

The cumulative off-grid renewable energy capacity has increased from 231 megawatts (MW) in 2008 to nearly 1.2 GW in 2017 (Figure 3). The deployment of solar technologies has been a key driver of growth in off-grid capacity, with over 820 MW installed as solar lights, home systems and mini-grids and for commercial/public services. The abundance of the resource, the distributed nature of technology and decreasing costs are leading solar to become a default choice for meeting a wide range of electricity services in areas largely underserved by the national grid.

The capacity of hydropower-based mini-grids has grown from 124 MW in 2008 to 162 MW in 2017, although its share in total off-grid capacity fell from 53% to under 15% during the same period. Besides electrification, off-grid capacity for self-consumption in industry has grown (*e.g.,* bagasse-based co-generation) from 29 MW in 2008 to nearly 200 MW in 2017.

Figure 3: **Population served by and capacity of off-grid renewable energy solutions in Africa**





Note: Other renewables primarily comprises industrial bioenergy. Other solar comprises off-grid power capacity in end-use sectors as industry and commercial/public, as well as reported capacity with unknown end-use.

Box 1: Innovation in delivery models for off-grid deployment in East Africa

Countries in East Africa have emerged as leaders in the deployment of stand-alone solar solutions for providing electricity access for lighting and mobile charging as well as for other services such as radio, television and productive uses (*e.g.,* pumping). Global investments in the off-grid solar sector reached USD 284 million in 2017, with East Africa accounting for over half (57%) of all investments (IFC, 2018). Incentivised by a supportive policy environment (mainly fiscal incentives), the international and local private sector has led a process of innovations in technology solutions, delivery and financing models to enhance the accessibility and affordability of off-grid solutions.

While direct sales have led the adoption of solar lighting solutions in the region, the rise of pay-as-you-go solutions for solar home systems has made larger systems affordable for rural households. PAYG involves households or individuals procuring the system from a supplier through a down payment, followed by periodic payments that are set at affordable levels (IRENA, 2017a). Such an arrangement could take the form of a perpetual lease or eventual system ownership after a defined period. The payments are usually collected through mobile payment platforms.

Leveraging these experiences, the private sector is adapting delivery and financing models to now provide off-grid solar solutions in other sectors, especially agriculture. Small-scale solar irrigation pumps are increasingly being deployed and paid for by farmers through programmes that are tailored to farmer incomes from crop cycles. An estimated 2 000 solar borehole pumps and 1 000 solar surface pumps (under 2.5 kilowatts, kW) are in operation in Kenya. Certain banks, microfinance institutions and equipment suppliers offer credit lines for solar-powered irrigation systems (FAO, 2018).

Looking ahead, Africa will be at the forefront of efforts to reach the objective of SDG 7 on universal access to modern energy services by 2030. The dominance of off-grid solutions that provide basic services, such as lighting, will need to pave the way for solutions that can support productive end-uses and livelihood development to harness the complete socio-economic development potential of such solutions. Given the gaps in centralised infrastructure development, off-grid renewable energy solutions will play a key role in securing universal access on the continent in a timely manner.

