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Rural renewable energy investments and their impact on employment

Michael Renner

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Preface

Employment is a key driver for development as it constitutes a bridge between economic growth and poverty reduction. People and households moving out of poverty most often do this through moving into more productive and decent jobs or improving existing jobs. Contrary, shortage of adequate decent employment opportunities is recognised as a root cause of migration, becoming more and more critical in view of demographic developments that will see record numbers of youth entering the labour market in the coming decades.

Placing the aim of achieving full and productive employment at the heart of development policy is therefore critical for reducing and eventually eliminating poverty, reducing inequality and addressing informality. This is also now globally recognized with the adoption of Sustainable Development Goal (SDG) 8 “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”

The European Commission (EC) and the International Labour Organization (ILO) recognize that achieving this goal will require an approach where the goal of more and better jobs is also integrated into sectoral and trade policies. However, this requires a shared understanding among policymakers and social partners about the positive interaction between sectoral, trade and employment policies and the elaboration of a policy framework allowing sectoral and trade policies to be formulated and implemented in a coherent way to achieve employment and development objectives.

The ILO clearly recognizes that putting the aim of full and productive employment at the heart of development policy is critical in creating decent work and fostering social justice. These perspectives reflect a commitment to the objective of creating quality jobs globally and to pursuing cooperative solutions to this challenge. In the “Agenda for Change”, the European Commission (EC) calls for a more comprehensive approach to supporting inclusive growth characterised by people’s ability to participate in, and benefit from, wealth and job creation while in its proposal for a new "European Consensus on Development" it is proposed to promote investment and innovation to boost growth and quality employment opportunities in partner countries

In order to build a shared understanding among policymakers through policy dialogue and contribute to a coherent policy framework that is centred on generating and upgrading employment, the EC and ILO have jointly initiated the project entitled “Strengthening the Impact on Employment of Sector and Trade Policies”. This project, being implemented in ten partner countries and working with national governments and social partners, aims to strengthen the capabilities of country partners to analyse and design sectoral and trade policies and programmes that would enhance employment creation in terms of quantity and quality.

This innovative project entails developing new methods and capacities to assess how sectoral and trade policies impact on both the qualitative and quantitative dimensions of employment. It requires new processes to bring together different Ministries, public and private stakeholders to have evidence-based dialogue about how their respective policies do, and could, better impact on employment.

This series of project publications aims to capture the tools, methods, and processes developed under this project, as well as the findings from implementing these in the ten partner countries. By doing so, the experience and learning of the project can be disseminated to other countries and partners for their benefit, thus supporting the integration of global and national employment objectives into sectoral and trade policies and consequently supporting the elevation of the global employment agenda and achievement of SDG 8.

Azita Berar Awad
Director
Employment Policy
Department

Jean-Louis Ville
Director Human Development and Migration
Directorate-General for International Cooperation
and Development

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Abbreviations

BGEF	Bright Green Energy Foundation
FFS	Fee-for-service
FRES	Foundation Rural Energy Services
FTE	Full-time equivalent
GW	Gigawatt
IDCOL	Infrastructure Development Company, Bangladesh
IEA	International Energy Agency
IIED	International Institute for Environment and Development
ILO	International Labour Organization
IRENA	International Renewable Energy Agency
Km	Kilometre
kW	Kilowatt
kWp	kW peak
MW	Megawatt
NGO	Nongovernmental organization
O&M	Operations and maintenance
PAYG	Pay-as-you-go
PO	Partner organization
PV	Photovoltaic
RET	Renewable energy target
SE4ALL	Sustainable Energy for All
SHS	Solar home system
SNV	SNV Netherlands Development Organisation
TWh	Terawatt hour
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
W	Watt
US$	United States dollar

1. Introduction and context

1.1 Access to energy

Energy enables virtually all of human activities, underpinning both the economy and employment. Access to modern energy is essential not only to properly support a range of economic activities, but also to provide critical social needs, such as clean water, sanitation, health care, lighting, heating and cooling, which are indispensable for a well-functioning economy.

Hundreds of millions of people have acquired access to modern energy sources over the last two decades, especially in India and the People's Republic of China. Successful initiatives have also been instigated in many other countries. From 1990 to 2012, the global electrification rate climbed from 75 per cent to 85 per cent (World Bank, 2015). This reflects broad factors like economic development, ongoing urbanization, and grid extension, as well as national and international efforts such as the Sustainable Energy for All (SE4ALL) initiative.

Rural electrification efforts through grid-extension have often entailed programmes for the development of conventional power sources. For example, in Brazil's Luz Para Todos programme, renewable sources of energy accounted for just a tenth of the supply extended to 2.5 million targeted rural households. Asian countries have focused fairly strongly on hydropower, which has not always been deployed at sustainable scales (IFAD, 2010).

Progress notwithstanding, as of 2012, an estimated 1.285 billion people remained without access to electricity, of whom more than 80 per cent were living in rural areas, where grid extension is often too expensive or too difficult (IEA, undated-a) (table 1). Others—perhaps as many as 1 billion people—have unreliable access and suffer from chronic power outages or load shedding. As a UNDP report (2012a) observed, "many rural industries (agro-based and non-agro-based) and enterprises of all sizes are unreliably served or not served at all by grid or conventional power infrastructure. Such enterprises have to create their own energy access (primary or backup) to fuels, electricity and mechanical power if they are to survive, let alone grow."

Table 1. Electricity access and electrification in developing countries, 2012

Regions/countries	Population without electricity (Millions of people)	National electrification rate (%)	Rural electrification rate (%)
All developing countries	**1 283**	**76**	**64**
Africa	622	43	26
North Africa	1	99	99
Sub-Saharan Africa	621	32	16
Developing Asia	620	83	74
China	3	100	100
India	304	75	67
Latin America	23	95	82
Middle East	18	92	78
World	**1 285**	**82**	**68**

Source: IEA, undated-a.

Sub-Saharan Africa and parts of Asia account for nearly all of the population without access to electricity (table 2). The largest populations without electricity are in Bangladesh, Ethiopia, the Democratic Republic of Congo, India, Indonesia, Nigeria and Pakistan—which together account for more than half of the global total. Rapid growth of energy-poor people in sub-Saharan Africa has outpaced electrification efforts; more than 620 million people (two-thirds of the region's total population) have no electricity.

The average rural electrification rate in sub-Saharan Africa was only 16 per cent in 2012. Today, in developing Asia, the percentages are for the most part much higher. The lowest percentages are found in the Democratic People's Republic of Korea (11 per cent), and Cambodia and Myanmar (both 18 per cent). In Latin America, the only country with a very low rate is Haiti, at eight per cent, although Nicaragua (50 per cent), Panama, Argentina, and Bolivia (61–66 per cent) have lower achievement rates than the rest of the region. Similarly, in the Middle East, only Yemen has a low rate at 29 per cent.

1.2 The promise of renewable energy in the rural context

The literature on access to rural energy through renewable energy is expanding rapidly, as are manifold initiatives to achieve universal access. However, much of the literature is concerned with technical aspects, financing, and the policies needed to generate an enabling environment. Only a minor portion addresses the employment aspects in more than a cursory manner. This report marshals relevant information in an effort to assess existing and potential employment impacts.

The most relevant renewable energy technologies for rural energy access are solar photovoltaic (typically in the form of small-scale residential or commercial units and portable solar lighting), bioenergy (biogas, biodiesel, biomass heating and power), and micro- or pico-level hydropower stations. Small-scale wind systems are still very limited in the developing world outside of China. With regard to bioenergy for cooking, there is also the issue of clean ("improved") cookstoves. However, it is not discussed in this report (table 2). Most attention and most financial investment revolve around solar photovoltaic technology, especially in the form of small solar home systems (SHS). An SHS typically comprises a solar panel, battery and light bulbs (most often LEDs), and is principally used for lighting and to charge mobile phones.

Table 2. Renewable energy technologies and employment potential in rural areas

Energy technology	Equipment	Employment potential
Solar energy	Portable solar lights (pico solar); solar panels (solar home systems); solar pumps	• Distribution and retailing of solar lanterns / panels, and of accessories (batteries, light bulbs, phone-chargers) • Installation of solar panels, pumps • Financing (microcredit operations) • Maintenance and repair • Decommissioning/recycling of solar equipment[1]
Traditional biomass	Fuelwood; charcoal	• Growing/cultivating forests • Gathering of wood and agricultural/forestry wastes • Production of charcoal • Distribution and sales
Modern bioenergy	Biodiesel; Biomass heating and power; Biogas	• Cultivation and harvesting of feedstock; gathering of agricultural / forestry wastes; processing of materials • Construction of biomass plants, biogas digesters (masonry, pipe-laying, etc.) • Operations and maintenance • Distribution of fuels • Manufacturing of improved cook stoves
Hydropower	Small- or pico-scale dams	• Construction of dam, penstocks, watermills • Manufacturing or assembly of turbines and other equipment • Operations and maintenance
Wind power	Small- or pico-scale turbines	• Import, assembly, sales of turbines • Site preparation and installation • Operations and maintenance

Source: Author's elaboration.

1.2.1 Supply chains

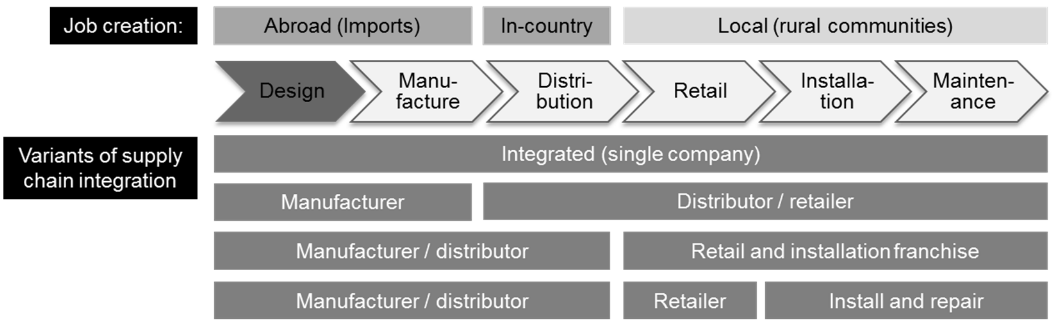
The deployment of various renewable energy technologies can be looked at from the perspective of supply chains, involving a number of functions and a range of actors, including international donor agencies, nongovernmental organizations (NGOs), or private companies, as well as national government agencies, local contractors or entrepreneurs, community/user associations, cooperatives, etc. In addition to the main supply chain, there are secondary value chains that provide support in the form of various inputs, services and finance. There is also the broader enabling environment, which encompasses political, regulatory, and social and cultural dimensions (EUEI PDF and Practical Action, 2015).

Figure 1 gives an approximate idea of the supply chain for rural renewable energy deployment. Different arrangements along the supply chain are likely to have an impact on how much employment is generated, and where. The figure depicts the principal stages of deploying and using renewable energy systems, from design and manufacturing all the way to installations and maintenance (after-sales service). It is most representative of household-scale solar systems (which are presently the dominant focus of energy access efforts). For mini-grids or other systems that are deployed at a scale greater than the household level (such as community-scale biogas, small hydropower, or small wind), there are additional requirements beyond simple installation (i.e. project development, site preparation and construction), as well as the procurement of needed materials, with additional employment opportunities. For mini-grids, there is also a need to install local transmission lines to individual homes and businesses, and for grid-connected systems, the construction of longer transmission lines is needed.

The top of the figure gives an indication where employment along the supply chain is likely to be generated. In most cases, the design and manufacture of equipment, such as wind towers and nacelles, hydropower turbines, solar panels, etc., takes place outside of poor developing countries. There are now a number of small manufacturing or assembly facilities in the developing world, but they represent only a small share of global capacity, and most countries remain dependent on imported equipment. Therefore, employment opportunities in rural parts of the developing world are principally found in distribution and sales, construction and site preparation, and installation, as well as in operations and maintenance (O&M).

Distribution involves shipping of (typically, imported) equipment from ports or other entry points to warehouses from where the equipment makes its way to local retail locations. Employment in distribution is thus generated in-country, but not in the rural communities where the equipment is destined. Rural community employment is concentrated in the retail, installation, and after-sales service stages. For community-scale systems, there is also a need for local construction and operating personnel.

Figure 1. Schematic value chain, rural renewable energy deployment



Source: Author's elaboration.

The bottom half of figure 1 shows variants of supply-chain organization. Particularly in solar lighting, there are multiple approaches. Some companies run an integrated operation covering the entire supply chain, not only designing and manufacturing the system, but also controlling distribution and sales to end users. An integrated supply chain (with a single organization coordinating and implementing all relevant activities) offers certain efficiencies that may translate into a need for somewhat less labour than other models. The retail distribution and installation of solar equipment in particular is still at a very early stage, with a number of start-ups rising to prominence and different business models in play.

In most cases, the manufacturer is not involved in downstream activities, so that retail, installations, and after-sales services tend to be provided by a range of actors (franchises, retail stores, entrepreneurs, NGOs, etc.). The biggest challenge lies in last-mile distribution in sparsely populated areas, where a central question is whether it is better to build a new network from scratch (through a sales force that works on commission) or to rely on existing stores. These different approaches have an impact on the quality of installations and the reliability of after-sales service, and that, in turn, has an impact on employment.

Once renewable energy systems are deployed in rural areas, they enable greater or improved productive uses of energy by existing and/or new enterprises. This opens up downstream opportunities for rural employment generation (discussed in chapter 6), in part by improving education, building skills, communications, and health and public safety.

1.2.2 Grid extension, mini-grids, and standalone installations

Access to energy in rural areas can be provided in three different ways, at deployment scales appropriate for the different needs and circumstances of communities, households and small businesses. The first concerns grid extension (although the sharing of renewables fed into the grid may vary substantially from case to case, to date, rural electrification has in fact often been based on fossil fuels or large-scale hydropower). Where the distance from the grid is too far or too expensive to reach, or where the population density is too low to economically justify a grid connection, standalone devices can be deployed at the household level.

Community-level mini-grid systems offer an intermediate alternative, powering several homes and local businesses (box 1). Most existing mini-grids are currently powered by diesel generators, but can be replaced with renewable power—solar, hydropower and biomass (agricultural waste materials and wood pellets), or with hybrid systems that combine renewables and diesel. For now, hybrids account for only 2–3 per cent of the world's total diesel generator capacity, but there is huge potential for increasing the share of renewable sources (IRENA, 2015a). Numerous governments have initiated policies in support of renewable mini-grids. In sub-Saharan Africa, Mali is the country with the most such systems; more than 160, each typically supporting connections to some 500 households or businesses (Knuckles, 2015).

Box 1. Mini-grids

A mini-grid is a village-level system that connects one or multiple generation sources to local households and small businesses. The EU Energy Initiative-Partnership Dialogue Facility (EUEI-PDF) defines a mini grid as "a power system where the produced electricity is fed into a small distribution network that provides a number of end-users with electricity in their premises." Mini-grids typically have a capacity of less than 1 megawatt (MW).

Customers may include farms and non-farm enterprises. Sometimes, there is an "anchor" customer such as a mobile phone tower or a larger business. Mini-grids can be standalone systems or be connected to the main grid. They are constructed, operated and maintained by a variety of actors including national-level utilities, private companies, local entrepreneurs, non-profit organizations and local communities.

Hydropower mini-grids are prevalent in Asia, but less so in Africa. Recently, however, there has been renewed interest particularly in the context of rural electrification and in the tea sector, with dozens of sites in Cameroon, Ghana, Kenya, Malawi, Mozambique, Swaziland, Uganda and the United Republic of Tanzania.

Biomass mini-grids convert biomass to gas or combust it directly in generators. Some burn methane from organic waste, while others generate steam by burning biomass in boilers. In Africa, such mini-grids are often found on sugar and timber plantations, while they are still less common in community electrification.

Sources: Energypedia, undated; Knuckles, 2015 p. 46; Africa-EU Renewable Energy Cooperation Programme, 2014.

No one has a reliable count on the number of existing mini-grids or their capacity and power generation. The International Renewable Energy Agency (IRENA, 2015a) reports that there are "a few thousand" renewably powered mini-grids. Bangladesh, Cambodia, China, India, Morocco, and Mali each have more than 10,000 solar PV village-level grids, while India has a substantial number of grids relying on rice husk gasification.

The pace at which clean energy mini-grids are being developed remains slow for the time being. A 2015 report by EUEI PDF and Practical Action Consulting (2015) finds that "mini-grids have struggled to expand beyond pilot projects and need to be scaled-up to make a meaningful contribution to the SE4All targets." As a report for SE4All (Wiemann and Lecoque, 2015) explains, mini-grid development faces a number of barriers, including: inadequate regulation, policy gaps and uncertainties; early-stage market fragmentation; capacity issues; a lack of standardization; a lack of proven commercial business models; and a lack of access to affordable longer term finance.

According to IRENA (2015b), some 26 million households worldwide have to date gained energy access through off-grid renewable energy systems. Of these, 20 million gained access through SHS, 5 million through mini-grids, and 0.8 million through small wind turbines. (However, the relevance of small wind for off-grid use in rural areas of the developing world outside of China is miniscule.[1])

IRENA (2013) estimates that almost 60 per cent of the additional power generation needed to reach the goal of universal access to electricity by 2030 will probably need to come from off-grid installations. And the World Energy Outlook 2011 (IEA, 2011a) expressed the expectation that more than 40 per cent of the capacity needed to achieve universal access to electricity by 2030 would most economically be delivered by mini- or micro-grids.