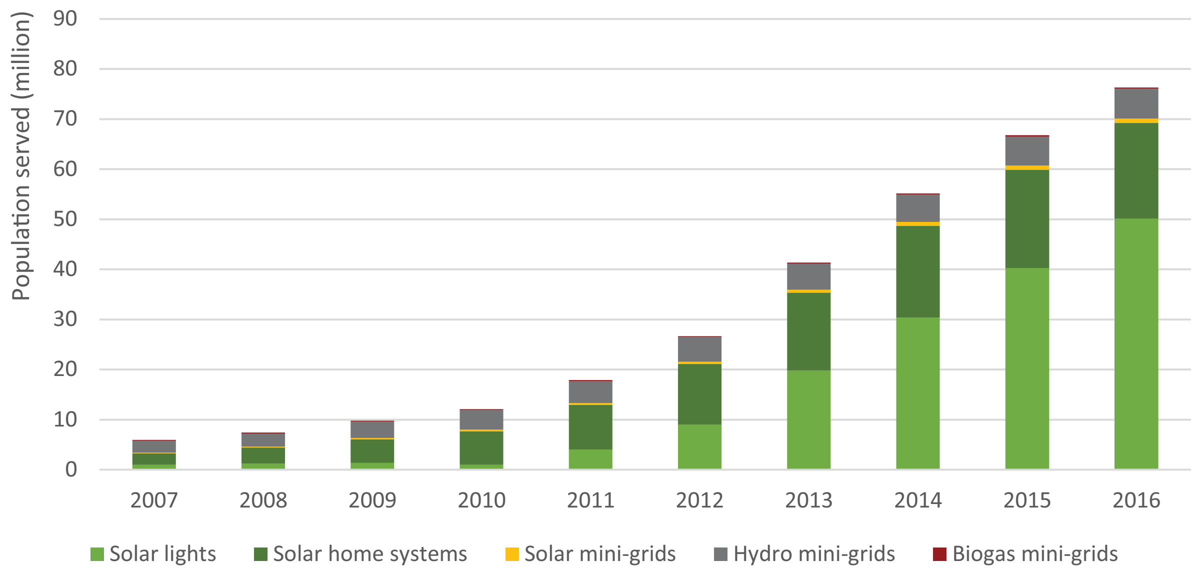
ASIA LEADS IN OFF-GRID RENEWABLES CAPACITY DEPLOYMENT

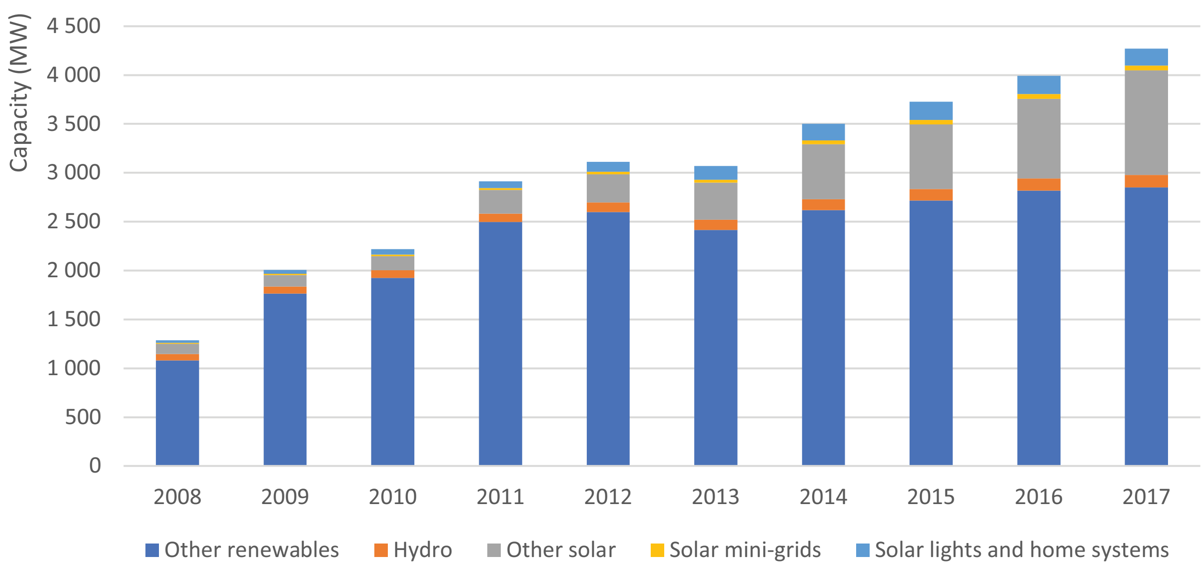
Asia has dominated the deployment of off-grid renewables globally over the past decades. Total capacity reached nearly 4.3 GW in 2017, up from 1.3 GW in 2008 (Figure 4). This growth has been largely a result of the increased use of industrial bioenergy, although the share of solar in total capacity has been significant, rising from 11% in 2008 to over 30% in 2017. Off-grid solar is being deployed to provide a wide range of services, including household electrification and industrial and commercial/public use (discussed in detail in the next section). Off-grid hydropower capacity has more than doubled between 2008 and 2017, reaching 127 MW.

In terms of the population served, off-grid renewables provided electricity services to under 10 million people in 2008, increasing almost eight-fold to over 76 million in 2016 (Figure 4). Solar lights have reached around 50 million people in the region, while solar home systems provided electricity services to over 20 million.

Bangladesh is a prominent example of deploying solar home systems at scale, reaching over 18 million people through 4.1 million systems in 2017 (IDCOL, 2018). Mini-grid solutions can provide higher tiers of electricity services and have reached over 7 million people in 2016, although the majority of these systems are hydropower-based. The region has a rich history of micro-hydro development for direct use in agro-processing and for electricity generation (see Box 2 on the example of Nepal).

Figure 4: **Population served by and capacity of off-grid renewable energy solutions in Asia**





Note: Other renewables primarily comprises industrial bioenergy. Other solar comprises off-grid power capacity in end-use sectors as industry and commercial/public, as well as reported capacity with unknown end-use.

Box 2: Micro-hydropower development in Nepal

Micro-hydropower solutions have been deployed across South and Southeast Asia to expand access to electricity, especially in remote communities.

Nepal has a long-standing history of harnessing hydropower for agro-processing and the provision of electricity. The installed capacity of micro-hydro installations has risen from an estimated 37 MW in 2011 (AEPC, 2011) to around 50 MW in 2017 (IRENA, 2018a). The micro-hydro sector (up to 100 kW) received an impetus with the introduction of the Subsidy for Renewable Energy policy in 2000 with revisions in 2006, 2009, 2013 and 2016.

The majority of these installations are developed under a public-private partnership model wherein the community plays an active role in the implementation of the project. To apply for a subsidy, the community registers a users' group such as a Micro Hydro Functional Group, a co-operative or a private company. Typically, the community mobilises half of the total project cost with the balance provided as a subsidy provided by the Alternative Energy Promotion Centre (AEPC) (World Bank, 2015).

Although over 2 500 systems are installed in Nepal, challenges remain to reach the full potential of the sector. These include sustainability aspects, such as ensuring maintenance, repair and load management, and the risk of stranded assets due to the arrival of the national grid. Low load factor, high transport cost, lack of quality control and standardisation of products are some of the other barriers.

The Asia region also offers valuable examples of development of off-grid renewables for cooking, although this is beyond the scope of the present review. Household biodigester programmes have been in place across a number of countries, including Bangladesh, Cambodia, China, India, Nepal and Viet Nam (Box 3). In addition, the use of solid biofuels in industry for heat is common across the region.

Box 3: Production of biogas for cooking, heat and off-grid electricity in Viet Nam

The Biogas Programme for the Animal Husbandry Sector in Viet Nam was launched in 2003 with the objective of developing a commercially viable biogas market. Biogas digesters produce both biogas and bio-slurry. The biogas is used for cooking (for household and livestock feedstock), as a fuel for electricity production that can then provide lighting and other income-generating activities, such as the production of rice wine and tofu, and for egg hatching. The bio-slurry, as a fertiliser, can result in increased yields of better-quality crops that can be sold at higher prices.

Since its inception, the programme has facilitated the construction of nearly 250 000 domestic biogas digesters, resulting in access to clean, renewable and reliable energy while addressing the waste management challenge of the country's growing livestock population and improving living conditions for over 1.2 million people. A flat-rate subsidy per digester was offered to incentivise households by reducing the initial investment required. Recently, the household subsidy is being phased out and replaced with a results-based financing incentive that goes to the suppliers to stimulate a competitive market. Between mid-2016 and 2017, 16 500 biodigesters were constructed under this mechanism.

Source: IRENA, 2018b

Substantial progress has been made in Asia recently in expanding electricity access. While grid-based approaches are responsible for most of the progress, off-grid solutions still have an important role to play in a variety of settings, including in areas underserved by the grid, remote areas and island contexts. Several countries, including China, have advanced rural electrification through a bottom-up approach with the development of decentralised power infrastructure with the possibility of integration into a larger grid (IRENA, 2015). Asia also offers unique experiences in the interaction between the main grid and off-grid solutions, as well as in the utilisation of off-grid renewables to power commercial, public and industrial end-uses (discussed later).

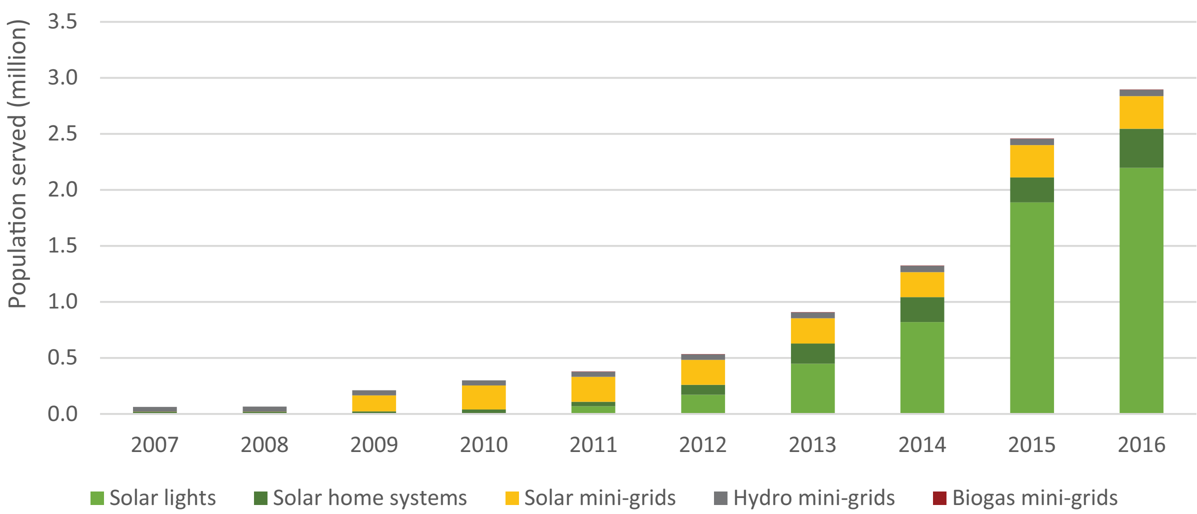
SOUTH AMERICA SEES OFF-GRID SOLUTIONS DEPLOYED FOR LAST-MILE ELECTRICITY ACCESS, WHILE ISLANDS ADOPT RENEWABLES TO REDUCE COSTS AND ENHANCE ENERGY SECURITY

Figure 5 highlights the trends in off-grid renewable energy capacity deployment and the population served in the rest of the world.[3] At least 3 million additional people have access to some form of electricity services through off-grid solutions in areas other than in Asia and Africa. Total installed capacity has risen from around 400 MW in 2011 to over 1.1 GW in 2017, with the South America sub-group accounting for the majority share of it (IRENA, 2018c).

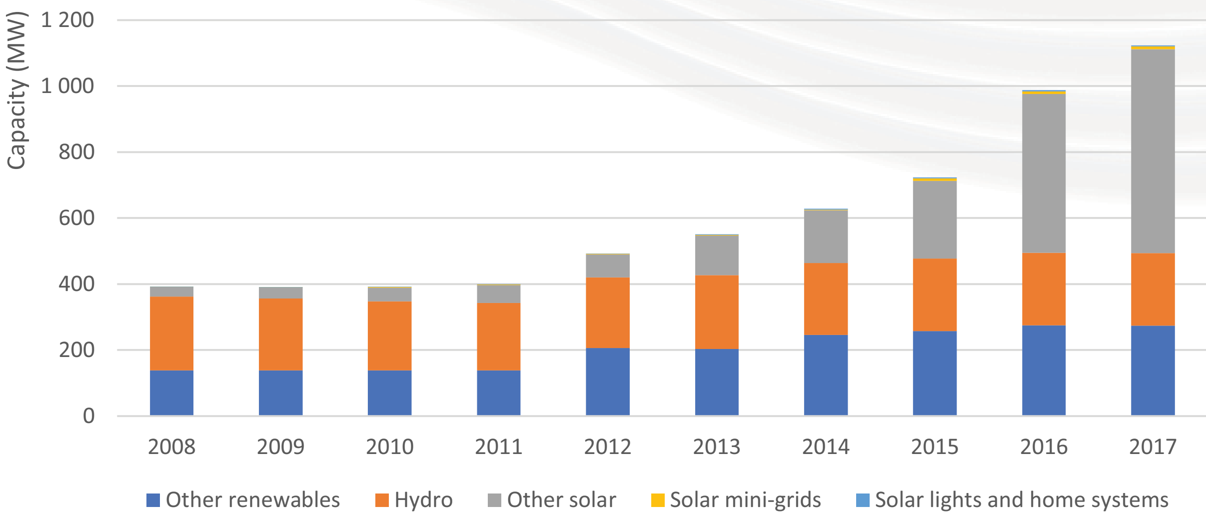
Electricity access rates in South America are among the highest in the developing world, and off-grid renewable energy solutions are considered key for last-mile electricity delivery (see Box 4 for the example of Peru) and for industrial (*e.g.,* mining) and commercial applications. Off-grid capacity on the continent rose from 256 MW in 2008 to 456 MW in 2017. The availability of hydropower resources has led to the development of related off-grid energy infrastructure, even as the use of bioenergy in industry for captive use has increased. The deployment of solar has grown remarkably since 2012, with capacity increasing six-fold to reach 88.5 MW in 2017.

The Oceania sub-group accounts for a marked share of total off-grid capacity as the comprising island nations transition away from fossil fuels towards greater use of renewable energy. Capacity has grown from over 125 MW in 2010 to above 150 MW in 2017. During the same time frame, the share of solar in total off-grid renewables capacity has risen from 4.7% to over 21%.

Figure 5: **Population served by and capacity of off-grid renewable energy solutions in the rest of the world**



3 The rest of the world comprises Central America, the Caribbean, the Middle East, Oceania and South America.



Note: Other renewables primarily comprises industrial bioenergy. Other solar comprises off-grid power capacity in end-use sectors as industry and commercial/public, as well as reported capacity with unknown end-use.

Most of the members of the Caribbean Community (CARICOM) have universal or high rates of electricity access. Exceptions include Belize, Guyana, Haiti and Suriname, which face enormous challenges related to rural electrification and/or energy poverty (IMF, 2016). Given the electrification and reliability issues in these four countries, self-generation is a common way for firms and larger consumers to ensure that they have reliable electricity access. In Guyana, several firms meet most or all their energy needs through self-generation. In Haiti, the unreliability of the existing grid system prompts even those consumers who are grid-connected to rely entirely or partly on self-generation, primarily with inefficient diesel generators (Ochs et al., 2015). As the economic case for renewables strengthens, islands in Oceania as well as in the Caribbean are expected to see a stronger transition towards a renewables-based power system.

Box 4: Tendering solar home systems in Peru

Rural electrification in Peru is characterised by remote villages with dispersed populations and low purchasing power. A strong focus on electrification led to the coverage almost doubling between 2006 and 2016 from 40% to 79% (Tozzigreen, 2018). In 2016, the number of households without access to electricity was approximately 450 000, around 85% of them in rural areas (Videnza, 2018). The Rural Electrification National Plans prepared by the Ministry of Energy and Mines prioritise extension of the grid; where this is not feasible, the use of solar systems is to be prioritised followed by small hydropower and wind.

In 2013 an auction was announced to supply electricity through off-grid solar systems to a minimum of 149 000 households and 2 890 community buildings. The contract was awarded to a private sector company in 2014 which plans to install and operate 220 000 systems (Tozzigreen, 2018). The contract is for 15 years, and the company is responsible for the design, installation, operation, maintenance and, if needed, replacement of the system. At the end of the contract, ownership of the renewable energy systems is transferred to the State.