1.2.3 Distributed renewable energy landscape

With the progression of the various distributed renewable energy technologies (RETs), dramatic price reductions are making them much more affordable. For example, the cost per watt of solar portable lighting technologies in 2015 was just one quarter of the 2008 level (Africa Progress Panel, 2015). BNEF and Lighting Global (2016) similarly report tremendous cost reductions for pico solar, larger portable lights, and SHS. This trend is aided by the spread of such technologies as LED lights and improved batteries. Together, they are making growing adoption of renewables possible in areas that have lacked energy access entirely or had unreliable access in the past. As the cost of renewables continues to decline, expenditures are saved relative to conventional fuels; money that can instead be invested in cleaner forms of energy, though the upfront costs of renewables can still be barriers for poor communities (requiring appropriate financing arrangements).

Reliable quantitative data on rural renewable energy capacity and markets remain relatively scarce. According to BNEF and Lighting Global (2016), some 44 million pico solar products (portable lights, low-power appliances, and mobile-phone chargers) had been sold globally by mid-2015, up from just 1.9 million by mid-2011. REN21 (2016) estimates that more than 6 million solar home systems are in use worldwide, with by far the largest number installed in Bangladesh. Close to 50 million biogas plants have been installed, with more than 40 million of these in China alone. No global estimate appears to be available for micro- and pico-hydropower stations.

Efforts are under way to map the rather fragmented current global landscape of energy access initiatives, including funding and support services. In the field of mini-grids, SE4All (Wiemann and Lecoque, 2015) lists 75 different key stakeholders (including national and international agencies, development banks, private companies, foundations and NGOs). With the same goal in mind, the Alliance for Rural Electrification (ARE) is compiling a second edition of its investment directory. It should be noted, however, that

[1] Close to 40 per cent of small wind turbines worldwide were installed in China alone, and another 40 per cent in the United States and the United Kingdom, mostly connected to the grid.

these mapping efforts tend to focus on project and market development, technical issues and financing, with little or no attention being devoted to employment aspects.

In contrast, the United Nations (UN) Foundation's survey (Energy Access Practitioner Network, 2015) of members does offer some employment data, among other information. Of a total of more than 2,000 members from more than 170 countries, 210 responded to the survey (including mostly small- and medium-sized enterprises, social enterprises, entrepreneurs, NGOs, as well as investor institutions and funds). During 2014, the respondents reported having collectively provided energy products and services to 31.4 million people over the previous 12 months (and 112.6 million over the collective lifetimes of the organizations). Cumulative installed renewable energy capacity ran to almost 5,300 MW. Solar PV is the dominant technology. In the 12 months prior to the survey, the respondents had distributed almost 5.6 million solar lanterns, about 389,000 solar PV units of less than 1 kilowatt (kW), and 47,000 units larger than 1 kW. The respondents reported employing about 17,600 people.[2]

In 2014, the International Finance Corporation (IFC) concluded that out of a total of 274 million households without modern lighting and electricity, 256 million could afford some form of modern lighting without subsidies. Using different levels of existing monthly expenditures on lighting and charging as indicative thresholds, the IFC analysis found that 112 million households could afford only low-cost solar and rechargeable lanterns. This compares with 86 million households able to afford modular solar kits that allow a household to run several lights and charge small appliances; 10 million for more expensive regular rooftop SHS, 29 million for mini-utilities and 19 million for grid extensions (IFC, 2014).

1.3 The state of renewable energy employment

Rising investment has been a driving force in expanding employment in the renewable energy sector, although most of money spent to date, the bulk of the installations, and therefore the lion's share of employment, has taken place in industrial country settings. Rural deployment of renewable energy in poorer countries has only recently acquired a degree of dynamism.

Globally, investment in renewable energy projects expanded from US$ 46.6 billion in 2004 to US$ 285.9 billion in 2015, excluding spending on mergers and acquisitions (Frankfurt School-UNEP Centre/BNEF, 2016). Of the 2015 figure, US $199 billion went to asset finance, which typically supports relatively large-scale facilities. By comparison, US$ 67.4 billion went to small, distributed capacity (down from a peak of US$ 79.3 billion in 2012). Most of this, however, was invested in China and developed countries. Flows to rural areas of the developing world still account for a minor share. For instance, an estimated US$ 276 million was invested in off-grid solar companies (solar lanterns and home systems) during 2015, with a cumulative figure of US$ 511 million for the period 2010–2015 (REN21, 2016).

Even though global renewable energy investment dipped in the period 2012–2014, total installed capacity has continued to expand strongly (lower costs meant that even reduced investments kept pushing capacity up). Alongside these trends, the number of associated jobs has grown substantially. The first global assessment, published by the

[2] This employment figure does not include the workforce of Schneider Electric, a multinational company whose business goes far beyond energy access-related activities. Including its workforce of 170,000 people in the tally would obviously distort the overall figure beyond recognition.

United Nations Environment Programme (UNEP) and ILO in 2008, put direct and indirect employment (see definitions in box 2) at 2.3 million jobs.

Box 2. Definitions: direct, indirect and induced employment

Direct employment refers to employment that is generated directly, without taking into account the various inputs needed to manufacture a particular piece of renewable energy equipment or to construct and operate plants.

Indirect employment includes the jobs along the supply chain, in industries that supply required material inputs (such as glass for a solar panel or steel for a wind turbine) or financial and other services essential to the deployment and use of renewable energy.

Beyond direct and indirect employment there is the category of induced employment. When people who are employed directly or indirectly in the renewable energy sector spend their incomes on a variety of items in the broader economy (such as food, clothing, transportation, etc.), the expenditure gives rise to induced employment effects.

Direct employment data may be estimated on the basis of an enterprise survey, or data derived from representative projects and facilities for the sector in question, or may be derived from economic data such as labour input coefficients. Indirect and induced employment estimates require economic modelling such as input-output analysis or a social accounting matrix. For rural areas in developing countries, the required underlying data for such analysis may not be available, but can be generated for specific projects or areas.

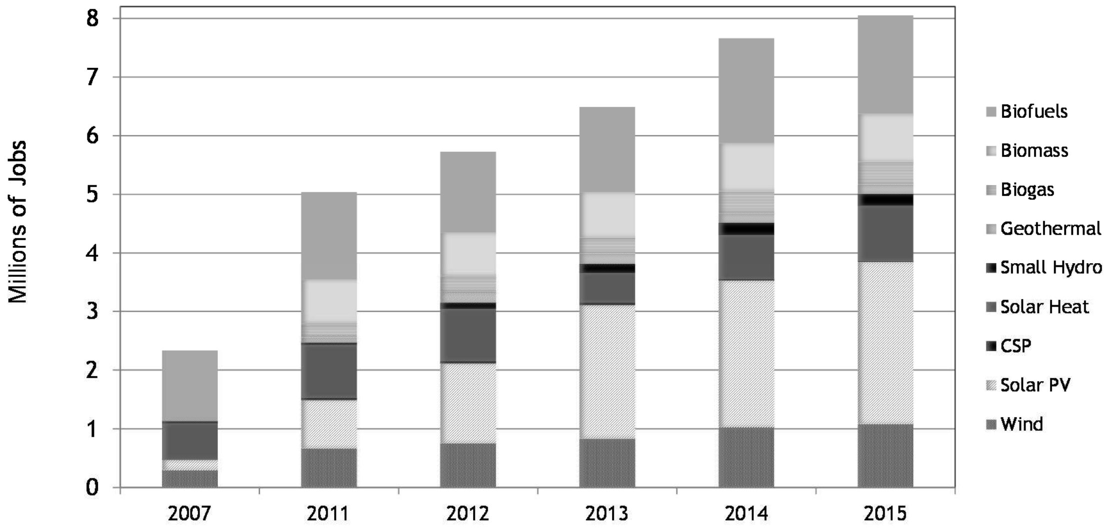
Source: UNEP, 2008.

According to surveys and estimates undertaken annually by IRENA since 2013, this figure has risen to 8.1 million in 2015 (figure 2). The estimates summarized in the figure reflect annual data collection efforts based on a wide range of sources, including government agencies, industry and NGO studies, academic reports, and interviews with experts. They represent successive efforts to broaden and refine data, although some data gaps remain.

Most renewable energy employment is found in China, Brazil, India, the United States and member countries of the European Union (EU) which, led by China, are the key equipment manufacturers (and account for the bulk of equipment exported to developing countries). They also account for the bulk of installed capacities. However, many other countries are now developing and expanding their domestic markets, with employment primarily being generated in installations and O&M.

Renewable energy industries directly employ a wide range of workers in a variety of trades and occupations with different skill sets, in project development and engineering, construction, equipment manufacturing, and diverse services in sales, installations and O&M. However, disaggregation along the value chain is frequently not available.

Figure 2. Estimates of global employment in renewable energy



Note: These estimates exclude large hydropower.

Sources: UNEP, 2008; ILO, 2012; IRENA, 2014; 2015b; 2016.

The scale of operations makes a difference in terms of how many and what kinds of jobs are required. For instance, building and operating a utility-scale PV or wind facility is more complex than rooftop solar assemblies or distributing and installing small SHS in rural areas. Similarly, large hydroelectric dams require engineers and specialists in numbers and at levels of qualification far beyond what is needed for a mini- or micro-hydroelectric facility. In the context of rural energy access, the more moderate levels of skill required mean that local workers can be trained to carry out needed activities rather than having to rely on foreign expatriates.

Unlike conventional fossil fuels, many renewable energy technologies do not require fuel inputs. In the bioenergy sector, however, this is an important aspect. Most of the jobs are in agriculture—growing and harvesting biofuels feedstock such as sugarcane or palm oil, and gathering agricultural wastes. Processing these materials into fuels requires comparatively few people (box 3).

Box 3. Employment in Malawi's sugarcane ethanol sector

In Malawi, processing of sugarcane ethanol is large-scale and mechanized, employing relatively few people. Two ethanol companies in the country employ 220 people directly, and indirect employment amounts to another 280 people. Most employment is found in the feedstock supply chain, molasses residues from the country's sugarcane crop. The sugarcane sector employs about 10,700 people directly, along with another 7,500 people in financing, transport and storage, and various supporting activities, and 3,850 people in distribution. However, most sugarcane employment is at large plantations (smallholders account for only about nine per cent of sugarcane production), which somewhat limits total employment. Furthermore, a United Nations Development Programme (UNDP) report argues that more jobs could be generated if ethanol were produced and distributed for use in household cook stoves.

Source: UNEP, 2012a.

One factor influencing employment concerns the scale of bioenergy operations, and the degree to which feedstock is grown by family farmers (outgrowers) or on large monoculture estates. This work is typically seasonal in nature, rather than representing full-time equivalent (FTE) employment. Mechanization is another factor, although the harvesting of some types of feedstock (such as palm oil) is far less susceptible to mechanization than others (such as corn or sugarcane).

In parts of Brazil, manual labour in sugarcane cutting is increasingly being replaced by greater reliance on machinery (this has reduced the number of direct jobs from close to 500,000 in 2007 to just above 300,000 in 2013) (MTE/RAIS, undated). The new mechanized processes provide fewer, but higher skilled and better paid jobs.

Making rural energy access a reality will most probably translate into a large number of jobs created in the decentralized, off-grid energy sector. The 2012 edition of the Poor People's Energy Outlook (Practical Action Consulting, 2012) refers to the International Energy Agency (IEA) estimates of the requirements for universal energy access by 2030. It is likely that of the 952 terawatt-hours (TWh) of electricity generation required annually, 400 TWh will come via mini-grids and 172 TWh from isolated systems. However, it is difficult to calculate just how much employment could be generated. Relevant data are typically at best available for selected individual programmes and projects rather than across entire countries or the developing world as a whole.

In 2012, IRENA (2012) undertook a rough calculation of potential employment if the rural energy deficit were addressed through renewables by 2030. Based on the Energy for All case from the IEA World Energy Outlook 2011 (2011a), the agency estimated that close to 148,000 megawatts (MW) of capacity would be required for off-grid electricity generation. IRENA then applied per-MW employment factors derived from an Indian government/industry study (MNRE and CII, 2010). IRENA thus estimated that some 3.7 million direct jobs in off-grid renewable electricity generation could be created by 2030 if the Energy Access for All scenario were fulfilled (table 3). This estimate is, however, quite conservative in that it does not include indirect employment along the value chain and also does not consider the employment potential in renewable fuels for heating/cooling and cooking.

Table 3. Potential employment creation through off-grid renewable electricity

RET[1]	**Energy use** (TWh)	**Load factor** (%)	**Capacity** (MW)	**Jobs factor** (Jobs per MW)	**Employment** (Thousands)
Solar	169.2	25	77 260	30	2 318
Small hydropower	37.6	70	6 132	4	31
Biomass	98.7	80	14 084	15	211
Wind	131.6	30	50 076	22	1 102
Total	**437.1**	**…**	**147 552**	**…**	**3 661**

[1] = Renewable energy technology.

… = data not available.

Source: IRENA, 2012.

Very little to no information is available concerning qualitative conditions such as formal and informal employment arrangements, wages, working hours, or skills development and training. This is due in part to the fact that, as the 2011 edition of REN21's Global Status Report (REN21, 2011) explained, such statistics "are not being collected systematically." In large part, the observation, made in a 2011 United Nations Research Institute for Social Development (UNRISD) paper (Bimesdoerfer, Kantz and Siegel, 2011), that "statistics on job creation and labor within this sector are not collected at all and little is understood about the labor market and conditions within the sector" still holds true today. The paper notes a lack of information concerning "a range of social indicators such as the total number of jobs created, the types of jobs, payments, gender, working hours, etc."

Focusing on the situation in sub-Saharan Africa, UNDP (2012a) similarly concluded: “A gap in knowledge and practice remains regarding the extent to which decentralized and renewable energy solutions can contribute to expansion of energy access at scale and in particular regarding their potential contribution to employment and development in sub-Saharan Africa.” A review of key publications on energy access undertaken for IRENA (2012) confirmed that many case studies and other reports contain generic references to opportunities for job creation, but lack detailed data or findings.

One difficulty in assessing employment in the energy access field is that it is characterized by fragmentation across a wide arc of projects and initiatives. Case studies typically offer employment or livelihood-related information, which is location-specific and of small- or micro-scale in nature. Their findings are thus not necessarily relevant in other local settings. Informal, and seasonal or part-time labour arrangements may be as common as formal employment.

1.4 Intent and structure of report

Ensuring access to energy for the hundreds of millions of people who do not have electricity or other modern forms of energy is a top priority for national policymakers and for the international community. But there are different ways to accomplish this goal. Access to electricity has traditionally been ensured through grid extension and reliance on fossil fuels or large-scale hydropower. But renewable energy has become an increasingly available, suitable, and affordable alternative, especially in areas where grid extension is slow or may never materialize. Another fundamental choice relates to the degree to which local communities and actors are actively involved and empowered to shape the projects that can improve their access to energy. It is distributed forms of renewable energy that have the most promise for rural areas which, so far, have not benefited from energy access. Strategies focusing on local areas offer the opportunity to improve access, and contribute to local employment opportunities, in contrast to centralized grid extension efforts, which typically rely on a workforce temporarily brought into a given area, with limited opportunities for people in local communities.

This paper marshals information from a broad range of sources in the literature and thus tries to contribute to a better understanding of the local employment opportunities that emerge from the deployment of renewable sources of energy in rural areas of the developing world. The intent is to enrich the debate about the best choices for ensuring access to energy, by adding employment considerations into the decision-making process. The paper also acknowledges the enormous, yet complicated role played by traditional biomass energy use. Fuelwood and charcoal account for the bulk of energy use especially by rural communities (in sub-Saharan African countries, they account for approximately 90 per cent). While reliable statistics are typically unavailable, indications are that the supply chain provides livelihoods—mostly informal jobs—for many millions of people. Fuelwood and charcoal are, in principle, renewable sources of energy, but tend to be used unsustainably. Rendering them more sustainable is a critical part of the rural energy challenge.

Chapter 2 of this report briefly reviews some of the main policies and financing mechanisms to promote the dispersion of renewable energy in rural areas of the developing world.

There are two types of renewable energy projects deployed in rural areas. The first, which is discussed in chapter 3, concerns large-scale wind farms, solar arrays, and other projects that are producing energy for grid feed-in or feedstock for large-scale biofuels production. Unless rural areas gain grid-connection, the energy generated through these projects is destined for markets other than the rural areas where they are situated, e.g. urban areas or even export markets. However, rural areas may still draw some economic benefits from such projects, in so far as that people from local communities find employment in project-related construction, infrastructure provision (such as road building) and maintenance activities, that the projects stimulate in the local economy (induced employment when project employees spend part of their wages locally).

The second type of renewable energy project is intended to serve the needs of rural communities themselves. The discussion in this report is split into two parts. The first part (chapter 4) focuses on fuelwood and charcoal. The second part (chapter 5) considers "modern" forms of renewable energy (solar PV applications, different forms of bioenergy and small hydropower). These projects comprise both mini-grids and single-household standalone systems.

Chapter 6 considers downstream linkages—economic development opportunities—that arise due to new or improved energy access through renewables. The chapter follows the distinction made in the literature between residential and productive uses of energy. The latter, briefly considers the potential inherent in agriculture (enhanced agro-processing, improved food storage and refrigeration), communications, education and skill building, and improved health.