ACROSS REGIONS, OFF-GRID RENEWABLES DELIVER A WIDE SPECTRUM OF ELECTRICITY SERVICES

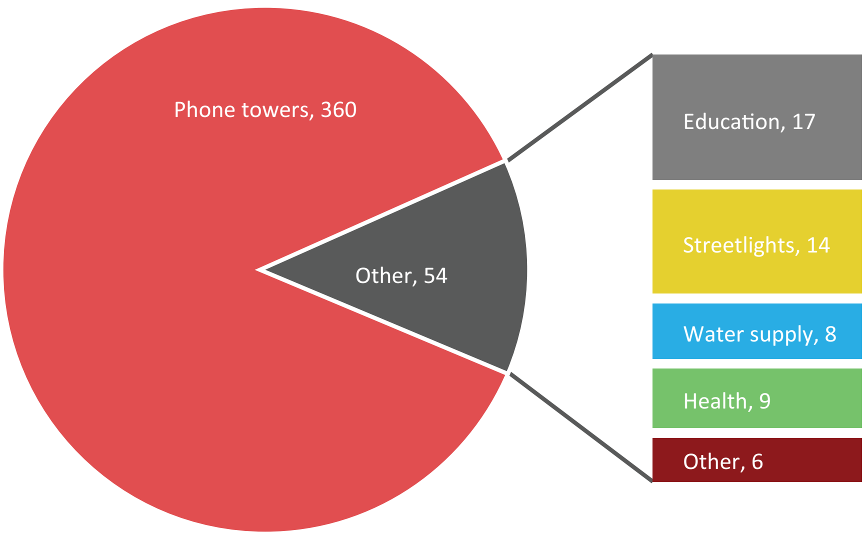
Off-grid renewable energy capacity has been deployed across a wide range of end-use sectors providing electricity services. Of the 6.6 GW of off-grid capacity in 2017, the industry sector dominates followed by mixed-use and commercial/public services (Table 1). Around 1.5 GW of off-grid capacity serves unknown sector(s) due to the lack of end-use disaggregated data. Bioenergy accounts for the majority share of industrial off-grid capacity with feedstock depending on local conditions, including agricultural and forestry residues. Solar photovoltaic (PV) accounts for the majority of use in the commercial and public sectors, as well as in residential and agriculture/forestry.

Table 1: **Off-grid electricity end-uses in 2017 (in MW and %)**

End-use sector	Hydropower	Solar PV	Wind	Bioenergy	Geothermal	Total (MW)	% of total
Industry	70	10	10	2 780	50	2 920	44%
Commercial/ public	10	430		10		450	7%
Residential	60	280		10		350	5%
Agriculture/ forestry	10	210		20		240	4%
Mixed-use (mini-grids)	360	310	480			1 150	17%
Use not known		1 500				1 500	23%
Total (MW)	510	2 740	490	2 820	50	6 610	
% of total	8%	41%	7%	43%	1%		

Within commercial and public uses, most solar PV use is for powering telecommunication infrastructure, followed by schools, street lighting, health centres and water pumping (Figure 6). The modular and distributed nature of solar PV enables it to be adapted to a wide range of off-grid applications, and several programmes and initiatives have been launched to accelerate deployment. Box 5 highlights advancements in the deployment of off-grid solar for agriculture and public end-uses in India, where a strong policy focus has led to rapid development, especially in the use of solar for water pumping. Solar pumps offer an attractive option to provide affordable and sustainable modern energy for meeting water pumping needs for irrigation and drinking water supply, and are increasingly being deployed (IRENA, 2016a). Another area of growing interest is the use of solar PV for powering rural healthcare centres.

Figure 6: **Commercial and public uses of solar PV in 2016, by capacity (MW)**



Box 5: Off-grid solar for agriculture and public end-uses in India

A strong policy push has led to a rapid deployment of off-grid solar in India. The number of solar pumps for irrigation and drinking water supply has risen from 11 626 in 2014 to over 177 000 in 2018 (MNRE, 2018).

Two types of financing schemes were adopted – first, farmers received a capital subsidy of 30% of the benchmark cost of the pump, and possible additional subsidies at the state level. The second, credit-linked scheme, involved a 40% capital subsidy, a 20% beneficiary contribution and the remaining amount extended as a loan implemented through the National Bank for Agriculture and Rural Development (NABARD). In March 2017, the Ministry of New and Renewable Energy closed the NABARD credit-linked subsidy scheme and set modified capital subsidy rates (CEEW, 2018).

Besides financing support, the government has taken steps to create an ecosystem for deployment through capacity building, standardisation, facilitating access to financing for farmers and enforcing standards for water-use monitoring. In addition, the number of solar street lights has doubled between 2014 and 2018 to over 620 000 (MNRE, 2018).

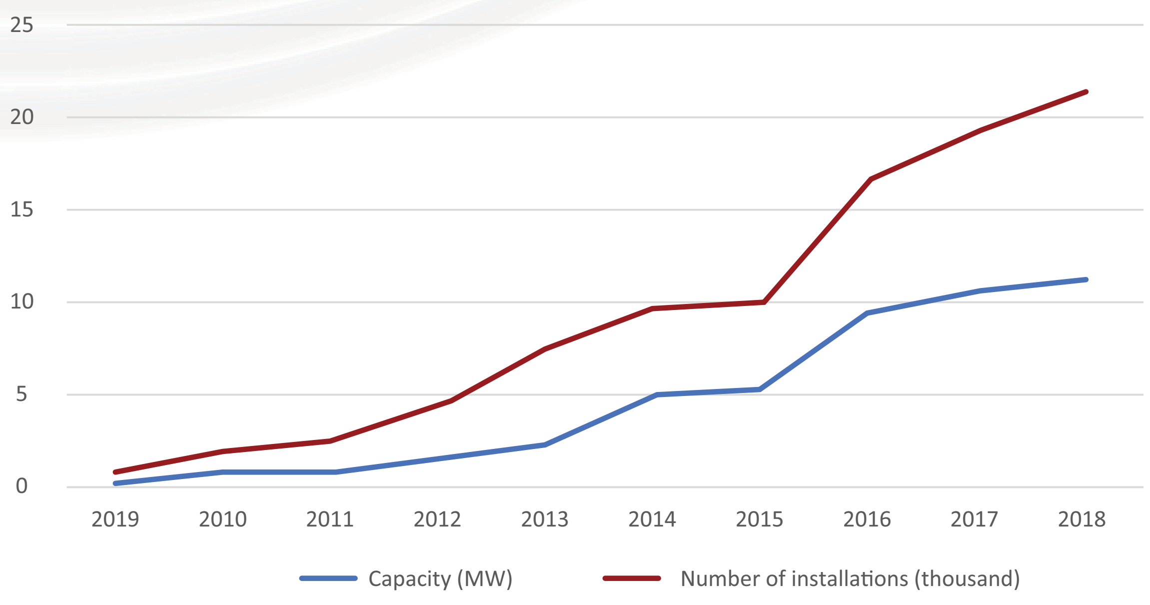
Growth in the use of solar PV for health care has increased five-fold since 2010 reaching over 10 MW by 2018 (Figure 7). Access to electricity plays a critical role in the functionality of healthcare facilities and in the quality, accessibility and reliability of health services delivered to rural communities. An estimated 1 billion people globally are served by health facilities without reliable electricity supply, 255 million of whom live in sub-Saharan Africa (Practical Action, 2013).


Photo credit: Shutterstock

This lack of, or unreliable, access to electricity contributes to the immense healthcare challenge that developing countries face. Developing regions accounted for approximately 99% of the global maternal deaths in 2015, with sub-Saharan Africa alone accounting for roughly 66% (201 000) due largely to limited access to emergency obstetric care and insufficient maternal care during pregnancy and delivery. According to the World Health Organization (WHO), “Unreliable electricity access leads to vaccine spoilage, interruptions in the use of essential medical and diagnostic devices, and lack of even the most basic lighting and communications for maternal delivery and emergency procedures. As disease patterns change, even more energy is required to expand services for prevention and treatment of non-communicable diseases (NCDs)” (WHO, n.d.).


Photo credit: IWMI/Prashanth Vishwanathan

Figure 7: **Growth in the use of solar PV in health care (MW and number of installations)**

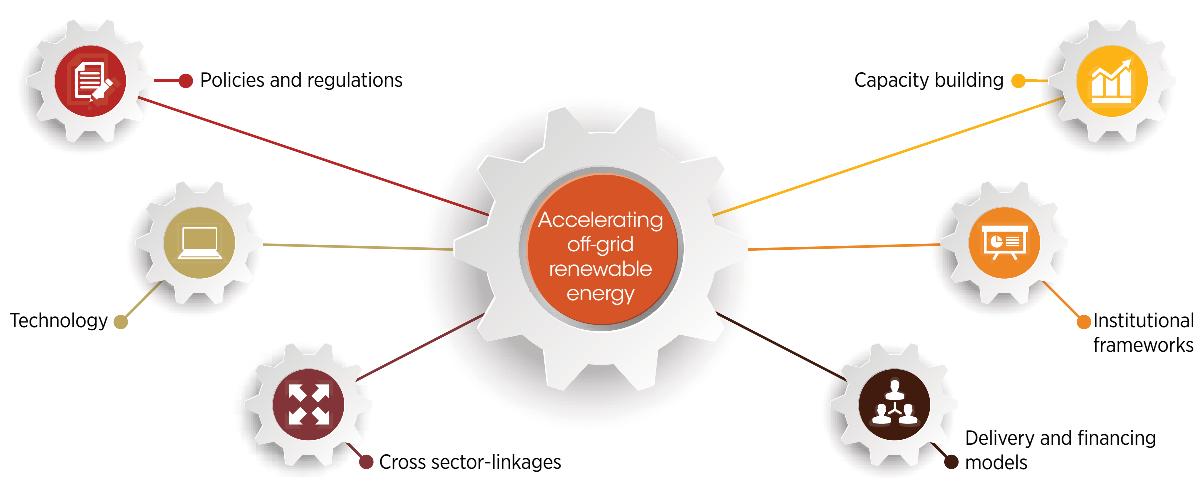


Rapidly emerging off-grid renewable energy solutions offer rapidly deployable, reliable and, in many cases, the most economically sustainable option to address the energy access needs of remote health centres. Electrification of rural health centres should be a priority in rural electrification programmes, taking into consideration its immense social impact.

ENABLING ENVIRONMENT FOR ACCELERATED OFF-GRID RENEWABLES DEPLOYMENT

Accelerating progress towards the SDG 7 goal on universal electricity access requires concerted action across multiple elements of an enabling environment, illustrated in Figure 8. These include policies and regulations, delivery and financing models, institutional frameworks, capacity building, technology adaptation and cross sector-linkages (IRENA, 2017a). There is no one-size-fits-all solution, and depending on the off-grid solution selected and on the local context, each element of the enabling environment needs to be tailored.

Figure 8: **The enabling environment for scaling up off-grid solutions**



Source: IRENA, 2017b

POLICIES AND REGULATIONS

The policy and regulatory landscape strongly influences the development of the off-grid renewable energy sector. Mainstreaming off-grid solutions within national energy access strategies provides a strong foundation for market development and incentivises different stakeholders to devise tailored solutions to provide energy services.

1. Electrification planning and strategies should identify clearly the areas to be reached by grid extension within a reasonable time frame and the areas suitable for off-grid solutions, and make the information available to all relevant stakeholders. Holistic and integrated energy access strategies need to be backed by dedicated policies and regulations designed for different off-grid solutions such as mini-grids and stand-alone systems.

2. Stability and clarity in policies and regulations is crucial for the development of off-grid renewable energy solutions. Policies, including incentive structures, need to be designed to attract investment and to encourage local enterprises to contribute to long-term market development.

3. In the case of mini-grids, traditional, centralised electricity sector frameworks need to be adapted to support deployment. Dedicated mini-grid policies and regulations need to address licensing and permitting requirements, tariff setting frameworks, main grid arrival implications and financing considerations (IRENA, 2016b). Nigeria, for example, released its mini-grid regulation in 2016 providing regulatory guidance for systems under 100 kW, between 100 kW and 1 MW, and interconnected mini-grids (NERC, 2016). There is also a large market (on a scale of hundreds of GW) to replace or hybridise existing off-grid diesel generators with renewable energy. The diesel capacity in operation is either in industrial facilities and mines operating remotely, as back-up units where electricity supply is unreliable or as community mini-grids (IRENA, 2015).

4. Adequate standards and quality control measures should be introduced to avoid the proliferation of low-quality products. Recognising that the regulation of the off-grid sector is still in its infancy, governments should focus on adopting standards that encourage sustainable development without discouraging adaptation and delivery model innovation. Furthermore, due consideration should also be given to the life-cycle impacts of the systems to address broader sustainability aspects such as end-of-life management of components.

INSTITUTIONAL FRAMEWORKS

An appropriate institutional framework is crucial to ensure the effective implementation of a national energy access strategy. Some countries have created new institutions (*e.g.,* Rural Electrification Agencies have been established in several countries in sub-Saharan Africa) with a mandate to support rural electrification activities, while others have placed the responsibility for rural electrification within existing ministries or agencies. Although approaches differ according to country contexts, successful strategies generally include:

1. Relevant institutions need to have clearly defined roles and responsibilities to give sector participants certainty about administrative procedures and institutional contacts.