2. Introduction and context

2.1 The policy landscape

The promotion of rural energy access involves a broad range of actors (and combination of actors), including national governments, regional developments banks, international agencies and donors, the private sector (which in itself involves a range of actors at different scales of operation), small-scale local entrepreneurs, as well as NGOs. All have different roles, capacities and responsibilities. Policies address technical aspects of renewable energy development, financing, capacity building, and training. These factors all impact on employment generation.

Governments have an important role to play in creating the right kind of conditions and in providing financing, but most observers agree that they will also need to facilitate the involvement of other actors, to increase the availability of capital and technology. This requires appropriate institutional and regulatory frameworks, incentives and enabling policies, and suitable financing and business models (IRENA, 2013).

Programmes, targets and agencies. A number of national governments have created programmes and targets for energy access. REN21's *Global Status Report* (REN21, 2015) observes that Brazil, China, India and South Africa are among the countries that have taken the lead in rural electrification efforts, including off-grid renewable energy programmes. Numerous countries have also adopted electrification targets. Nations as diverse as Barbados, China, Ghana, South Africa, South Sudan and Sri Lanka are aiming for 100 per cent electrification. Others, such as the Philippines with its Expanded Rural Electrification Program, aiming to achieve 90 per cent household electrification by 2017, are almost as ambitious.

In addition to rural electrification programmes, governments are also setting up dedicated government bodies—either semi-autonomous agencies or specialized divisions within existing line ministries. A recent example mentioned by REN21 (2015) is Bangladesh's Sustainable and Renewable Energy Development Authority (SREDA), which was set up in 2014. The same year, Chile launched an Energy Access Fund for small-scale rural renewable energy projects. Chad has also recently created an agency for the purpose of promoting energy access through distributed renewable energy.

Regulations, incentives and subsidies. In addition to governmental bodies and programmes, regulations and financial incentives also play an important role. IRENA points to the need to develop a sustainable market for off-grid applications by breaking down existing barriers and putting in place enabling conditions, including tariffs, tenders, and other modalities for mini-grid projects. In doing so, "regulators should consider the local socio-economic conditions as well as the commercial feasibility for private sector mini-grid developers" (IRENA, 2013).

IRENA further points to a broad range of tax measures (such as exemptions from import duty or value added tax) and other financial support measures (including soft loans, grants, publicly backed guarantees). Eliminating market distortions such as subsidies for fossil fuels (in the rural energy context, for kerosene in particular) is another complementary and important aspect.

According to REN21 (2015), fiscal incentives have been used successfully by many countries in their off-grid renewable electricity programmes in an effort to address the barrier of high upfront costs. Apart from reducing or phasing out subsidies for fossil fuels, a common practice is to provide subsidies for renewable energy solutions in remote communities.

The same report offers an overview of government regulatory and financial policies. Although this overview does not provide a breakdown of policies targeted specifically at achieving energy access, it gives a sense of which types of policies are most used around the world. Many of the regulatory policies it surveys (feed-in tariffs, quota obligations, net metering, etc.) focus on grid-connected projects. For others (such as tendering or biofuels obligations), no distinction is available between grid/off-grid or urban/rural purposes. But it is clear that virtually all of the 146 countries for which information is available have adopted renewable energy targets. Among financial policies, there is again no breakdown of energy access policies, but what emerges is that reductions of various taxes is one of the major tools that governments rely on (lowering the cost of importing renewable energy equipment). This is especially the case among lower income and low-middle income countries (table 4).

Table 4. Regulatory and financial policies in support of renewable energy, as of 2015*

Countries by income group (number)	Capital subsidies, grants, rebates	Investment or production tax credits	Tax reductions (energy, CO_2, VAT, etc.)	Public investment, loans or grants
High income (49)	31	20	32	33
Upper middle income (44)	11	10	26	23
Low-middle income (36)	14	11	26	17
Lower income (17)	3	3	16	10

* Includes national and subnational government policies.

Source: Adapted from REN21, 2016.

Bilateral and multilateral actors. Beyond national government action, many international donor agencies, multilateral developments banks and NGOs have become involved in the promotion of decentralized renewable energy in developing countries. The Renewable Energy Network for the 21st Century (REN21) lists at least 30 individual programmes and 23 global networks active worldwide as of 2015 (2016). Among the most prominent are SE4ALL, ARE, the Renewable Energy and Energy Efficiency Partnership (REEEP), the EU Energy Initiative Partnership Dialogue Facility (EUEI PDF), which is responsible for the implementation of the Africa-EU Renewable Energy Cooperation Programme (RECP), Power Africa (a United States initiative), and Energizing Development (EnDev), a joint undertaking by Australia, Germany, the Netherlands, Norway, Switzerland, and the United Kingdom. EnDev reports that, so far, it has helped 14.8 million people gain access to modern energy services to date, and it has provided training for some 37,000 individuals in solar PV technology, cookstove manufacturing, and other skills and crafts related to renewable energy deployment (REN21, 2016).

There are also technology-specific initiatives, such as the Global Lighting and Energy Access Partnership (Global LEAP), which has benefited an estimated 7 million people in 29 countries), Lighting Africa, Lighting Asia, and the Global Clean Cookstove Alliance (REN21, 2015). Meanwhile, a 2016 report (EUEI PDF, 2016) counts 42 different “operative programs and delivery mechanisms” as well as nine “high-level initiatives” just in the African context. It maps these efforts, including both renewables and other forms of energy, grid and off-grid projects, as well as mini-grids, covering electricity, heating and cooling, cooking energy, and energy efficiency.

The problem is certainly not a shortage of initiatives. Rather, there may be too many of them. Amid the proliferation of initiatives and programmes, it is difficult to analyse the overall impact, and especially specific outcomes such as employment creation.

2.2 Local content and skill building

National governments will want to undertake policy measures that provide energy access as quickly as possible to as many people as possible. But they will also want to ensure that the capacities and structures that arise are stable and sustainable over time, which means that a significant part of the effort needs to be well-grounded domestically, rather than being overly dependent on foreign actors.

For example, providing rural households and communities with renewable energy equipment such as solar panels, hydropower turbines, or biogas digesters in a timely fashion, and ensuring affordability, may make it imperative that import duties for such goods are low or non-existent. Because of their technological leadership and economies of scale, leading international manufacturers typically can offer equipment at more reasonable prices than domestic producers. Their experience in the field may also give them advantages in terms of equipment quality and reliability. Employment in the importing country would thus principally occur in sales, installations, and O&M, rather than in manufacturing. Over time, however, such policies tend to inhibit the creation of an integrated domestic renewable energy supply chain.

Scale makes a difference in the above observations. The technologically less-complex renewable energy equipment relevant in the energy access context can be more readily produced (or at least assembled) domestically than is the case with large-scale facilities, where additional experience is needed with industrial site preparation, engineering, procurement, project integration, etc. Equipment such as family- or community-scale biogas digesters can also be more readily built domestically. The same is true for small-scale hydropower facilities. Still, even the experience with portable solar technologies suggests how dependent most developing countries are on supplies from leading suppliers (in this case, principally Chinese companies).

A number of governments in various parts of the world have instituted so-called domestic content requirements (DCR), sometimes also called local content requirements, in a bid to establish a domestic renewable energy industry and to create and secure related employment (Kuntze and Morenhout, 2013). In various ways, these rules compel renewable energy companies to source a specified share of equipment, or a portion of overall project costs, from domestic suppliers. DCR policies are often concerned with manufacturing aspects, but they are also applicable to the planning and design of projects, engineering, construction and installation, and O&M. In the energy access context, DCR policies need to be adapted to target small-scale suppliers and rural entrepreneurs.

Experience suggests that without a stable and sufficiently sizeable domestic market that offers adequate economies of scale, DCR measures are unlikely to succeed. They need to be part of comprehensive policies including training and skill-building policies (IRENA, 2014). This is evident in a country such as South Africa, which intends to expand its renewable energy sector, but faces skill shortages. A 2012 study put the number of engineers, technicians and skilled workers needed in the wind industry (manufacturing, construction and installation) at 6,250 per year, and estimated the number of skilled workers needed for O&M at 2,000 by 2020, and 4,500 by 2030 (GL Garrad Hassan, 2012). A new South African Renewable Energy Technology Centre (SARETEC) has been set up to help fill this need.

2.3 Investments and financing arrangements

The *World Energy Outlook* (IEA, 2012) estimated total "energy for all" investment needs at US$ 678 billion by 2030, or about US$ 30 billion a year, which is more than triple the funds that were available in 2009. This would give access to close to 50 million people a year. The IEA projects that some US$ 11 billion will need to be spent annually for grid-extension, US$ 12.2 billion for mini-grids and US$ 7.4 billion for standalone projects. Of the cumulative sum, it is anticipated that US$ 602 billion would be needed for electricity access. The remaining US$ 76 billion would be earmarked for clean cooking energy.

Other estimates vary in the projected investment sums needed. For instance, a report by the Finance Committee of the Sustainable Energy for All Advisory Board projects that the level of expenditures needs to grow to as much as US$ 45 billion annually. It puts 2012 spending on universal access to electricity at just US$ 9 billion (SE4All, 2015a and 2015b).[3] This is still a minor portion—about 3.5 per cent—of the US$ 257.3 billion in global renewable energy investments for all purposes that have been estimated for that year by the Frankfurt School-UNEP Centre (2016). Due at least in part to market fragmentation, it appears there is no reliable, comprehensive information on global energy access investment trends over the years, and no detailed breakdown by geographical area or by technology.[4]

Even though it is growing fast, the global off-grid solar market remains comparatively small; it was estimated at just US$ 200 million in 2013, and may have grown to US$ 900 million in 2015 (A.T. Kearney, 2014). Sales of pico-solar lights (Lighting Global quality-verified products only) have grown from 0.6 million units in 2011 to 5.3 million in 2014 (including all brands, the numbers are 2.4 million and 15 million, respectively) (Orlandi, 2015). Still, it is believed that only about 3 per cent of the potential solar lighting market (for SHS and portable solar combined) in Asia and sub-Saharan Africa has been tapped to date (GOGLA, 2014).

REN21 (2015) and the *World Energy Outlook* (IEA, 2011a) identify a range of funding sources:

National governments. Subsidies, grants and loans are made available by national development banks, state-owned utilities, and rural electrification agencies or other specialized institutions in developing countries. Donor countries typically make funding available as loans, grants, guarantees, and equity. But, as the British example illustrates, such funding can be further improved in favour of renewable energy access (box 4).

Another, programme-specific example is CARE2 (Capital Access for Renewable Energy Enterprises) which ran from late 2012 to 2015 and was supported by the Swedish International Development Cooperation Agency (SIDA) with US$7 million. Targeting 1,400 micro-, small- and medium-sized enterprises, it was intended to improve access to capital in the renewable energy sectors of Kenya, Rwanda, Uganda and the United Republic of Tanzania, with the aim of creating 3,600 new jobs (GVEP International, undated-a).

In 2015, the EU launched a new "ElectriFI" financing mechanism for rural electrification projects to complement private financing. This grant programme will make available up to 3.5 billion Euro (€) through to 2020 and is expected to leverage €15–30

[3] Depending on the source, estimates of needed investments actually vary widely.

[4] The 2016 edition of REN21's *Renewables 2016: Global status report* collates information on distributed renewable energy for energy access in developing countries (Personal communication with REN21 personnel and with Fabiani Appavou, author of the relevant chapter in the report).

billion in loans and equity investment. It is likely that the eligible projects will be small-to-medium sized projects (European Commission, 2015).

Box 4. United Kingdom government support for energy access in developing countries

A recent analysis by the Overseas Development Institute (ODI) found that the United Kingdom's government support for energy in developing countries during 2009–13 amounted to a total of US$ 8.23 billion. Of that sum, just 19 per cent went to renewable energy and energy efficiency. Just 8.5 per cent or about US$ 700 million, went in support of energy access.

Yet, the energy access figure needs to be further broken down: close to US$ 47 million (seven per cent) was spent on fossil fuel projects; US$ 38 million (five per cent) on efficiency; and US$ 246 million (35 per cent) on renewables. Another US$ 369 million (53 per cent) is identified only as mixed or unspecified. Counting only the share unambiguously identified as energy access through renewables yields a share of three per cent of total support for all energy projects in the developing world.

The sum of US$ 246 million is composed of: 29 per cent for geothermal projects; 19 per cent each for solar and hydropower; seven per cent for wind; two per cent for bioenergy; and 24 per cent for mixed or unspecified purposes. Disaggregated by stage of energy delivery: 48 per cent went to transmission and distribution; 17 per cent to generation; one per cent to point of use; close to eight per cent was devoted to research and policy; and about 26 per cent was "unclear or mixed".

Source: CAFOD, undated..

International institutions and mechanisms. In addition to the World Bank, regional development banks have a number of relevant programmes and initiatives, including the Asian Development Bank (Energy for All initiative); the Inter-American Development Bank (Multilateral Investment Fund); the African Development Bank (Sustainable Energy Fund for Africa); and the Islamic Development Bank (Renewable Energy for Poverty Reduction Program).

However, NGO "scorecard" reports (Sierra Club and Oil Change International, 2014 and 2016) argue that an inadequate share of multilateral developments banks' overall energy portfolios is dedicated to energy access and, within the energy access lending, an inadequate share goes to distributed renewable energy solutions (as opposed to conventional energy sources). During a 3-year period, fiscal year (FY) 2012–2014, the energy access lending of four multilateral development banks (MDBs) amounted to a combined US$ 1.9 billion, or just under 15 per cent of their total energy portfolio. Distributed energy funding received US$ 244 million of the total energy access sum, equivalent to only 12 per cent (table 5).

Table 5. Multilateral bank support for energy access, FY 2012–2014

International institutions/ mechanisms	A: Total energy funding (US$ millions)	B: Total energy access funding (US$ millions)	C: B as a share of A (%)	D: Distributed energy funding[1] (US$ millions)	E: D as a share of B (%)
World Bank Group	8 252.5	841.8	10.2	167.4	19.9
Inter-American Dev. Bank	1 124.5	63.0	5.6	15.7	25.0
African Dev. Bank	1 127.4	293.1	26.0	0.5	0.2
Asian Dev. Bank	2 952.4	794.2	26.9	59.9	7.5
All MDBs[2]	**13 456.8**	**1 992.0**	**14.8**	**243.6**	**12.2**

[1] Off-grid and mini-grid projects. [2] Multinational development banks.

Source: Adapted from Sierra Club and Oil Change International, 2016.

Similarly, an assessment published by the International Institute for Environment and Development (IIED) and Hivos (Rai, Best and Soanes, 2016) found that of the US$ 14.1 billion in approved climate finance between 2003 and 2015, US$5.6 billion had been earmarked for energy projects. Of those, just US$ 475 million had been allocated for decentralized energy. Multilateral funds for energy access, and especially for distributed renewable energy, need to be scaled up, if stated objectives are to be met.

The Green Climate Fund, a fund within the framework of the United Nations Framework Convention on Climate Change (UNFCCC), was set up to assist developing countries with projects and programmes related to climate adaptation and mitigation, and to harmonize diverse funding flows from sources including the World Bank, the Global Environment Facility, the Adaptation Fund, the Clean Development Mechanism (CDM), and other sources. Distributed rural energy is one of the core focus areas of the Fund. However, low-income countries have so far made little use of carbon finance mechanisms such as the CDM for energy access purposes. Part of the reason is that CDM project approval is often a long, uncertain and expensive process. Meanwhile, the United Nations Climate Change Conference (COP21) held in Paris in December 2015, led to an array of new financing initiatives, including the African Renewable Energy Initiative, which aims to install 10 gigawatt (GW) of renewable energy capacity by 2020 and 300 GW by 2030 (REN21, 2016).

Private sector sources. This includes international commercial banks, local banks, microfinance institutions, venture capitalists, as well as international and domestic project developers and contractors. These actors rely on a range of financing mechanisms including equity, debt and mezzanine finance.[5] Microfinance can be useful in a number of energy access situations. Incubator funding is another pathway. For example, the REEEP offers seed-level grants for small- and medium-sized enterprises working on distributed renewable energy programmes. In a new development, Bloomberg Business (Hirtenstein, 2016a) reports that the nascent off-grid solar industry active in sub-Saharan Africa has

[5] The IEA characterizes mezzanine financing as "debt capital that gives the lender the right to convert to an ownership or equity interest in the company under certain pre‐agreed conditions."

now been "turned into an asset class for the first time, bundling contracts for thousands of the sun-powered rooftop electricity systems to sell as bonds."

Investments in off-grid solar are growing particularly rapidly, albeit from a small base. According to BNEF and Lighting Global (2016), between 2008 and 2015, some US$ 511 million in private investment has materialized, more than half of which since the beginning of 2014. Most of the money has gone to companies following a Pay-as-you-go (PAYG) business model (see below for a brief explanation of the concept).

In order to scale up available funding, the *World Energy Outlook* report (IEA, undated-b) has called for the public sector "to use its tools to leverage greater private sector investment where the commercial case is marginal and encourage the development of replicable business models." This means better governance and regulatory frameworks, as well as measures to enhance capacity in rural areas.

Further, "government and concessional funds could also be used directly to support microfinancing networks or local banks that, in turn, provide loans down the chain to end-users, as has happened, for example, in UNEP's India Solar Loan Programme … and in several African countries under the Rural Energy Foundation …" (IEA, 2011a). For the poorest communities, subsidies are needed, though the question persists whether subsidized projects can become financially self-sustaining.