2. Simple and streamlined administrative procedures are required to reduce transaction costs, for example, in procuring the necessary licences and permits. To this end, a single institution that is mandated with co-ordinating stakeholders, documenting processes and procedures, managing the project approval process, delivering capacity building and facilitating the administration of financial and other incentive schemes may be preferred.

3. Institutions implementing electrification strategies need to have adequate capacities ranging from technical knowledge and skills to stable budgetary allocations. As such, assessments are necessary to identify the capacity gaps. In addition, co-operation among diverse national and international institutions and agencies is essential for the creation of an effective and efficient environment for off-grid renewable energy deployment.

DELIVERY AND FINANCING MODELS

The recent rapid growth in off-grid renewable energy deployment has been a result of tremendous innovation in delivery and financing models to make solutions accessible and affordable for end-users and to enhance the sustainability of off-grid infrastructure. Key success factors include:

1. Delivery models need to be designed based on local socio-economic conditions, technologies adopted, and current and projected demand for electricity services. Actively engaging communities in the design, construction, operation and maintenance phase of the projects can increase community buy-in, enhance sustainability and increase opportunities for rural employment (Box 6). In many contexts, such as micro-hydropower in Nepal (discussed earlier), the policy integrates community ownership as part of the delivery model to maximise socio-economic benefits.

2. Access to long-term, tailored and affordable financing for end-users can improve the accessibility of off-grid solutions, whether products (*e.g.,* solar home systems) or services (*e.g.,* mini-grid connection fee). Designing end-use financing in a manner that engages local financial institutions can also help unlock a wider range of financial services for households beyond energy. Tying innovations in delivery model and financing can overcome challenges related to setting up dedicated channels for technology and financing delivery in rural areas. Examples include the utilisation of the micro-finance infrastructure in Bangladesh and the integration of mobile payments and pay-as-you-go in East Africa.

3. Enterprises in the off-grid sector seek improved access to affordable, long-term financing with different financing requirements depending on the stage of enterprise, its product/service portfolio and the phase of the project development. Public finance will play a key role in meeting the funding gap in the off-grid renewable energy sector through: i) direct financing for powering public services and rural households unable to access available solutions; and ii) financing instruments that de-risk investments and leverage private capital for enterprises and projects (*e.g.,* high-risk innovation funds, funds for initial feasibility study). The public sector also plays a crucial role in supporting delivery model innovation through research and pilot projects.

4. The use of financial instruments, such as crowdfunding, can facilitate access to capital for off-grid projects when traditional financing is not available or is too costly. It is estimated that in 2016, at least USD 8.7 million was raised through crowdfunding platforms for energy access projects in Africa and Asia, up 156% from 2015 levels (Cogan and Collings, 2017). Debt- and equity-based financing accounted for more than 90%. Crowdfunding can help raise financing quickly and at relatively low cost, while also fostering community awareness and acceptance in some cases. Enabling conditions, including policies and regulations, are needed to support the use of such instruments to contribute to filling existing financing gaps in the sector.

Box 6: Off-grid renewable energy and jobs

Off-grid renewable energy solutions can create value locally in terms of both employment and livelihood development (IRENA, 2013). In recognition, national off-grid renewable energy programmes are increasingly integrating the employment dimension of deployment. The Scaling Up Off Grid Energy in Rwanda programme, for example, aims to deliver access to energy to 77 500 people while creating 7 000 jobs to drive economic development (Energy4Impact, 2018).

Direct and indirect jobs can be created throughout the value chain of off-grid renewable energy technologies. Substantial induced jobs also can be created as a result of economic activities enabled through improved access to modern energy services.

Job creation is generally higher in the downstream segment of the supply chain, particularly in distribution, sales, installation, operation and servicing of off-grid systems. M-KOPA, a Kenyan solar home system company, for example, employs some 2 500 people in East Africa, including full-time staff and sales agents (IRENA, 2017c). Some countries, such as Bangladesh, have developed upstream supply chains and incentivised local manufacturing and assembly, including balance-of-system components (*e.g.,* inverters, batteries, charge controllers), thus creating additional jobs in the sector. In Bangladesh around 133 000 jobs have been created through the Solar Home System programme (IRENA, 2018c).

The characteristics and number of jobs depend largely on local variables such as social factors (*e.g.,* family relations, societal structures), market-based factors (*e.g.,* demand fluctuations, deployment model) and policy-based factors (*e.g.,* employer legal obligations) (IRENA, 2013). The distributed nature of the technology means that the bulk of the skills needed can be developed locally. However, the active participation of women in the sector is often hindered by factors such as social structures, traditions, mobility, access to skills and capital, and the perception that technology is better served by men (IRENA, 2012).

Beyond deployment, the potential for employment opportunities and income generation is enhanced considerably when off-grid solutions are integrated with local commercial activities, through either the scaling up of existing small businesses or the creation of new ones (IRENA, 2012). A better understanding of the employment effects of different energy access approaches (*e.g.,* number of jobs created by technology, type of employment, wages, skills and training requirements, gender dimension, etc.) can guide policy making towards achieving the full potential for job creation and ensuing socio-economic development from off-grid renewable energy development.

TECHNOLOGY INNOVATION

Technology adaptation and improvements – in generation, balance-of-system components and end-use applications – are essential to the success of off-grid solutions for expanding electricity access and supporting livelihoods in rural areas. IRENA's analysis finds that technology innovation, accompanied by advancements in delivery models and system operation, will dramatically reduce the cost of producing electricity in renewable mini-grids to one-third of its current cost in the next two decades (IRENA, 2016c). Several steps can be taken to support the technology innovation process:

1. Adapting off-grid renewable energy technologies to local conditions and repurposing them to provide diverse electricity services in rural areas should be supported. This involves a holistic process that includes generating assets (*e.g.,* micro-hydro turbines), balance-of-system components (*e.g.,* inverters, electronic load controllers, smart meters) and appliances to deliver accessible and affordable electricity services in rural areas for households, public centres (*e.g.,* health care, education) and productive uses (*e.g.,* agriculture, rural enterprises).

2. Public-private partnerships and loan grants can help develop and implement projects, while public venture funds and subsidies contribute to generating and exchanging knowledge. Funding from the public and private sectors is critical to support the fundamental research activities that generate new ideas.

3. Policy makers play a critical role in providing market policies to support commercialisation of renewable mini-grid equipment for a larger growth of the industry. In addition, programmes such as, Mission Innovation, the Global Cleantech Innovation Programme and Powering Agriculture, play a crucial role in facilitating and guiding innovation activities in the off-grid sector.

CAPACITY BUILDING

Capacity building is a central pillar of an enabling environment for off-grid renewable energy development. Adequate capacity needs to be built within public and financial institutions to support the implementation of the national energy access strategy. Awareness raising and sensitising stakeholders on the characteristics of off-grid renewable energy solutions can address some of the barriers faced by the new technologies.

1. A capacity needs assessment is necessary to determine gaps across the value chain of off-grid renewable energy technologies, including the public sector, financing institutions, private sector and standardisation agencies. Technical assistance programmes and international development finance should be designed to support local capacity development to ensure long-term development of the sector. A readiness assessment for accelerating renewable mini-grid deployment in the Philippines, for instance, noted the importance of capacity building of the banking and the private sector for better technical, managerial and financial understanding of projects (IRENA, 2017d).

2. Entrepreneurship support schemes that are accessible for the local private sector could support the development of a sustainable market for off-grid solutions. In this context, dedicated platforms are needed through which small and medium-sized renewable energy enterprises can access advisory assistance (Box 7).

3. Dedicated project facilitation tools can also play a key role in supporting the deployment projects by helping project developers secure financing more efficiently. IRENA's online platform, Project Navigator (http://irena.org/navigator), for instance, provides the tools and guidance to assist in developing renewable mini-grid projects, and introduces the best practices to assist project

developers in preparing, developing, and operating bankable projects, particularly in the context of SIDS. The Sustainable Energy Marketplace (http:// irena.org/marketplace) connects renewable energy project owners, financiers/investors, services providers and technology suppliers.

4. The presence of adequate skills is key for the sustainability of the off-grid renewable energy sector. The skills needs vary depending on the technology, the segment of the value chain and the nature of the task. Certification programmes for off-grid skills development, integration in training curricula and a focus on local skills building for operation and maintenance would provide employment opportunities for rural communities and support wider socio-economic development.

Box 7: Fostering Renewable Energy Entrepreneurs

Local renewable energy entrepreneurs have a crucial role to play in adapting delivery models and off-grid technological solutions to meet diverse energy needs. Through the Renewable Energy Entrepreneurship Support Facility, IRENA, together with regional partners, strengthens the capacity of small and medium-sized enterprises in West and Southern Africa.

The ECOWAS Renewable Energy Entrepreneurship Support Facility provides advisory assistance to small and medium-sized enterprises in West Africa. Since its launch in 2015, the Facility has supported over 80 enterprises through various training courses, advisory assistance, facilitating partnerships, networking and match-making with financial institutions. Enterprises benefiting from technical assistance managed to scale up their business activities through increasing their human resources and revenues, implementing innovative operation and marketing strategies, developing bankable project proposals and securing financing.

Replicating the success of the Facility in West Africa, a similar facility in Southern Africa has been established. In March 2018 the SADC Centre for Renewable Energy and Energy Efficiency and IRENA launched the first call for applications from entrepreneurs seeking support in the form of mentorship, technical assistance, training as well as facilitation for access to financing.

CROSS SECTOR-LINKAGES

Access to modern, sustainable energy is fundamental to meet several SDGs. Off-grid renewable energy solutions can support the provision of basic services, such as health, water and education, and livelihoods through productive end-uses. Some measures to maximise the cross-sector benefits of off-grid solutions include facilitating dialogue with stakeholders across sectors at the project design stage, adequate capacity building on potential productive end-uses, technology and delivery model adaptation, and the dedicated treatment of such solutions in sector development strategies.

1. A holistic view of off-grid renewable energy development should be adopted that considers the diversity of energy services needed across sectors. Better linking energy-service delivery to end-uses could enhance the sustainability of projects/ programmes and maximise the socio-economic and environmental development outcomes.

2. Innovations in technology, delivery and financing models for off-grid solutions can be leveraged to support the delivery of electricity services for cross-sector applications, including the agriculture sector (IRENA, 2016d). Pay-as-you-go, for instance, has been tailored into pay-as-you-grow such that small-scale farmers are able to finance off-grid solar systems for irrigation based on cash flows linked to crop cycles.

3. Off-grid renewable energy solutions can be designed to provide affordable and reliable electricity supply for a wide range of public services, including water, education and health. Assessing the role of off-grid solutions across sectors and mainstreaming within the respective sector development strategies can incentivise cross-sector collaboration and maximise the benefits across multiple Sustainable Development Goals.

Box 8: IRENA methodology to track off-grid renewable energy capacity development

IRENA currently collects off-grid capacity and generation data from a variety of sources, such as IRENA questionnaires and national databases, as well as unofficial sources (*e.g.,* project reports, news articles, academic studies and websites). For some countries IRENA also estimates off-grid solar PV capacity, based on solar panel import statistics. During the second half of 2017 IRENA made a concerted effort to systematically organise and improve its off-grid renewable energy data. This exercise had three main aims:

1. To validate and expand the information already collected about off-grid renewable electricity plants (including small solar devices).
2. To identify the end-uses of electricity generated in off-grid renewable plants, so that this can be correctly added to the electricity flows in a country's energy balance.
3. To estimate the numbers of people served by these off-grid electricity sources and the level of electricity access provided.

The exercise focused on off-grid solar PV, hydropower and biogas production in developing countries. Data were collected from a wide variety of sources, including publicly available information from online databases, websites and reports, as well as data obtained from IRENA's statistical correspondents and other institutions contacted by email.

A major part of the exercise was checking and validating the raw data obtained from these different sources. The first step was to convert all of the figures to common measurement units for capacity, production and numbers of beneficiaries. The data were then adjusted to account for the lifetime of some devices (*e.g.,* assuming that solar lights will be used for only about three years and that biogas digesters will be gradually retired as they get older). Additional checks were made to avoid over-estimation by, for example, checking that the number of household connections was used as the measure of the population served by mini-grids (rather than the total population in the locality) and, for older plants, checking that plants are still functioning and could be included in the analysis. As a final step, the dataset was reviewed as part of the REN21 Global Status Report peer review process in the first quarter of 2018.

At the end of this exercise the new database of off-grid power plants included information about 38 600 small hydropower plants, 500 biogas generators, 8 100 solar mini-grids, 107 300 solar water pumps and 168 300 other solar power plants. It also included 650 records of annual sales of small solar devices in different countries (amounting to about 51 million units in total), as well as information about the 42 million biogas digesters that have been built over the last three decades.

This new dataset partly overlaps with the off-grid data previously collected by IRENA, but it also has expanded the information available about off-grid power supplies in many countries and for some technologies such as small-scale hydropower. It has confirmed the existence of much of the off-grid solar PV currently estimated from import statistics and has identified the end-uses of about 70% of off-grid power capacity. IRENA is currently in the process of integrating the new data into its existing off-grid power statistics and analysing the data for further insights into the linkages between off-grid power supplies and the achievement of other Sustainable Development Goals.