Although the cost of renewables has declined in recent years, many poor rural households are not often able to afford the up-front costs. Also, most people in these areas do not have access to commercial financing (or, to put it differently, commercial lenders do not see an opportunity for what they regard as an adequate return on loans) (Meier, 2014). As the Energy Access Practitioner Network (2015) emphasizes, "access to financing–in the right amounts, structured in a way that is most useful to them, and available at the time needed – remains their number one obstacle to further growth."

At the same time, however, rural households spend considerable sums on conventional energy supplies and services such as kerosene-fueled lamps, candles, and battery-operated flashlights. In comparison with kerosene lamps, for example, solar lamps offer lower cost and better lighting quality. According to estimates by A.T. Kearney (2014), people who currently lack access to electricity spend an estimated US$ 30 billion a year buying 25 billion litres of kerosene for lighting purposes, which puts the cost to supply equivalent light through solar equipment at just US$ 2.7 billion. The transition to renewables could thus, in principle, free up US$ 27 billion in spending (GOGLA, 2014). A report for the 4th International Off-Grid Lighting Conference (Orlandi, 2015) suggests lower spending figures for kerosene: US$ 11.5 billion in Africa and US$ 4.7 billion in Asia.

Rural households' ability to pay is a key distinguishing factor for determining what type of financing (loans, grants, etc.) and sources of financing (domestic government, multilateral or bilateral development funding, or the private sector) might be most appropriate. In an analysis published in 2011, IEA (2011a) used an expenditure threshold of US$ 5.50 per month to distinguish "lower" from "higher energy expenditure households." The latter are considered more likely customers for private entities, whereas the former will require government subsidies. Pointing to experiences in Bangladesh and Nepal, mini-grid projects for low-energy expenditure households may best be accomplished via government-initiated cooperatives or public-private partnerships.

A number of financing models—some old, some new—are intended to address rural households' circumstances and to allow them to purchase or lease renewable energy systems, particularly solar equipment. The falling cost of LED lights and the rising cost of kerosene have helped to popularize these new approaches.

Microfinance. Microfinance schemes are, of course, not new, nor are they uniquely addressed to energy access issues. But according to REN21 (2015), they have been among the most popular models for disseminating energy systems in the developing world over the past decade or so. Microloans allow households or small businesses to sidestep the problem of high upfront costs in purchasing renewable energy equipment since they pay in instalments over time.

As we will discuss later, Bangladesh's successful approach to distributing SHS in rural areas has centrally relied on microfinance institutions. They have a long history in rural communities and have developed an approach that integrated financial and technical services for rural households (Sadeque et al., 2014). There is no comparable history in sub-Saharan African countries, where microfinance institutions typically provide financing separately from renewable energy providers, often with insufficient coordination. This approach led to problems with regard to the responsibility for issues of systems' maintenance and repair. In recent years, however, two new concepts have emerged: "pay-as-you-go" and "fee-for-service".

PAYG. Customers pay a small initial fee, followed by regular micro-payments over time for the energy they actually use. Price levels and payment schedules are typically set to match households' cash flows and their energy consumption patterns. REN21 (2016) counts at least 32 commercial companies operating in nearly 30 countries under the PAYG model. Equally important, this model is made possible by the spread of mobile phones. A number of mobile payment schemes have emerged, including M-Pesa in East Africa, as well as others based in Afghanistan, India and South Africa (Lacey, 2014).

Fee-for-service (FFS). This model is similar in approach (REN21, 2015). Customers pay regular fees for the use of a renewable energy system that is owned, operated and maintained by an energy service company. The company retains ownership of the equipment, and is responsible for service and maintenance (and replacement, if needed).

Both approaches have pros and cons. Under a FFS model, a potential problem is that users may not feel responsible for the careful handling of the equipment ("lack of ownership"). But the "ownership" model underlying the PAYG approach can be problematic if there is not a strong and reliable provision for after-sales service to ensure that the equipment functions reliably (Sadeque et al., 2014). Chapter 5 discusses some examples of both concepts.

3. Impacts of large-scale renewable energy projects

As mentioned earlier, there are two types of renewable energy projects deployed in rural areas, the first concerns large-scale facilities oriented towards urban markets, and the other, smaller scale operations focusing on rural communities' needs. This section addresses the impacts on the former. It begins by briefly discussing employment factors and the impact of scale on employment generation, and then discusses a number of specific wind, solar and biofuels projects.

The project profiles presented in this chapter indicate that the employment and livelihoods impacts are frequently mixed presenting local communities with both opportunities and risks. A key difference is whether the aim is mostly to produce for the urban or global market, or whether there is a strong commitment to community development. For the latter to succeed, there is a need to build skills, generate infrastructure that benefits not only the project in question but also the surrounding areas, and to plan carefully for the broader economic impacts that come with an influx of labour and capital into rural communities (some of which may have had limited or no exposure to formalized labour markets).

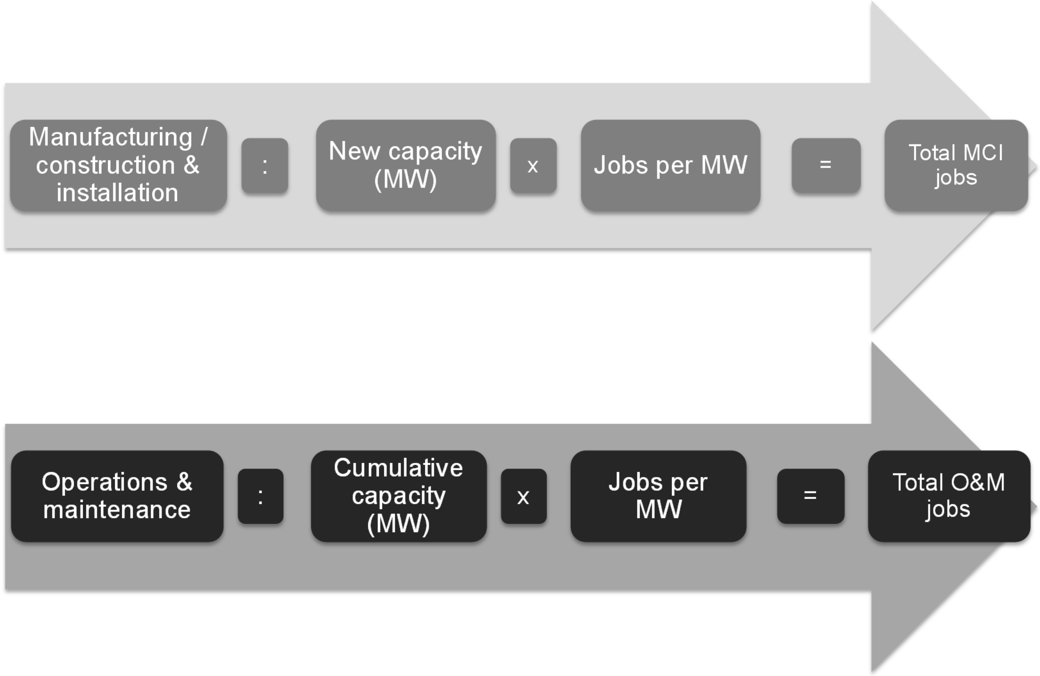
3.1 Employment factors

The employment impacts of renewable energy projects can be assessed via a number of methods, including input-output (I-O) modelling, the use of employment factors, and supply chain analysis. Enterprise surveys can generate valuable data, including detailed labour requirements for specific manufactured inputs that are useful in supporting various methodologies (Breitschopf, Nathani and Resch, 2011).

The analysis of I-O, for example, permits a full examination of indirect and induced employment effects. But it requires I-O tables with highly disaggregated information (Bacon and Kojima, 2011). Maia et al. (2011) point out that the relevant existing studies and models for the renewables sector are primarily based on the economic circumstances prevalent in developed nations of the Organisation for Economic Co-operation and Development (OECD). Highly disaggregated sectoral, and up-to-date data are often not available in developing countries. Furthermore, I-O analysis typically focuses on economy-wide or sectoral assessments, rather than on specific individual projects.

Another approach is to rely on employment factors, estimating the number of direct jobs that may be created per unit of electrical or heating capacity or per unit of fuel (separated into manufacturing, construction, and O&M) (figure 3). The underlying data for calculating employment factors can be derived from broad industry surveys, from specific enterprises or projects, or from feasibility studies and technical literature specifications (Breitschopf, Nathani and Resch, 2011).

Figure 3. Schematic view of employment factor calculations



MCI = MCI group.

Source: IRENA, 2012.

A number of different reports offer estimates of employment factors in the renewable energy field, although they sometimes yield incongruous results, focus on different renewable technologies or time frames, and do not always reveal the underlying methodologies applied. The 2015 edition of the Energy [R]evolution report (Greenpeace International, Global Wind Energy Council and SolarPowerEurope, 2015) offers estimates of direct jobs per MW of installed capacity, based on detailed work by the Institute for Sustainable Futures at the University of Technology Sydney. It also offers estimates for both the present as well as future years (2020, 2030) that are based on projections of labour productivity gains (table 6).

Table 6. Employment factors for renewable energy, global averages

Renewable energy technology	Construction and installation (Jobs years/MW)	Manufacturing	O&M
Biomass	14.0	2.9	1.5
Hydropower – large	7.4	3.5	0.2
Hydropower – small	15.8	10.9	4.9
Wind onshore	3.2	4.7	0.3
Wind offshore	8.0	15.6	0.2
Solar PV	13.0	6.7	0.7
Solar heat	8.4	0[1]	n.a.

[1] Included in construction and installation estimate.

n.a. = data not available.

Source: Adapted from Greenpeace International, Global Wind Energy Council and SolarPowerEurope, 2015.

The basic estimates are derived from conditions in OECD countries, since this is where most of the data are available. The *Energy [R]evolution* report uses "regional job multipliers" intended to adjust OECD labour productivities to regional conditions elsewhere. These adjustment factors are based on average, economy-wide labour productivity (excluding agriculture) in different regions. For Africa the multiplier, relative to the OECD value, is 5.7, for Latin America 3.4, for the Middle East 1.4, and for non-OECD countries in Asia 2.4 (but 6.9 for India and 2.6 for China). In short, deploying a given capacity of renewable energy in developing countries provides employment for considerably more people than it does in OECD countries.

At best, these multipliers serve as an approximation, however, because productivity within the energy sector varies from that of the broader economy, and productivity among individual RETs probably varies from that of the energy sector as a whole. Excluding the agriculture sector makes sense because its lower productivity would distort calculations for manufacturing-centred RETs, such as wind and solar. On the other hand, excluding agriculture leads to an underestimation of bioenergy fuel-related employment. The resulting figures thus need to be regarded with caution, and the *Energy [R]evolution* report itself states that its estimates are only indicative in nature.

3.1.1 Matters of scale: the Indian experience

To be more reliable, country-specific employment factors are needed. The Indian government published a report (MNRE and CII, 2010) that offers estimates per MW of capacity installed (90 direct and indirect jobs/MW for off-grid solar PV; 43 jobs for on-grid biomass power; 300 jobs for biomass gasifiers; five jobs for small hydropower). However, no updates have been undertaken since.

More recently, the Delhi-based Clean Energy Access Network (2015), which aims to bring together stakeholders across the country to improve energy access, issued a report assessing employment and skills development. Based on interviews, project field visits, and a literature review, the study generated rough estimates for the number of people needed for various types of renewable energy deployment. This is based not on capacity figures, but on the volume of equipment installed (millions of units, except for mini-grids and small hydropower facilities, which are measured in thousands of units). This approach is thus not comparable with that of the Indian government (and it unfortunately also renders cross-technology comparisons difficult). Job requirements are indicated by major type of occupation, and broken down by where the jobs will be generated. Most employment (sales and installations) takes place in rural areas, but others—higher skilled and paid—in managerial and support functions are more likely be located in semi-urban and urban areas (table 7).

Table 7. Job requirements for renewable energy deployment in rural India

Renewable energy sources	Rural areas: Jobs (Employment per million units installed)	Rural areas: Occupations	Semi-urban and urban areas: Jobs	Semi-urban and urban areas: Occupations
Solar lanterns; improved cookstoves; portable biogas	5 000	Sales; service	500 100	Sales; marketing Managers, engineers
Solar home systems	10 000 2 500	Sales; service Service technicians	1 000 500	Sales; marketing Managers, engineers
Small biogas facilities	10 000 1 000	Installers Site supervisors	3 000	Managers, engineers
(Employment per thousand units installed)				
Solar and biomass mini-grids; small hydropower facilities	1 000 1 500 500	Electrical and civil works Operations; maintenance Technicians	200 200 50	Projeckt engineers Managers Design engineers

Source: Adapted from Clean Energy Access Network, 2015.

The extent and nature of employment that can be created by renewable energy projects depends strongly on the scale of deployment. Large-scale projects may, in absolute terms, employ substantial numbers of people. But on a per-unit (of capacity or production) basis, arguably they generate less employment than smaller scale projects.

For solar PV, a joint study by Bridge to India and Tata Solar Power (2014) suggests that small residential rooftop systems (1–5 kW typical size) deployed in India could generate 39.3 jobs per MW installed. This compares favourably with the number for commercial and industrial rooftop assemblies, and with utility-scale projects and “ultra mega-scale” projects. At assumed levels of capacity installed, a far larger number of jobs overall would be created in small-scale projects (see table 8 for details). The smaller-scale deployment could also, in principle, be completed much faster and at a lower cost, although it would face the challenge of creating sufficient consumer market demand. It should be noted that the analysis focuses on urban rooftop deployment in 38 cities with at least 1.25 million inhabitants. Expanding this to smaller cities—and to rural areas—would increase these numbers tremendously, although securing adequate financing and skill-building programmes in rural areas would present significant challenges.

Table 8. Employment estimates for solar PV energy at different scales, India

Solar PV deployment	Residential rooftop	Commercial rooftop	Utility scale	Ultra-mega scale
Typical plant size	1–5 kW	10–500 kW	5–50 MW	1–3 GW
Projected total capacity	26–35 GW	31–41 GW	32–42 GW	21–27 GW
Jobs per 1 MW, of which:	**39.3**	**26.5**	**9.4**	**5.7**
Supply chain	3.3	2.5	0.8	0.6
Installations (contractual)	6.7	4.0	2.0	1.0
Installations (permanent)	6.7	4.0	1.0	0.6
Design	n.a.	2.0	0.1	0.1
Manufacturing	6.0	5.0	3.8	3.0
Business/project development	13.3	6.0	0.3	0.1
O&M	3.3	3.0	1.5	0.3
Jobs over 10 years (1000s)	**325**	**220**	**71**	**63**

n.a. = data not applicable.

Source: Bridge to India and Tata Solar Power, 2014.

In table 8, capacities given for any electricity-generating equipment indicate the maximum possible amount of power. For example, a 1 MW facility running at maximum power for a full year produces 8,760 MWh: 1 MW x 8,760 [= 365 days x 24 hours]. However, capacity factors determine how much power can actually be generated under real-life conditions. Solar PV capacity factors typically vary between 15 per cent and 40 per cent. The U.S. Energy Information Administration reports that solar PV facilities in the United States ran at 25.9 per cent capacity during 2014 (EIA, 2014). Using this factor, a 1 MW plant would produce 2,190 MWh of electricity. How many homes this amount can power depends on households' average energy usage, which varies enormously around the world (and between urban and rural settings). Using 2010 consumption data, the output from a 1 MW plant would suffice for just 187 homes in the United States, but for much larger numbers in developing countries like India or Nigeria, as table 9 illustrates.

Table 9. Electricity capacity and output calculations, 2014 – India, Nigeria and the United States

Annual electricity capacity/output			India		Nigeria		United States	
Capacity (MW)	Nominal output (MWh)	Actual output (MWh)	Household used (MWh)	Household served (No.)	Household used (MWh)	Household served (No.)	Household used (MWh)	Household served (No.)
0.01	88	22	0.9	24	0.57	38	11.7	2
0.10	876	219	0.9	243	0.57	384	11.7	19
1	8 760	2 190	0.9	2 433	0.57	3 842	11.7	187
5	43 800	10 950	0.9	12 167	0.57	19 211	11.7	936
20	175 200	43 800	0.9	48 667	0.57	76 842	11.7	3 744
50	438 000	109 500	0.9	121 667	0.57	192 105	11.7	9 359
1 000	8 760 000	2 190 000	0.9	2 433 333	0.57	3 842 105	11.7	187 179

Source: EIA, 2014.

As this brief discussion indicates, employment factors can provide some broad insights into employment generation by renewable energy projects. But it is useful to examine individual projects to gain a more detailed sense of the specific impacts, as presented in the next section.

3.2 Selected examples in wind, solar and biofuels

This section examines a number of selected large-scale projects in the wind, solar, and biofuels sectors, and highlights key employment and other socio-economic impacts. The examples demonstrate that large-scale corporate-led projects tend to have very different outcomes to projects that incorporate a strong community-development dimension.

3.2.1 Lake Turkana Wind Power Project, Kenya

In Kenya, a number of wind farm projects are in the planning or construction stage, including the Lake Turkana wind farm in the northeastern part of the country, the Kipeto Project in the Rift Valley Province, the Electrawinds project in Lamu, and the Kinangop project in central Kenya (Jacobs, 2014).

By far the largest of these is the Lake Turkana Wind Power Project (LTWP). It entails a total of 365 wind turbines (supplied by Denmark's Vestas) across 40,000 acres with a generating capacity of 300 MW, making it one of the largest wind farm projects to be built in Africa. The construction of the facility was delayed by difficulties in securing financing, but it is expected to be fully operational by April 2017 (Jacobs, 2014). Some 70 billion Kenyan Shillings (€625 million) are expected to be invested, the largest single private investment in Kenya's history (Lake Turkana Wind Power Project, 2015). Electricity generated in one of the poorest parts of the country will be destined for the distant capital of Nairobi.

According to impact assessments completed in 2009 and 2011, construction employment will average 300 workers over the entire construction phase, reaching as high as 600 workers during peak periods. Once operational, the wind farm is expected to provide about 150 permanent jobs (Lake Turkana Wind Power Project, 2009 and 2011). Arguably, these are relatively low employment figures given the scale of the investment, which is explained in part by the fact that employment in manufacturing the towers, turbines, and other equipment will be created outside of Kenya.

Skilled jobs will overwhelmingly go to workers from outside the project area, and the impact assessment expresses concern about possible negative socio-economic impacts from the influx of workers. Local employment will principally be for semi-skilled or unskilled jobs, and it is expected that more than 400 people will be employed locally as drivers, masons, loaders, carpenters, cooks, security personnel, etc. (Lake Turkana Wind Project, 2009 and 2011).

The project entails work to upgrade an existing 204-kilometre (KM) road to the wind farm site, as well as an access road network in and near the site for construction, and for O&M purposes. Road construction will create about 300 jobs at any one time over a 15-month period. Of these, it is estimated that there will be just 50 jobs available for people from the area (AfDB, 2011).

An additional local economic stimulus from the project and road construction is expected as workers spend their salaries in nearby towns and trading centres along the road. Local populations may also benefit from improved roads, facilitating the transportation of livestock and fish products to markets. The impact assessment also notes that a portion of the carbon credits that will be generated by the wind farm will be used to fund unspecified local community benefits.

The employment impact of projects such as the LTWP is in some ways a two-edged sword. While local populations can gain to some extent, a significant part of the workforce is brought in from elsewhere, with some potentially negative repercussions. In order for the local population to derive greater benefits from these projects, they need training and skills development, which is a long-term process.

In early 2016, protests by local landowners and farmers led to the cancellation of the US$ 144 million, 60.8 MW Kinangop project in central Kenya. Disputes over compensation for land and other concerns could not be resolved (Reuters, 2016). There have also been land and compensation disputes with pastoralists surrounding the LTWP, although a Kenyan court rejected calls for a halt to construction (Williams, 2015; Waruru, 2016). The official Resettlement Policy Framework document for the Lake Turkana wind farm acknowledged that the project would entail a number of negative impacts, including loss of land and related assets such as trees and crops, loss of income, and loss of livelihood (World Bank, 2011). The document suggested a number of mitigation measures to "avoid or at least minimize involuntary resettlement," provide compensation, ensure that resettlement goes hand in hand with "appropriate disclosure of information, consultation, and the informed participation of those affected", and improve or restore the livelihoods and standards of those displaced by the project.

The disagreements that have ensued—together with those in southern Mexico (see section 3.2.2 below)—suggest that projects need to be evaluated not only with regard to (promised) employment, but also in broader terms that assess overall livelihood impacts and adequately weigh the pros and cons of large-scale projects. In this regard, there are commonalities of concern with other renewable energy projects, such as large-scale biofuels projects (which are discussed further below in sections 3.2.5 and 3.2.6).

3.2.2 Wind energy development, Mexico

The bulk of Mexico's wind development is taking place in the southern state of Oaxaca—the state's superb wind resources were the earliest to be mapped (Wood, Lozano Medecigo and Romero-Hernandez, 2012). Since 2006, 26 wind facilities have been brought into operation with a total capacity of about 2.4 GW (AMEE, 2016). This represented 82 per cent of total Mexican wind capacity in 2015.

In 2011, the Inter-American Development Bank (IDB) approved financing for a 396 MW wind farm at San Dinisio, intended to be one of the largest in all of Latin America, with a projected workforce of some 300 workers during construction, but just 30 workers for operations (IADB, 2011a and 2011b). However, an intense conflict with local indigenous communities developed. Residents cited loss of land and detrimental impacts on fish, mangroves and livestock among the reasons for their antagonism (Backwell, 2012; Peterson, 2012; Smith, 2012; Stevenson, 2012), along with complaints that the project owners had failed to comply with the ILO Indigenous and Tribal Peoples Convention, 1989 (No. 169), which requires prior, free and informed consent (Godoy, 2015). Intensifying protests and blockades, and a December 2012 federal court injunction that put construction on hold, prompted the project consortium to move to a new location (Wilton, 2014).

The San Dinisio protests are part of a broader opposition in Oaxaca to the particular way in which wind energy is being developed in the state. Local communities have complained about unfair contracts, bribing of local leaders, inadequate consultations, and unfulfilled promises. Wind developers can secure consent and 'buy-in' from local communities when they have an adequate share of the economic benefits and employment (direct or indirect). But Wood, Lorzano Medecigo and Romero-Hernandez (2012) point out that in Oaxaca, wind companies typically share only 1 per cent of their profits with local communities (serving as royalties for land leased to wind projects)—far less than the five per cent that has been typical in industrialized countries.

The case of Oaxaca highlights not so much the need for better planning or project design, but the stark asymmetries of information and power between project developers and local communities. Many of the local communities are poor and illiterate and have inadequate information about the potential value of wind energy and lack the legal, technical and financial resources needed to ensure beneficial outcomes of large-scale projects. They are consequently unable to determine a fair value for the use of their land (Cheng and Hertel, 2013; Wragg and Hughes, 2015).

Wragg and Hughes (2015) observe that "land is often illegally obtained through settling of contracts individually rather than through the communal self-governing community bodies that exist in most of Oaxaca …" Further, Cheng and Hertel (2013) note that "land usage leases can extend up to thirty years and can be renewed by the companies at their sole discretion. During the terms of these contracts, companies have effective territorial control and decide the terms under which a community may use its own territory."

Mexican government policies prioritize rapid wind development and have thus favoured project developers. Mexico's Federal Electricity Commission (CFE), an agency with broad powers to regulate and develop the country's electricity sector, has "allocated communities' land in a way that effectively creates territorial monopolies for many companies, thereby further reducing each community's options and bargaining power in the process" (Cheng and Hertel, 2013).

Plans for a 44-turbine, 100 MW capacity wind farm by the community of Ixtepec indicate the potential for an alternative, community-centred approach. This will be the first large-scale community-owned indigenous wind power project in Latin America. Ixtepec is partnering with the Yansa Group, a social enterprise, to assist in tasks such as wind resource assessment, infrastructure and logistics, environmental permitting, and contract negotiation (Yansa Group, undated). Electricity is to be sold to the CFE (for feed-in into the national grid) over a 20-year period at a fixed price, and operations are intended to minimally affect local farming. The Ixtepec community and Yansa hold an equal share in the US$ 200 million venture. Once built and operational, the wind farm is expected to generate a total annual net surplus of about 50 million Mexican Pesos (US$ 3.8 million) for the next 20 years (Environmental Justice Atlas, 2015).

To ensure that revenues are used for local community purposes, the project is controlled by the local *comuna*, a democratic agricultural body that operates the majority of Ixtepec's land. In sharp contrast with corporate-led wind farms in Oaxaca, it does not involve the leasing of community land rights. Banks and impact investors are providing concessional loans that do not give investors equity ownership or shares. Half of the profits will be reinvested back into the Ixtepec community via a locally controlled Development Trust (Wragg and Hughes, 2015).

Wood, Lozano Medecigo and Romero-Hernandez (2012) note that, "increasingly, Oaxaca is seen as a textbook case for how not to develop wind power in politically and socially fragile areas." Proper consultation, sensitivity to local needs and concerns, and adequate profit sharing are key ingredients for a more sustainable approach. Baja California offers a more positive model of how wind development can move forward while benefiting local communities. The La Rumorosa I wind plant (built in 2009) involved a strong local labour component, and the developers emphasized the importance of gaining local acceptance, sharing data and information in a transparent manner, and involving the community at every stage of the project. The main contractor and several subcontractors came from the local area, as did 90 per cent of the personnel involved in planning and construction. Local mechanical and welding workshops found employment opportunities in the maintenance of on-site equipment, whilst other members of the local community benefited from the rising demand for services such as food and lodging. Some 270 people were directly employed in construction over a six-month period. In total, about 500 local temporary jobs were created, although permanent employment in running the facility turned out to be much lower.

3.2.3 Tafila wind farm, Jordan

Jordan's planned Tafila wind farm, 150 km south of Amman, is the first of its kind in the country and entails the construction and operation of 38 turbines with a combined capacity of 117 MW. Work on this project has not started and details are not yet available, but an initial rough assessment (IRC and Al Jidara, 2014a) suggests that during the 18–24 month construction period, labour equivalent to 230 person-years may be required, as well as some 480 person-years during the 20-year projected operational life of the facility (table 10).

Table 10. Tafila wind farm, projected employment generation, in person-years

Wind farm construction/operation phases	Estimated local staff (person-years)	Estimated foreign staff (person-years)
Construction phase		
- Construction management and engineering	6	8
- Tower erection	10	30
- Construction works	90	10
- Support staff and security	40	10
- Commissioning works	6	20
Sub-totals	**152**	**78**
Operations phase		
- Technical operations	60	60
- Commercial operations	60	–
- Maintenance works	80	40
- Support staff and security	160	20
Sub-totals	**360**	**120**

– = negligible.

Source: IRC and Al Jidara, 2014a

The project will be designed, built and operated by a European wind company under an Engineering Procurement and Construction (EPC) and 10-year O&M contract. The share of non-Jordanian labour is expected to be quite high (34 per cent for construction work and 25 per cent for operations). This is not altogether surprising, given that this is Jordan's first wind farm, which means the country still lacks experienced national labour. It is primarily unskilled jobs, such as security guards, drivers, and possibly equipment operators that are likely to be filled by people from the local communities. The EPC contractor will probably employ local subcontractors for the majority of the civil works such as foundations, buildings, access roads, utilities, and so on. However, only a small proportion of the needed materials will be manufactured in Jordan, limiting domestic multiplier effects.

3.2.4 Ourzazate concentrated solar power plant, Morocco

The Ourzazate Solar Power project is a 160 MW grid-connected Concentrated Solar Power (CSP) plant (eventually intended to reach 500 MW), and constitutes the first part of the larger Moroccan Solar Plan, which aims to install some 2 GW of electricity-generating capacity by 2020.

According to a 2014 assessment (IRC and Al Jidara, 2014b), EPC contractors, including companies providing the water infrastructure, drainage work and road access, provided a total of nearly 950 person-years of employment. These numbers and the timeline for contract work suggest that an average of six person-years of employment will be created per MW. An extrapolation to the full 500 MW of capacity yields a figure of almost 3,000 person-years. These numbers, however, do not include jobs generated by local subcontractors, which account for the majority of the unskilled labour. Once the plant is operational, it is expected that it will provide 2,175 person-years of employment over a 25-year concession period (or 87 FTE jobs throughout the duration).

The impact assessment estimates that during construction, 70 per cent of all labour will be unskilled and will focus on site preparation and access roads. The report notes that the construction of the CSP facility itself is not very labour intensive, relying heavily on machinery. During operations, skilled technicians will account for nearly 50 per cent of jobs, followed by engineers at 26 per cent. Other skilled labour will account for five per cent of jobs, roughly the same share as for administration and security personnel each.

Because of the lack of local labour with the required skills, personnel from outside the project area fill the majority of professional positions. In fact, a considerable number of top managerial staff and operational specialists are non-Moroccan. The majority of construction workers are Moroccan nationals, with some exceptions for highly specialized work. In this regard, there is a marked difference with Jordan, for instance, where significant numbers of non-Jordanian labour are employed in construction activities. The Ourzazate project is creating a pool of workers for whom there will be substantial demand as the country's renewable energy strategy unfolds.

3.2.5 Biofuels – general observations and experiences, the United Republic of Tanzania

In a number of developing countries, biofuels development has been advocated as a means of reducing dependence on imported energy, promoting agricultural growth, addressing pervasive rural poverty, and creating much-needed employment (Arndt, Pauw and Thurlow, 2010).

While biofuels development creates jobs, the broader livelihood impacts require careful analysis. The environmental and social impacts depend strongly on the particular way in which biofuels are produced: the type of feedstock used (with different labour needs for sugarcane, palm oil, jatropha, etc.); the scale of feedstock production (commercial plantations versus smallholders); and the way in which feedstock production is expanded (via increased yields or expanded harvest areas). In general, smallholder production tends to generate larger benefits for local communities, whereas plantations are more beneficial for agribusiness investors (Arndt, Pauw and Thurlow, 2010). The degree of mechanization also makes a major difference in terms of labour needs for planting, growing and harvesting of feedstock. Some feedstock sources (like palm oil) lend themselves less readily to mechanization than others.

When farming communities relinquish land to biofuels ventures, they typically do so in the expectation of gaining employment and improving their economic status. However, reviewing findings from a range of studies focusing on Africa, Gasparatos et al. (2012) note that, "the number of jobs being eventually generated (and the wages offered) by large-scale investors has, in several cases, been far lower than initial community expectations. "

Although estimates vary widely, there seems to be agreement in the literature that the number of new jobs created by biofuels plantations is relatively low. A modelling exercise for Mozambique in 2010, for example, assumed a figure of 0.33 workers per hectare at plantations, compared with a much higher figure of three workers per hectare for small-scale operations (Gasparatos et al., 2012). Similarly, data for sugarcane and cassava feedstock production in the United Republic of Tanzania show that smallholder feedstock production creates a substantially larger number of jobs than plantation operations. Mixed operations, which rely on plantations and contract farming, also fare better than plantations alone (Arndt, Pauw and Thurlow, 2010) (table 11).

Table 11. Employment potential of different types of biofuel operations, United Republic of Tanzania

Scale/employment potential	Sugarcane					Cassava			Jatropha
Scale	Large	Mixed	Small	Small	Small	Small	Small	Mixed	Small
Feedstock yield	Low	Low	Low	Low	High	Low	High	High	High
Outgrowth	Land	Land	Land	Land	Yield	Land	Yield	Yield	n.a.
Productivity (MT[1]/person)	201.1	96.6	19.0	20.4	85.9	4.6	30.0	13.0	3.1
Workers per 100 hectares of land									
Farm workers	41.8	78.4	225.2	209.5	81.5	215.7	66.6	153.3	130.2
Processing	3.36	3.15	2.33	10.33	4.18	0.45	0.91	0.91	1.36
Workers per 100 000 litres of biofuel produced									
Farm workers	7.16	14.92	75.81	70.51	16.77	117.66	18.17	41.82	92.7
Processing	0.58	0.60	0.78	3.48	0.86	0.25	0.25	0.25	0.97

[1] Metric ton.

n.a. = data not available

Note: "Large" scale denotes commercial plantations; "small" scale denotes smallholder outgrower land. Distrinctions are made between achieving output growth by putting more land under production or by improving yields.

Source: Adapted from Arndt, Pauw and Thurlow, 2010

From an overall livelihoods perspective, trading land against employment at biofuels plantations may not be a winning proposition for many villagers. In the Tanzanian context, a study by the International Food Policy Research Institute notes that, "shifting resources away from food production could increase households' reliance on marketed foods, and biofuels may not generate sufficient incomes for poorer households to offset rising food prices." (Arndt, Pauw and Thurlow, 2010.) Action Aid Tanzania (2009) suggests a similar conclusion. Income from biofuels plantation jobs often do not represent adequate compensation for local farmers' loss of land, due in part to the fact that most of the jobs are unskilled and seasonal in nature, and usually do not come with benefits such as social security and medical assistance.

In the United Republic of Tanzania's Kisarawe District (a coastal region south of the capital Dar es Salaam), a large portion of land acquired by SUN Biofuels (a British company that acquired land in 2007 but ceased operations there in 2011) was previously part of a reserved village forest area. The community thus lost access to natural resources such as fuelwood, food products, and medicinal plants and associated livelihood activities (Mdemu, 2011). But wages at the plantation were insufficient to offset the loss of income. Bergius (2012) concludes that the affected communities became financially worse off. Mdemu (2011) and Sulle and Nelson (2009) report that compensation for the loss of land and other properties is frequently inadequate.

3.2.6 Makeni bioenergy project, Sierra Leone

Addax Bioenergy Sierra Leone's (ABSL) Makeni project involves about 10,000 hectares of land for sugarcane production, as well as a bioethanol distillery to produce some 85,000 cubic metres of ethanol annually for export to Europe and a biomass energy plant that will generate electricity by burning bagasse (sugarcane residue). Slightly more than half of the electricity is to power the company's operations. The remainder is to be fed into Sierra Leone's national grid, where it would account for 20 per cent of the country's total power supply (Davis and Fielding, 2015). It has also been suggested that the project has the potential to expand rural energy access by building a mini-grid to connect local communities to the ABSL power plant, or by selling some of the ethanol locally. However, just as these facilities were completed in 2014, the Ebola outbreak began to take its toll on the country, including the Makeni project, delaying further development (Burger, 2015).

A detailed assessment report by the Stockholm Research Institute (Fielding et al., 2015) finds that the Makeni Project had become a major employer in the area, reaching a peak of close to 3,500 workers in December 2014. As is common in agricultural employment, many of the jobs are short-term or seasonal, although permanent employment increased between 2012 and 2014. The share of workers from the immediate area is about half the total, although it has declined over time (table 12.)