REFERENCES

AEPC (Alternative Energy Promotion Centre) (2011), AEPC Annual Report for 2010, Alternative Energy Promotion Centre, Patan, www.aepc.gov.np/files/20131029070205_AEPC%20Annual%20Report%202066-67.pdf.

Bhatia, Mikul and Nikolina Angelou (2015), "Beyond Connections: Energy Access Redefined", ESMAP Technical Report, World Bank, Washington, DC.

CEEW (Council On Energy, Environment and Water) (2018), *Solar for Irrigation A Comparative Assessment of Deployment Strategies, Council on Energy, Environment and Water,* New Delhi, http://ceew.in/pdf/CEEW%20-%20Solar%20for%20Irrigation%20-%20Deployment%20Report%2017Jan18.pdf.

Energy4Impact (2018), *SOGER (Scaling Up Off Grid Energy in Rwanda) Mid Term In-Depth Evaluation,* www.energy4impact.org/file/2024/download?token=Qs5Bi2ge.

Cogan D. and Collings S. (2017), *Crowd Power: Can the crowd Close the Financing Gap?,* Energy4Impact, www.energy4impact.org/file/1883/download?token=aft0NCOX.

FAO (Food and Agriculture Organization) (2018), *The benefits and risks of solar-powered irrigation – a global overview,* Food and Agriculture Organization of the United Nations, Rome, www.fao.org/3/I9047EN/i9047en.pdf.

IDCOL (Infrastructure Development Company Limited) (2018), Project and Programs: Solar Home System Programme, Infrastructure Development Company Limited, Dhaka, www.idcol.org/home/solar.

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.

IMF (2016), *IMF Working Paper Caribbean Energy: Macro-Related Challenges, International Monetary Fund, Washington, DC,* www.imf.org/en/Publications/WP/Issues/2016/12/31/Caribbean-Energy-Macro-Related-Challenges-43776.

IRENA (International Renewable Energy Agency) (2018a), *Renewable Capacity Statistics 2018,* International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2018/Mar/Renewable-Capacity-Statistics-2018.

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

IRENA (2018c), *Renewable Energy and Jobs - Annual Review 2018,* International Renewable Energy Agency, Abu Dhabi.

IRENA (2017a), *REthinking Energy 2017: Accelerating the global energy transformation,* International Renewable Energy Agency, Abu Dhabi.

IRENA (2017b), *Accelerating Off-grid Renewable Energy: Key Findings and Recommendations from IOREC 2016,* International Renewable Energy Agency, Abu Dhabi.

IRENA (2017c), *Renewable Energy and Jobs – Annual Review 2017,* International Renewable Energy Agency, Abu Dhabi.

IRENA (2017d), *Accelerating renewable mini-grid deployment: A study on the Philippines,* International Renewable Energy Agency, Abu Dhabi.

IRENA (2016a), *Solar Pumping for Irrigation: Improving Livelihoods and Sustainability,* International Renewable Energy Agency, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Solar_Pumping_for_Irrigation_2016.pdf.

IRENA (2016b), *Policies and regulations for private sector renewable energy mini-grids,* International Renewable Energy Agency, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Policies_Regulations_minigrids_2016.pdf.

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

IRENA (2016d), *Renewable Energy Benefits: Decentralised solutions in the agri-food chain,* International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2016/Sep/Renewable-Energy-Benefits-Decentralised-solutions-in-agri-food-chain.

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

IRENA (2013), *Renewable Energy and Jobs,* International Renewable Energy Agency, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/rejobs.pdf.

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

MNRE (Ministry of New and Renewable Energy) (2018), *4-Year Achievement Booklet, Government of India,* Ministry of New and Renewable Energy, New Delhi, https://mnre.gov.in/sites/default/files/uploads/MNRE-4-Year-Achievement-Booklet.pdf.

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

Ochs, Alexander et al. (2015), *"Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS): Baseline Report and Assessment",* Worldwatch Institute, Washington, DC.

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

Tozzigreen (2018), *La electrificación rural en Perú y el papel de Ergon, www.tozzigreen.com/es/proyecto/lelettrificazione-rurale-peru-ruolo-ergon/.*

UN (United Nations) (2018), *Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all,* www.un.org/sustainabledevelopment/energy/.

Videnza (2018), *"Agenda pendiente de electrificación rural en Perú, Lima",* https://gestion.pe/blog/evidencia-para-la-gestion/2018/04/agenda-pendiente-de-electrificacion-rural-en-el-peru.html.

WHO (World Health Organization) (2015), *Trends in Maternal Mortality: 1990 to 2015,* Estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division, Geneva, Switzerland, http://apps.who.int/iris/bitstream/10665/194254/1/9789241565141_eng.pdf

WHO (n.d.), *Health and sustainable development: Energy access and resilience,* www.who.int/sustainable-development/health-sector/health-risks/energy-access/en/.

World Bank (2015), *Nepal: Scaling Up Electricity Access through Mini and Micro Hydropower Applications,* World Bank, Washington, DC, http://documents.worldbank.org/curated/en/650931468288599171/pdf/96844-REVISED-v1-Micro-Hydro-Report-0625-2015-Final.pdf.

This publication should be cited as: IRENA (2018), 'Off-grid renewable energy solutions: Global and regional status and trends'. IRENA, Abu Dhabi.

ISBN 978-92-9260-076-1

About IRENA

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 co-operation, 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.

Acknowledgements

This brief was developed under the guidance of Rabia Ferroukhi (IRENA), authored by Divyam Nagpal (IRENA). Valuable contributions were made by Adrian Whiteman and Salvatore Vinci (IRENA).

The brief benefited greatly from internal feedback received from Henning Wuester, Dolf Gielen, Elisabeth Press, Ahmed Abdel-Latif, Paul Komor, Salvatore Vinci, Bishal Parajuli, Abdullah Abou Ali, Michael Renner, Xavier Casals, Costanza Strinati and Anna Charles (IRENA).

Disclaimer

This publication and the material herein are provided "as is". All reasonable precautions have been taken by IRENA to verify the reliability of the material in this publication. However, neither IRENA nor any of its officials, agents, data or other third-party content providers provides a warranty of any kind, either expressed or implied, and they accept no responsibility or liability for any consequence of use of the publication or material herein.

The information contained herein does not necessarily represent the views of the Members of IRENA. The mention of specific companies or certain projects or products does not imply that they are endorsed or recommended by IRENA in preference to others of a similar nature that are not mentioned. The designations employed and the presentation of material herein do not imply the expression of any opinion on the part of IRENA concerning the legal status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

IRENA
International Renewable Energy Agency

P.O. Box 236
Abu Dhabi, United Arab Emirates
Tel: +971 2 4179000
www.irena.org