Table 12. Employment at the Makeni project, Sierra Leone, 2012-2014

Employment type/share	February 2012	November 2012	December 2013	December 2014
Permanent employees	312	523	1 108	1 594
Casual workers	946	911	1 044	1 861
Total employees	1 258	1 434	2 152	3 455
% permanent	25	36	51	46
% employees within 20 km	60	58	53	-
% local employees + Makeni	68	70	69	-
% female employees	10	8	12	10

– = negligible

Source: Fielding et al., 2015

Local hiring has been limited by the lack of necessary skills, especially for factory construction and ethanol-related production. The influx of workers from elsewhere has had somewhat contradictory impacts. On one hand, it led to a degree of price inflation and attendant worries that the local people could end up poorer than before. On the other hand, it brought some fresh opportunities for new businesses and small trade. Following a labour dispute, the agricultural project workforce has been unionized and employees subsequently report that their household incomes had increased after ABSL's arrival (Fielding et al., 2015; Davis and Fielding, 2015).

The Stockholm Environment Institute (SEI) analysis by Fielding et al. (2015) observes that the ABSL venture represented the first opportunity for the subsistence farmers in the project area to engage in formal wage labour. However, this can be a challenge since "the jobs for which they qualify are likely to be seasonal and may coincide with the rice planting and harvesting seasons" and thus "affect local food security" (Fielding, et al., 2015).

Unlike many other biofuels projects, ABSL sugarcane cultivating is not carried out on a single massive estate. Fields are interspersed with smallholdings, and ABSL is running a Farmer Development Program to promote improved farming techniques, offer ploughing services and other benefits. Roads built by ABSL near villages can, in principle, benefit the local communities, although the government has failed to make last-mile connections (Davis and Fielding, 2015).

4. The employment dimensions of kerosene and traditional biomass

Before presenting the findings of the literature review on the employment implications of small-scale renewable energy deployment in rural communities, we will first briefly consider the following: whenever energy services are provided where previously there were none or only limited ones, new economic and job opportunities are created, while few or none are put at risk; and where renewable energy substitutes conventional energy such as kerosene, fuelwood, or charcoal, this new supply potentially displaces labour.

4.1 Kerosene versus solar lighting

Many people who do not have access to electricity rely on kerosene lamps for lighting. A study by Mills for UNEP (2016) draws on data and experiences from projects and the broader literature in order to arrive at a rough employment estimate for kerosene distribution among member countries of the Economic Community of West African States (ECOWAS). The study estimates that kerosene distribution provides the equivalent of about 20,000 full-time jobs across the region, or one kerosene retailer per 10,000 people without access to a grid. If the same ratio holds across all of sub-Saharan Africa, there might be some 62,100 kerosene dealers.

As conventional energy such as kerosene is replaced by renewables, what is the likely net employment impact? Only very rough, back-of-the-envelope calculations can be made, but the UNEP study does offer some evidence that the impact is likely to be positive. It considers the job potential inherent in the spread of solar portable lighting (LED lanterns) in the region.

In manufacturing, major companies report that on average they need one worker (1 FTE/year) to produce 300 LED lanterns. It should be noted, however, that as of 2012 manufacturers based in China (both domestic and European) accounted for about 90 per cent of cumulative sales of portable solar lights worldwide. Indian companies accounted for another 5 per cent, whilst local assembly in African countries was essentially limited to a number of pilot projects (IFC, 2013). To change this substantially will require a number of obstacles to be overcome, such as the lack of a well-developed component supply chain, quality control, cost competitiveness, tariff structures, and skills training.

Greater local employment potential is found in distribution and especially in retail sales. With the help of a survey of the number of solar lantern companies, the UNEP study estimated that large distributors need one worker for each 6,000 lanterns handled per year. In retail, one employee is needed for 50-100 lanterns sold annually. It should be emphasized that these numbers represent a mix of full- and part-time jobs. The latter is particularly relevant for the retail side. However, there is no robust information on the share of retail employees' time devoted to selling solar equipment. Overall, UNEP (2014) estimates one FTE job per 58.8 lanterns. This may be an overly generous figure but, if it is correct, it would mean that for every million LED lanterns sold annually, there would be employment for an estimated 17,000 people across the entire solar lantern value chain.[6]

[6] UNEP (2014) notes: "These values should be regarded as approximations and will vary based on business model, local conditions, the level of a company's maturity and efficiency, and full inclusion of a wide variety of job categories. Because the level of employment varies, these should be regarded as a combination of part- and full-time jobs."

This rough estimate will need to be validated by more focused local studies, both in West Africa and other regions.

The UNEP study (2014) further offers some calculations, which suggest that the LED lantern sales volume to date may have generated some 15,000 jobs across sub-Saharan Africa. This is equivalent to 30 jobs per 10,000 people living off-grid, and thus 30 times the ratio of one kerosene retailer job per 10,000 people mentioned above. The net employment impact of switching from kerosene to solar is thus clearly positive, even if further research were to yield a somewhat lower than 30:1 ratio. Many kerosene vendors sell a range of products, so a switch from kerosene to solar may be expected to be gradual. However, such a switch to solar would need to be accompanied by skills training which, for example, is what Solar Tuki has done in India.

The UNEP study points to the enormous employment potential of switching to solar. At a projected annual sales volume of 33 million LED lanterns (it assumes that each household in the ECOWAS region can afford three lanterns with a service life of three years), the future employment potential in solar manufacturing/importing, distribution, and retail sales is 561,000 jobs. Again, these numbers will need additional scrutiny.

Mills (2016) subsequently undertook a study to assess the number of livelihoods globally supported by the kerosene distribution chain (or other fuel-based lighting products), and compared these estimates with potential global solar-LED employment. For distribution, Mills assumes a figure of three kerosene sellers per 10,000 inhabitants. He applies this ratio to a population of 112 million households; non-electrified households for which solar-LED lights are deemed an appropriate alternative to kerosene. This yields an approximate figure of 150,000 kerosene sellers (most of whom may be assumed to derive part, rather than all, of their livelihoods from kerosene sales).

In order to estimate employment in solar-LED product distribution, Mills relies on the figure of 17,000 jobs per million solar lanterns sold which he developed for the earlier UNEP study (2014). Assuming annual lantern sales of 112 million, he postulates an employment potential of about 1.9 million jobs. At present, global solar lantern sales may run to about 10 million units, which would suggest some 170,000 distribution jobs. These are of necessity very rough estimates and will need to be refined as better information becomes available.

4.2 Fuelwood and charcoal

Wood remains a very important source of renewable energy, and demand for it is growing. Wood energy currently accounts for more than two-thirds of global renewable energy supply. In some developing countries, more than 90 per cent of people rely exclusively on fuelwood, charcoal and crop residues for cooking and heating. Globally, some 2.6 billion people, principally in developing countries, depend on wood energy for cooking and/or heating, given that other sources of energy are often unaffordable to poor households (BMZ and GBEP, 2014).

Africa accounts for half the world’s charcoal production, and this section is based on the African experience (IEA, 2011b). Statistics tend to be unreliable, but it is estimated that African charcoal production has increased close to sixfold between 1960 and 2011 (BMZ and GBEP, 2014). Charcoal is the dominant fuel in urban households, whereas firewood is mainly a rural fuel, used by households and small enterprises for a range of activities from tea drying and fish smoking to brick making, bakeries and others (Oduor, 2012). Even though it is mostly used in urban settings, people in rural communities produce charcoal to provide a source of income (Practical Action Consulting, 2012).

Virtually invisible in official government statistics due to its informal and seasonal characteristics, this sector holds great economic significance. UNDP (2012a) estimates that charcoal is the second biggest employer in rural sub-Saharan Africa, following agriculture.

Charcoal is a labour-intensive sector. A 2002 study for sub-Saharan Africa (Neufeldt et al., 2015) estimated that charcoal creates 200–350 work-days per terajoule (TJ) of energy consumed; a much higher figure than for energy alternatives such as electricity (80–100), liquefied petroleum gas (LPG) (10–20), and kerosene (10). Thus, increasing demand in the charcoal sector has an important role in creating employment opportunities. Studies carried out in Kenya, Malawi, Mozambique, the United Republic of Tanzania and Zimbabwe offer some estimates of employment, as outlined below.

Kenya. Studies indicate that each hectare of woodland has the potential to produce on average 18 tons of charcoal and create two jobs (Oduor, 2012). Total employment in Kenya's charcoal production increased from 200,000 people in 2004 to almost 254,000 in 2013. The number of people involved downstream, i.e. transporting, distributing and retailing charcoal, has risen from an estimated 500,000 to about 635,000 over the same time span. Altogether, the sector thus provides livelihoods for close to 900,000 people, and their dependents (KMEWNR, 2013).

Malawi. Openshaw (2010a) has closely examined the fuelwood and charcoal value chain in Malawi, which supports the livelihoods of an estimated 133,000 people (table 13). A 53 per cent increase in the quantity of fuelwood and charcoal traded between 1996 and 2008 (driven by population growth) compares with employment rising by 42 per cent; thus indicating an increase in labour productivity over the observed period of time.

Openshaw (2010a) argues that an extrapolation of his findings to sub-Saharan Africa (on the basis of estimated wood energy consumption) yields a rough estimate of 13 million people whose livelihoods depend on the production, transport and trading of fuelwood, and the production of charcoal. Openshaw (2010b) further estimates that nearly 30 million people may be involved in all aspects of biomass energy across the developing world. This estimate is based on findings in Malawi of one person employed in the informal woodfuel sector for every 100 users of all biomass energy.

Table 13. Employment in Malawi's fuelwood and charcoal sector, 1996-2008

Fuelwood/charcoal production	Fuelwood	Charcoal	Total
	(Full-time equivalents)		
1996			
Growing wood	4 921	1 492	6 413
Producing, transporting, trading wood	56 131	30 934	87 065
Total	**61 052**	**32 426**	**93 478**
2008			
Growing wood	5 375	5 178	10 553
Producing, transporting, trading wood	63 148	59 337	122 485
Total	**68 523**	**64 515**	**133 038**

Source: Openshaw, 2010b

United Republic of Tanzania. A 2002 study concluded that the charcoal industry directly employed some 70,000 people in the country. However, while acknowledging that no reliable estimate was possible, a later study by Van Beukering et al. (2007) argued that the entire charcoal sector might provide employment for over a million people. The largest numbers by far are found in transport, trade and retail, but most are informal jobs and may not be FTE.

Mozambique and Zimbabwe. Estimates of people directly depending on charcoal for their livelihoods in Mozambique and Zimbabwe are 40,000 and 78,000, respectively (Seidel, 2008).

Although the importance of employment in the fuelwood and charcoal sector is difficult to overstate, there are also profound social inequities and significant health and environmental impacts (Neufeldt et al., 2015) that need to be remedied:

- **Inequality.** Charcoal producers are the weakest link in the charcoal supply chain; with little negotiating power with their intermediaries. A report by the World Agroforestry Centre puts the revenue share of charcoal producers in Malawi and Mali at just 20–21 per cent of the final value of the product. Female producers are especially marginalized.
- **Gender.** Wood gathering activities tend to be highly onerous for the rural women and girls who spend hours every day on this backbreaking chore. And where male labour is diverted from agriculture to charcoal production, women end up with extra work burdens.
- **Pollution.** Along with kerosene, fuelwood is a source of indoor air pollution that sickens and kills large numbers of people. Charcoal produces less smoke than firewood (causing fewer illnesses and deaths from respiratory diseases). But traditional charcoal stoves still emit large amounts of carbon monoxide.
- **Climate.** The production and use of charcoal also contributes large amounts of greenhouse gases (carbon dioxide and methane).
- **Pressure on forests.** The main driver of tropical deforestation is agricultural expansion, but fuelwood gathering and charcoal production can lead to severe local deforestation (where wood harvesting exceeds the rate of biomass replenishment), and to national and regional forest degradation.

Given the extent of the fuelwood and charcoal sector, its substitution by “modern” forms of renewable energy is likely to be slow. It is therefore important to render the charcoal sector more sustainable. Better woodland management and agroforestry practices are required, as are tree planting efforts (afforestation/reforestation), improved energy efficiency in generating charcoal, and improved cookstoves to reduce indoor air pollution.

Openshaw (2010a) argues that generating more accurate data (of biomass yields, demand, and areas of woodland shortages and surpluses) are of fundamental importance for policy-making. Reducing deforestation requires integrated rural development that takes into account forestry, agriculture, energy, environmental, and other aspects. Small-scale biomass energy producers need increased support in the form of training (in woodland management, charcoal production and marketing), better market information, micro-loans, improved infrastructure, and other support measures.

To improve sustainability in the charcoal sector, the World Agroforestry Centre (Neufeldt et al., 2015) recommends strengthened community-based forest management, more secure tenure and property rights, increased participation by disempowered stakeholders, and better governance and financial management to bring about a regulated and more transparent sector, among other measures. (Sudan’s government, for instance, has sought to organize charcoal producers into associations, improving their bargaining power.)

Under the right conditions, agroforestry has the potential to be a sustainable alternative, reducing pressures on fuelwood harvesting in natural forests. This is particularly the case if it is combined with assisted regeneration and short rotation plantations. In Malawi, up to 40 per cent of all wood fuel is sourced from agroforestry.

Improving kiln efficiency is another critical dimension of a more sustainable charcoal sector. Most sub-Saharan African producers use traditional kilns with an efficiency of only 9–15 per cent. More advanced designs exist that can raise efficiency to as high as 70–80 per cent in some cases. However, some are only appropriate for large-scale production, and different designs have their own advantages and disadvantages (including cost, ease of construction, and other aspects) (KMEWNR, 2013). Also, financing, capacity building, and training are needed to successfully introduce more advanced kilns (Neufeldt et al., 2015).

The employment implications of making the biomass and charcoal sector more sustainable are somewhat contradictory. Replacing traditional kilns with improved designs is positive for employment. But more efficiency kilns reduce the number of trees needed per unit of charcoal production. In turn, this means that fewer people are needed to process and transport the wood (unless overall demand rises so strongly that similar volumes of wood are turned into charcoal as before). In that case, improved management of forests and woodlands, agroforestry and afforestation would probably create substantial new rural employment opportunities.

A successful example of a community-driven commercial afforestation project is found in Siaya County in southwestern Kenya (box 5). An assessment by Practical Action Consulting (2009) found that the project had increased forest cover significantly, and that training in farming skills had yielded positive results.

Box 5. Rarieda Agroforestry Development Initiative, Kenya

A community-driven commercial afforestation project was launched in Rarieda District in September 2002 aimed at enhancing the livelihood of local communities. A group of 545 farmers set aside lots totalling 240 hectares to grow two species of acacia trees for charcoal production, under a 6-year harvesting cycle. The estimated yield was 100 tons of round wood or 30 tons of charcoal per hectare.

The project was initiated by Youth to Youth Action Group (YYAG), which later became known as the Rarieda Agroforestry Development Initiative Programme (RAFDIP), with financial support from Thuiya Enterprises Ltd. The participating farmers were lent 500–2000 seedlings, at zero interest rates, to plant as woodlots for charcoal, to be repaid at the end of the 6-year rotation cycle. Thuiya Enterprises supported the construction of six half-orange kilns (with conversion efficiencies that can reach as high as 50–60 per cent). Staff from Kenya Forestry Research Institute trained the farmers in their use, and teamed up with Moi University to provide other advice to farmers on efficient growing and production methods.

The farmers were also given 40 kilograms (kg) of groundnuts and beans per hectare for intercropping with the acacia trees (providing income during the first two years of the acacia trees' growth). In the four years before the trees reach maturity, they derive income from honey, poultry and dairy goats. Farmers are lent one beehive for every 500 Acacia trees they plant, and repay RAFDIP with honey.

Source : Oduor, 2012.

Finally, improved cookstoves help reduce the amount of energy needed for cooking, and thus contribute to reducing the pressure on woodlands. Their production varies widely. Some takes place on a large-scale, with centralized production and distribution channels and upwards of 100,000 stoves produced annually by some firms. A highly efficient mass assembly in a country like China is likely to churn out large numbers with comparatively few people, whereas the small-scale, hand-produced production typical of many developing countries requires more labour. The latter is lower cost and requires little or no transportation to reach intended customers and offers local employment opportunities in rural areas. There is now also a growing trend toward semi-industrial production of improved biomass stoves, with imported components, and local production and assembly. Depending on the type of stove and its durability, the supply chain of materials and inputs required for producing stoves, more labour may be required for an improved stove than for a traditional one (IRENA, 2012). According to the Global Alliance for Clean Cookstoves (2013), some 5.5 million clean cookstoves were produced by its partner organizations (POs) in 2012 (out of a total of 8.2 million stoves in total), providing employment for an estimated 76,188 people. By 2014, the number had risen to 12.1 million clean stoves, but there were no updated employment estimates. If employment rose in a comparable fashion, close to 170,000 workers may have found employment that year. However, the Alliance's report for 2014 notes that the gain is primarily due to large companies that presumably require fewer workers per unit produced and sold (Global Alliance for Clean Cookstoves, 2015).

Openshaw (2010a) argues that because biomass stoves are produced mainly by the informal sector, which can ill afford to undertake research and development, governments should:

- offer programmes for training in stove manufacturing techniques, business management and marketing;
- provide loans for micro-enterprise development;
- test stoves and materials; and
- undertake quality control.

5. Impacts of investments in rural renewable energy

The discussion now turns to the deployment of renewable energy technologies intended to provide benefits directly to rural communities. The principal technologies of interest here are solar energy (PV and thermal applications), biomass (especially from agricultural waste products), and small hydropower plants. Small-scale wind power is still deployed on a very limited basis, with very little information available about its rural employment impacts.

5.1 Rural renewable energy deployment: solar PV

Solar PV systems are being disseminated through a variety of approaches, and business and financing models. In some cases, the public sector plays a central role, but in others NGOs and the private sector are the driving forces. Bangladesh, for example, has been running a highly successful programme driven by a state-owned company but implemented by a large number of NGOs (profiled below). In other countries (such as Ethiopia and Mozambique), similar efforts are just beginning to unfold, but on a small scale. In other cases, social enterprises, some of which have transformed into commercial ventures, have taken the lead in making solar equipment available in rural areas. Finally, the last few years have seen the emergence of a growing number of start-up enterprises. The following sections discuss a number of examples for each of these approaches.

5.2 Public sector-led approach, Bangladesh

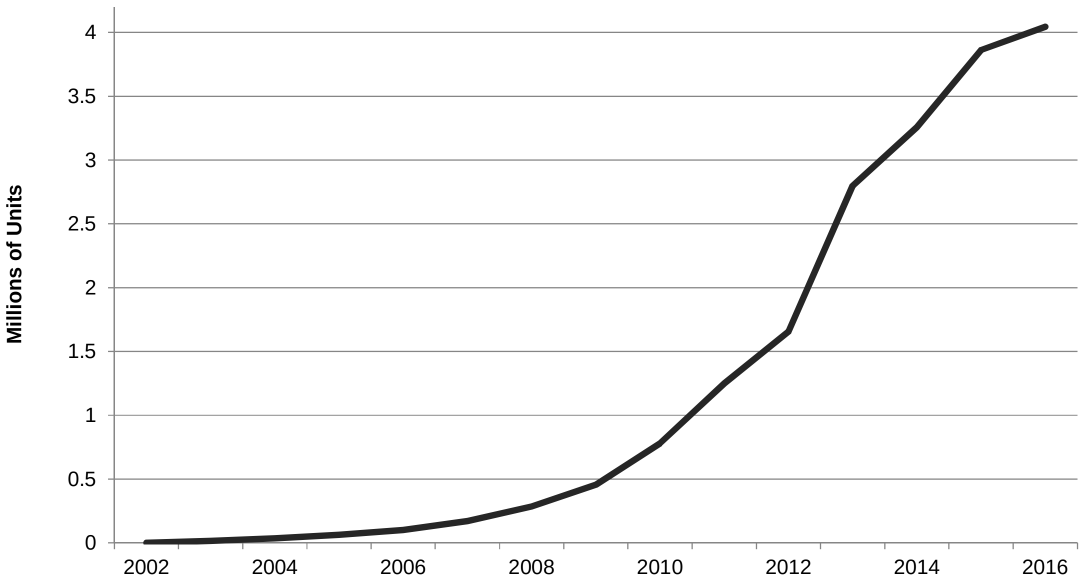
The experience of Bangladesh, which has the largest and fastest growing off-grid rural electrification programme worldwide, indicates the tremendous potential inherent in providing energy access and generating associated employment. Prior to 2002, the lack of finance prevented the purchase of solar panels by poorer rural households. Many banks were either unwilling to lend to the poor at all or imposed large down payments and exorbitant interest rates (Rai et al., 2015). But under the aegis of the government-owned Infrastructure Development Company (IDCOL), solar installations grew rapidly, reaching four million units in May 2016 (figure 4). The target for 2017 is six million units (Haque, 2014). The installed systems collectively generate about 160 MW of electricity,[7] benefiting about 20 million people (D. Barua, Bright Green Energy Foundation, e-mail communication, 23 February 2015). In comparison with Bangladesh, SHS installations are far more limited. REN21 (2016) estimates that some 2.4 million systems were sold in China, India, Kenya and Nepal combined by the end of 2014).

IDCOL channels donor funding into small-scale finance, sets technical specifications for solar systems, certifies products and components, and selects POs. Among the current 47 POs supplying SHS are NGOs and microfinance institutions. Following screening against eligibility criteria by IDCOL's selection committee, the various POs are responsible for conducting assessments of the type of solar system rural households need and can afford, installing the systems, providing after-sales services and maintenance, and developing a viable supply chain (Rai et al., 2015).

[7] As of late 2014, 3.3 million units were installed with 135 MW of capacity (Saha, 2014). Extrapolating to the 3.9 million units installed by late 2015, this works out to about 160 MW.

The World Bank and the Global Environment Facility (GEF) were the earliest funders of the SHS programme. The former has so far provided US$ 560 million, enabling the purchase of about 2.2 million SHS (Sadeque et al., 2014). In addition, support comes from the ADB and the Islamic Development Bank, as well as from bilateral agencies – Japan International Cooperation Agency (JICA), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Gmbh [German Corporation for International Cooperation], KfW Development Bank, U.S. Agency for International Development (USAID), and the United Kingdom's Department for International Development (DFID).

Figure 4. Cumulative SHS installations in Bangladesh, 2002–2016



Sources: Haque, 2012; IDCOL, undated

By mid-2015, IDCOL had channeled about US$ 700 million in funds to POs in the SHS programme (Haque, personal communication, 2015). In addition to financing for solar systems, IDCOL initially also offered "institutional development grants" to build the capacity of these organizations. These grants were gradually phased out, declining from US$ 20 per system in 2003 to US$ 3 in 2010–11, and to zero in 2012 (Rai et al., 2015).

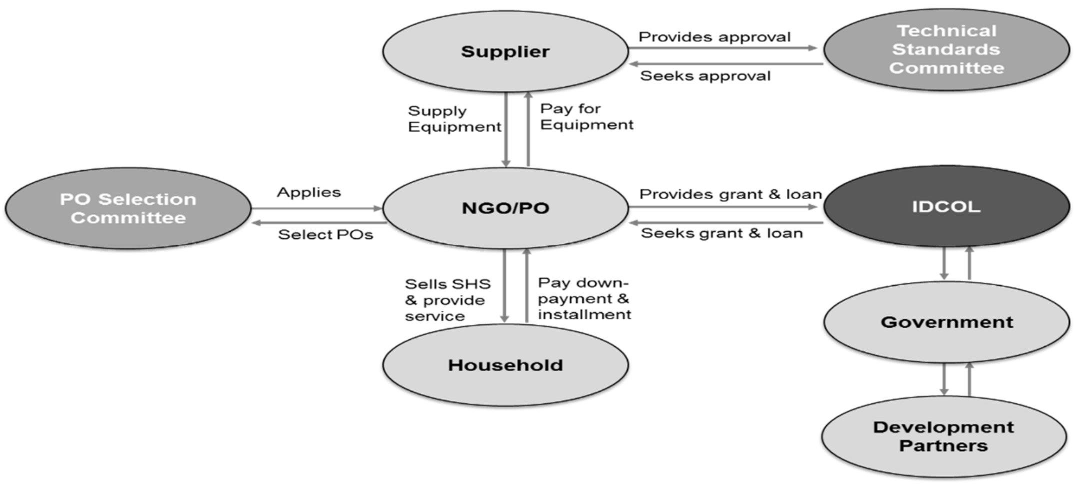
Figure 5 offers an illustration of the tasks and responsibilities of the various actors involved, and table 14 illustrates costs and financing for two examples, indicating how the loan terms have moved from concessional towards commercial. The process works as follows (Rai et al., 2015):

- IDCOL provides a "capital buy-down" grant up front to reduce the cost to households. (As SHS costs declined, the amount was reduced from US$ 70 in 2003 to US$ 20 in 2013–14, and is now only available for systems of up to 30 kWp, purchased by the poorest households.)
- The household makes a down payment equivalent to 10 per cent of the reduced solar system cost.
- The remaining amount is financed by a micro-loan, at a rate of 15–20 per cent per annum over a 3-year period.
- Following the down payment, a PO installs the equipment and provides free after-sales service during the first three years.

- Following installation, IDCOL inspectors carry out a physical inspection of the system. If it is satisfactory, IDCOL refinances 70–80 per cent of the PO's loan to the household at a lower interest rate.

IDCOL's top priority has been commercial viability. From the beginning, it was intended to align monthly payment costs for SHS with expenses for kerosene and dry cells, to ensure that households could afford the systems. Rising kerosene prices, dropping solar costs, and the advent of efficient LED lights have made it easier to reach this objective (Tiedemann, 2015; Sadeque et al., 2014). Also, a World Bank analysis notes that rising rural incomes in Bangladesh (a consequence of greater agricultural productivity and a huge inflow of remittances from workers abroad) have helped make solar panels more affordable (Sadeque et al., 2014). According to a World Bank survey, these factors permitted subsidies to decline from 25 per cent of the SHS price in 2004 to under 10 per cent in 2012 (Samad et al., 2013).

Figure 5. Responsibilities under Bangladesh's SHS programme



Source: Haque, 2014.

Table 14. Financing of SHS in Bangladesh, 50 kWp and 20 kWp

Terms	50 Wp SHS (terms in 2012) Cost in USD	20 Wp SHS (terms in 2014)
a. Market price[1]	400	193
b. Buy-down grant[2]	25	20
c. System price to household (a-b)	275	173
d. Household down payment to PO (10% of c)	56	17
e. Loan payable by household to PO (c-d)		
Loan period	3 years	3 years
Interest rate	12% pa	15-20% pa
Monthly instalment	8.50	5.50
f. IDCOL refinance (70-80% of e)[3]	255	109-125
Loan Period	5-7 years	5-7 years
Interest rate[4]	6-9% pa	6-9% pa

[1] System costs in these two examples reflect not only different size, but also the fact that, over time, the cost of solar equipment has generally declined.

[2] Buy-down grants started out at 70 USD per system, but were reduced over time to 20 USD (and are now only available for small systems of up to 30 kWp)

[3] Refinance was available for 80% of the loan until 2011, but for the period of 2012-2015, it was reduced to a range of 70-80%.

[4] Interest rates started at six per cent, but were subsequently raised.

Sources: Adapted from Islam, 2014, Haque, 2012

However, many of the poorest households still find it a challenge to afford down payments and monthly instalments, and the reduction of subsidies may limit the programme's ability to reach some of the poorest communities (Rai et al., 2015). The generous spread among interest rates charged along the chain of intermediaries should, in principle, allow for improved loan terms for the poor without undermining commercial viability. While World Bank funds are provided to the government at 1–2 per cent over 40 years, the government in turn lends to IDCOL at 3–6 per cent over 15 years. IDCOL's refinancing rate of 6–9 per cent is substantially lower than the 15–20 per cent rate that applies to households' microloans (Bardouille et al., 2014).

Employment has grown along with the expanding number of installed solar systems. Projects run by IDCOL's implementation partners employ an estimated 70,000 people. This includes 39,000 direct jobs in IDCOL POs and 31,000 supply chain jobs (Haque, 2015). In addition, Dipal Barua of the Bright Green Energy Foundation (BGEF) estimates that there are perhaps 10,000–15,000 jobs in solar projects not linked to IDCOL, and domestic solar manufacturing and assembly support an additional 30,000 jobs (D. Barua, BGEF, e-mail communication, 23 February 2015). This adds up to a total of 110,000 to 115,000 jobs in 2014.[8] Thus, on average, one job in the supply chain is required to serve the energy needs of 174 to 182 people (or about 34 to 36 households, assuming an average of five persons per family).

Grameen Shakti (2015), the dominant PO, sold and installed more than 1.6 million SHS units as of December 2015. During 2015, when it employed 7,845 workers, the NGO installed about 105,000 systems. These figures work out at 13.4 systems per worker. However, the underlying numbers have fluctuated strongly over the years. UNEP (2014) cites an annual installation rate of 365,000 SHS that year and employment of about 12,000, yielding a figure of about 30 systems installed per worker, which is more in line with the overall calculation for Bangladesh in the example above.

Initially, almost all of Bangladesh's solar system components were imported (Grameen Shakti, undated). But Bangladesh managed to develop a domestic manufacturing and assembly capacity, led by firms such as Rahimafrooz Renewable Energy Ltd. (RREL), which set up the country's first solar module manufacturing plant (Sevea Consulting, 2015). Nine domestic companies have a production capacity of 80–100 MW compared to annual demand of 60 MW, according to the Solar Module Manufacturers Association of Bangladesh. But they are hard-pressed to compete against cheap (though often low-quality) Chinese imports. Domestic plants are running far below capacity; RREL, for instance, uses only about a third of its capacity. Altogether, local companies are supplying about a fifth of the total domestic demand (Saha, 2014).

Comprehensive quality control has been a key aspect of the SHS programme from the very beginning, to build households' confidence that the solar equipment they buy will function reliably:

- IDCOL set up an independent technical standards committee (TSC). The TSC establishes (and updates as necessary) equipment and service standards, designs quality assurance programmes, and reviews dealers' product credentials. Equipment that does not meet the TSC's specifications is not eligible for IDCOL's grants and refinance.
- Suppliers have to offer 20-year warranties for solar panels and 5-year warranties for batteries. Also, after-sale services have ensured that customers remain

[8] Based on Barua's data, IRENA (2016) subsequently estimated that employment might rise further to 127,000 jobs.

satisfied with their systems over time (Sadeque et al., 2014).

- The number of IDCOL inspectors monitoring the quality of equipment and installation services, ensuring that installed systems are fully operational, has grown to 150 (Rai et al, 2015).
- Another important aspect, related to quality control, concerns training efforts. By 2013, more than 15,000 PO field staff and managers, as well as local technicians, had received training in SHS configuration, positioning of SHS, installation procedures, maintenance and troubleshooting (Haque, 2013). By late 2013, Grameen Shakti had established 46 technology centres where locals are trained as technicians to service and repair solar equipment in their own villages. Most of the trainees have been women (Khandker et al., 2014).
- Measures also include raising consumers' awareness of SHS and training in their use to foster a sense of ownership (which helps ensure proper maintenance and upkeep) (Sadeque et al., 2014).

Bangladesh's SHS programme has been successful for a number of reasons (Bimesdoerfer, Kantz and Siegel, 2011; Strietska-Ilina et al., 2011; UNDESA, 2011; Sadeque et al., 2014).

Some aspects may be unique due to the country's circumstances and thus difficult to replicate in other countries, but other lessons are applicable elsewhere (Sadeque et al., 2014). Among the unique conditions are Bangladesh's existing strong network of microfinance institutions, and the country's high rural population density (which has permitted economies of scale and fostered competition among equipment dealers). The replicable factors include a number of issues discussed below:

- The need for a committed "local champion" (a role fulfilled by IDCOL).
- The design of the technical and financial aspects so that they match the target population's needs and abilities. This not only includes the ability to pay (i.e. matching solar costs with existing household expenses for conventional energy such as kerosene), but also adapting technologies to particular local needs.
- The establishment and enforcement of product standards to ensure solar equipment is of robust quality, which in turn will foster consumer trust.
- The training of technicians and quality assurance monitors.

5.3 Social enterprises: SELCO Solar Pvt. Ltd., India, and Iluméxico, Mexico

In addition to public policy as a driver of providing energy access as in Bangladesh, private actors, social enterprises, some of them transforming into quasi-commercial companies, are also playing an important role.

In India, **SELCO Solar Pvt. Ltd.** is a social enterprise established in 1995. To date, it has sold more than 200,000 solar systems (of which two-thirds since 2007). SELCO has also completed the construction of four solar PV mini-grids, and is planning another 10 in the next two years. One distinguishing feature of SELCO is that it customizes products based on local individual needs instead of merely distributing a given piece of equipment. The solar equipment is manufactured in India. The enterprise offers installation and after-sales services. It also offers end-user financing (through rural banks, microfinance, and farmers' cooperatives) tailored to rural customers' cash flow. With headquarters in Bangalore, SELCO has a number of regional branch offices, each of which oversees a number of energy service centres that reach out to remote villages (sales, installations and after-sales services). The number of energy service centres has grown from 25 in 2010 to 45 today, and employment grew from more than 150 employees to 392 people (mid-2015) in Bihar, Gujarat, Karnataka, Maharashtra and Tamil Nadu. Most personnel are recruited locally. Some centres also rely on local sales agents who work on commission. Just over 20 per cent of service centre employees are female, but at headquarters this rate is 43 per cent. SELCO also mentors a small number of solar entrepreneurs at its Incubation Center (Ashden Awards, 2009; SELCO, 2010; SELCO, undated-a; SELCO, undated-b; Energy Access Practitioner Network, 2015).

In Mexico, **Iluméxico** is of much more recent provenance, started in 2009 as a small grant-supported pilot project. From its origins as a social enterprise reliant on government subsidies, it has moved to a more revenue-driven model and grown significantly, now operating in four Mexican states. To date, Iluméxico has installed about 3,500 SHS (in addition to other solar-powered products such as water pumps, refrigerators, and electric fences). Customers pay for systems either in full upfront or via low-interest payments. In late 2013, Iluméxico received a contract from the Oaxaca state government to install SHS in unelectrified rural communities. It led to a larger programme in 2014 and 2015, and Iluméxico is now collaborating with national and subnational government agencies to replicate its model across Mexico (Morris and de Been, 2015).

Central to that model are a number of local branches called ILUCentros deployed as part of a hub-and-spoke model. They provide customer service and troubleshooting under annual maintenance plans that include a free replacement battery after three to four years of subscription. They are also intended as hubs for community development (offering, for example, workshops in local schools on workforce skills). Each of the ILUCentros typically employs two or three technicians (Morris and de Been, 2015). As of late 2015, the intent is to expand the number of ILUCentros from 5–50 locations, with the goal of distributing SHS to 50,000 off-grid rural homes by 2020. It is estimated that this will create 180 new jobs, of which 70 will be based in rural communities. The plan is also for women to occupy half of the additional jobs (The Guardian, 2015).

5.4 Commercial enterprises

Since 2010, a considerable number of private start-ups have emerged and are now rapidly scaling up, gaining prominence in selling or leasing standalone solar equipment. This section discusses their approach and the implications for employment generation. However, there are also some companies that have been in existent for a while. **Chloride Exide**, for example, was established in the 1960s as a purveyor of automotive batteries, but it has more than 20 years of experience in rural pico-level SHS, and also installs solar water heating and wind energy systems. The company has 13 branches in Kenya, three in the United Republic of Tanzania, and one each in Rwanda and Uganda, each staffed by technicians trained for installations and spare parts. It also has more than 500 dealers selling solar equipment in remote villages. Customers either pay the full cost up front or purchase panels through microfinance institutions (Meier, 2014; Cloride Exide, undated). **Sunlabob**, a Laos-based company, has become known particularly for its Solar Lantern Rental System (SLRS), which has been a catalyst for local-enterprise development. Since 2001, it has installed more than 10,000 systems in over 500 villages in Laos. SLRS consists of a central solar lantern charging station (able to charge 50 lanterns). A single station is managed by a rural entrepreneur and maintained by local, Sunlabob-trained technicians. SLRS is based on a FFS model (UNDP, 2012b). Sunlabob has also branched out into SHS and other solar technologies (water heating, water pumping, etc.), as well as into hybrid mini-grids. The company has expanded operations into Afghanistan, Cambodia, Liberia, Mozambique, Sierra Leone and Uganda, (Sunlabob, undated).

5.4.1 Start-ups

The amount of money invested by private equity firms, development banks, and other investors into off-grid solar companies has risen from US$ 64 million in 2014 to close to US$ 200 million in 2015 (Lacey, 2014; Wesoff, 2015). Most of these companies are developing markets in sub-Saharan Africa, although others operate in Asia and Latin America. Table 15 offers an overview of selected companies' employment, countries of operation, and number of customers reached. Large established companies like France's Engie and Italy's Enel are also beginning to venture into this field (Hirtenstein, 2016b).

Table 15. Selected off-grid solar companies operating in rural areas, mid-2015

Company name	Full-time employees	Countries of operation	Number of people reached (last 12 months/cumulative)
Azuri Technologies	15 / 465[1]	Kenya, Rwanda, Sierra Leone, Uganda, United Republic of Tanzania, Zambia	n.a. 75 000 (total; early 2014)[2]
BBOXX	168	Kenya, Rwanda, Uganda	23 105 250 000
d.light	>400	China, Kenya, India, Uganda	n.a. 10 000 000
Fenix International	120	Kenya, Uganda	115 000 165 000
Foundation Rural Energy Services (FRES)	5 / 337[3]	Burkina Faso, Guinea Bissau, Mali, South Africa, Uganda	30 000 330 000
Mera Gao Power	125	India	8000 22 000
M-KOPA	>700	Kenya, Uganda, United Republic of Tanzania	1 100 000[2] 3 750 000[2]
Mobisol	>500	Rwanda, United Republic of Tanzania	70 000 110 000[4]
Off-Grid Electric[5]	>800[6]	Rwanda, United Republic of Tanzania	n.a.[4] n.a.
Renewable Energy Foundation	>400	Sub-Saharan Africa	n.a. >93 000
Simpa Networks	300	India	55 000 75 350
Solaraid / SunnyMoney[7]	130/600[8]	Kenya, Malawi, Uganda, United Republic of Tanzania, Zambia	519 212 10 000 000
Solar Kiosk[7]	70	Botswana, Ethiopia, Ghana, Kenya, Rwanda, United Republic of Tanzania, Viet Nam	802 500 1 000 000
Solar Now	194	Uganda, United Republic of Tanzania	3114 8476
Solar Sister[7]	58	Nigeria, Uganda	152 000 281 000
Sunlabob	42	Afghanistan, Cambodia, Laos, Liberia, Mozambique, Sierra Leone, Uganda	n.a. >25 000
Tessa Power	300	Mali, Niger, Nigeria	2000 5000

[1] Headquarters in London, the United Kingdom: 15; in the field: 465 full- or part-time. [2] Azuri and M-KOPA report the number of households they reach; these numbers (15,000 cumulative for Azuri; 220,000 and 750,000 for M-KOPA, respectively) were multiplied by five on the assumption that a typical rural household comprises five people. [3] Five at headquarters, 337 direct and indirect jobs at FRES companies operating in the field. [4] By mid-2016, this number had risen to 250,000, indicating rapid expansion. [5] Off-Grid Electric reports it installs solar equipment in more than 10,000 homes and businesses per month. [6] According to a mid-2015 survey, 570 jobs; more than 800 at year-end 2015. [7] Solaraid, Solar Kiosk, and Solar Sister include solar lanterns in their offerings. These much smaller, more affordable units may explain why the numbers of people they reached are quite high relative to the other companies listed. [8] In addition to 130 regular staff, a network of 600 independent sales agents.

Source: Adapted from Energy Access Practitioner Network, 2015; and IRENA, 2016. Data for Azuri, d.light, M-KOPA, and Sunlabob, as well as employment estimates for FRES, Mobisol, Off-Grid Electric, and SunnyMoney are derived from company websites

The companies selling standalone equipment differ from each other in a number of ways:

- Companies like Azuri and M-KOPA focus on pico-scale solar products (10 W or less), whereas other firms like BBOXX or Mobisol also offer more powerful equipment affordable to wealthier customers or businesses (BNEF and Lighting Global, 2016). Off-Grid Electric and Fenix International occupy somewhat of an intermediate position, selling above the pico-level (products up to about 50 Watt).
- Another distinction among these companies is that many use a PAYG approach (see the profile of M-KOPA in section 5.4.2 below), whereas some others rely on a FFS model (see the profile of FRES in section 5.4.3). According to REN21 (2016), there are at least 64 enterprises using the PAYG model in developing countries, 45 of which in sub-Saharan Africa.
- Finally, some companies have decided to build their own distribution networks with commissioned sales agents (this is prevalent among firms relying on the PAYG model), while others prefer to rely on existing local stores and other distributors. Also, as the report by BNEF and Lighting Global (2016) points out, "Telecom operators have emerged as a natural partners for the PAYG industry, largely because they are among the few brands in Africa that reach far into rural areas, and because many PAYG companies rely on the telecom industry's data networks and mobile-money systems. "

The extent to which differences in business models have a noticeable or even decisive impact on economic success, and on employment generation, is still difficult to discern, given the limited length of time during which these firms have been in existence and the very limited data available about their operations. The local employment impact is in distribution, installations, and after-sales service; the equipment is typically produced in China and some other Asian countries, and system design usually takes place in the United States or Europe.

To be successful, an FFS model can be expected to place a premium on equipment reliability, since this is a critical aspect. Trained staff to provide quality maintenance and troubleshooting is a must (as is the availability of spare parts). Nominally, for the PAYG approach this applies only to the period of time until an SHS is paid off, plus whatever warranty period is offered. But it is important even under that model to ensure that solar panels and other components are fully functioning. For start-ups in a still new business environment, customer satisfaction is essential (satisfied customers are more likely to recommend a given piece of equipment to friends and neighbours, and to consider upgrading to a more powerful system themselves) (Energypedia, 2015).

Partnering with an existing local distribution network can be a critical advantage. On the one hand, these companies (most of which were launched, and may even have their headquarters in industrialized countries far from the rural areas of developing countries they intend to serve) may find it difficult to build distribution and after-sales service structures that function smoothly. On the other hand, existing networks of stores and dealers do not focus exclusively on solar equipment, but rather sell a broad range of goods and services (Energypedia, 2015). Attracting suitable sales personnel and technicians, and providing adequate training, is thus a critical element.

The experience to date of a number of start-ups provides a set of early indications of the employment impacts of off-grid solar development, and gives a sense of the distribution networks that are emerging. Four brief company snapshots, Azuri, BOXX, Off-Grid Electric, and Mobisol, are followed by somewhat longer profiles of two additional companies, M-KOPA and Foundation Rural Energy Services (FRES):

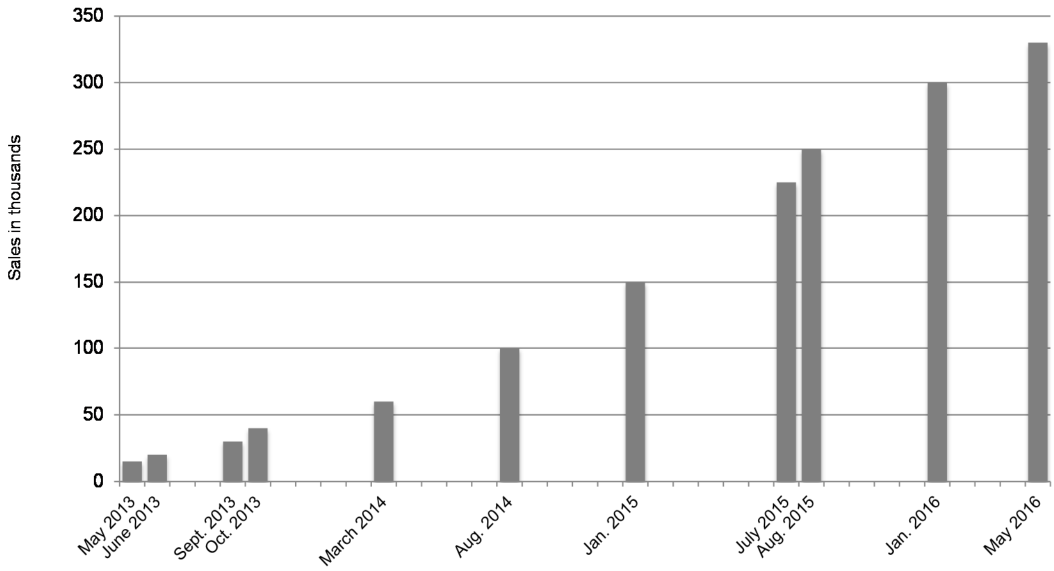
- Launched in 2012, Azuri, based in the United Kingdom, uses a PAYG business model. In addition to an installation fee of US$ 10, customers either purchase weekly "scratchcards" (US$ 1.50 to US$ 2 a week), or pay via mobile phones to activate energy service. Customers own the solar system after about 18 months. By early 2014, Azuri had about 15,000 SHS units installed. It is involved in an effort with GVEP International to distribute 10,000 more in Rwanda. Unlike competitors BBOXX or M-KOPA, Azuri relies on local businesses in 10 East and West African countries for rural distribution; these partners are responsible for installation, selling top ups, and after-sales service (Meier, 2014 Azuri, undated; GVEP International, undated-b). The company reported that its partners in the field had added some 465 full- and part-time employees in a 12-month period between 2013 and 2014, selling, supporting and maintaining solar systems. Azuri also estimates that approximately 25 jobs are created in the field for every new headquarters employee in the United Kingdom (at the time of writing this report there were 15 employees at headquarters). The solar equipment is manufactured in Malaysia (Azuri, 2014).
- Headquartered in London, BBOXX had, as of mid-2015, sold some 50,000 SHS units in East Africa. Design engineering is carried out at its headquarters, and the panels are produced in China. The company had a total of 130 full-time employees at the end of 2014 (BBOXX, 2014), growing to 168 by mid-2015 (Energy Access Practitioner Network, 2015). The expectation is that by 2020, it will employ 2,000 people as operations expand into other African countries, as well as Colombia and Peru. Of the current staff, 86 are based in Kenya, Rwanda and Uganda, with women accounting for more than 30 per cent of their employees. BBOXX runs its own shops (a network of 30 by end of 2014), rather than relying on existing distributors. Each shop employs a manager and a technician. Groups of about 10 shops are managed by a hub that employs five middle-management personnel (Kent, 2015).
- **Off-Grid Electric** is the implementation partner of the Tanzanian government's "One Million Solar Homes" initiative, which is expected to supply 10 per cent of the population with solar-generated electricity by the end of 2017 and create more than 15,000 local solar jobs in the process (USAID, 2016). The company installs solar equipment in more than 10,000 homes and businesses per month and employs more than 800 workers in the United Republic of Tanzania. Having raised US$70 million during 2015, it plans to expand into Rwanda next (Wesoff, 2015). The company relies on a network of local businesses and agents for door-to-door sales.
- Berlin-based **Mobisol** focuses on larger capacity panels (averaging 100 kWp) than some of its competitors. A third of its customers are small entrepreneurs in Rwanda and the United Republic of Tanzania. The company claims that it has installed the largest total capacity (3 MW) of any rent-to-own provider in sub-Saharan Africa. The ambitious aim is to reach as many as 10 million households by the end of 2020 in Africa and Asia. As of November 2015, Mobisol has trained about 750 people as sales personnel and technicians and says it directly created over 500 jobs in East Africa. On average, this would mean one job per 60 units installed (Mobisol, 2015).

5.4.2 M-KOPA, East Africa

Based in Nairobi and operating principally in Kenya, as well as Uganda and the United Republic of Tanzania,[9] M-KOPA has become the global leader in the PAYG market for off-grid customers. It sells small solar energy systems to people in poor rural communities. A SHS unit includes an 8-Watt solar panel, two LED bulbs, a portable solar torchlight, a portable solar radio, and a mobile phone charger with five USB connections (M-KOPA, undated). Following an initial deposit of US$35, customers purchase daily "credits" over a 12-month period, after which they own the solar system (to date, 80,000 units have been fully paid, and the company has a repayment rate of 90–95 per cent). Payments are made via Safaricom's M-Pesa, a mobile phone app (Maritz Africa, 2015).

Since June 2012, M-KOPA has sold a cumulative 330,000 SHS units (Mutemeri, 2016) (figure 6). In 2015, it sold an average of more than 600 solar systems per day (or about 220,000 per year), a number expected to rise to 1,000-1,200 units soon. The goal of 1 million units by the start of 2018 thus seems well within reach (Maritz Africa, 2015).

Figure 6. Cumulative SHS sales by M-KOPA, selected data points for May 2013–May 2016



Sources: M-KOPA, 2015a; M-KOPA, 2016; Mutemeri, 2016.

By August 2015, when M-KOPA had reached cumulative sales of 225,000 units, the company calculated that its customers were collectively saving some US$ 170 million compared to what they would have spent on kerosene for conventional lamps (the figure is based on US$ 750 saved per household over four years). Assuming that each SHS unit avoids 1.3 tons of CO_2 over four years, total emissions reductions run to about 260,000 tons of CO_2 (M-KOPA, 2015a).

M-KOPA expects to increase the number of permanent employees from 757 in 2016 to about 2,000 by 2018. Jobs include software developers, technicians, payment and credit analysts, accountants, and others. Through the company's "M-KOPA University", training

[9] In late 2014, K-KOPA also licensed its technology to Persistent Energy Ghana (PEG), which is following the same business model. With financing from investors in France, German and the United States, PEG hopes to reach more than 100,000 households by 2016 and 500,000 across West Africa over five years (PEG Ghana, undated).

is provided for all employees, and middle and senior managers (Maritz Africa, 2015). Among the company's workforce are more than 250 people (as of late 2015) working in a customer care centre in Nairobi, Kenya, addressing questions from customers and sales agents (M-KOPA, 2015b). These numbers suggest that there is one customer care employee for each thousand units sold. It is not clear whether this relationship is sustainable, but it might serve as an informal way of calculating employment as sales continue to expand.

M-KOPA also has a fast-expanding workforce of sales representatives. Their ranks have risen from just five in 2012 to 232 in 2013, 1,169 in 2014, and 1,500 in 2015 (M-KOPA, 2015b), and are currently expanding at a rate of 50 additional workers per month (Runyon, 2016). Dividing the number of total units sold per year (220,000) by the number of sales agents (1,500) yields a figure of 147 per worker. How robust an indicator this is for how many jobs could be created as sales scale up in the coming years remains to be seen.[10] The model of sales representatives travelling to remote villages and cultivating a customer base limits economies of scale.

Initially, M-KOPA relied on d.light to design the solar equipment it sells, but in 2014 it decided to set up its own in-house unit, and today employs about 40 hardware engineers. The equipment is manufactured in China and shipped to Mombasa, from where it is trucked to Nairobi and then on to some 60 retail outlets in larger Kenyan towns. The sales representatives pick up the solar products at these outlets and take them to rural villages (Maritz Africa, 2015).

The use of a mobile payment system like M-Pesa allows for a versatile business model, but it also implies some limits to employment generation, with regard to finance and repair. Mutemeri (2016) explains that with mobile payment systems, there is no need to dispatch large numbers of loan officers to remote villages: a SIM card in the solar system can shut off the unit in case a customer fails to make required payments. Also, because M-KOPA's network-connected system allows remote monitoring of battery and solar panel performance, repair workers are sent out only as needed, avoiding the necessity for a permanent maintenance workforce in villages. While the precise arrangements vary, other companies have similar capabilities.

5.4.3 Foundation Rural Energy Services (FRES) SHS

In contrast with M-KOPA's approach, FRES uses a FFS model (an initial installation fee, plus monthly payments). FRES has set up a number of small commercial companies in Burkina Faso, Guinea-Bissau, Mali, South Africa and Uganda (with Cameroon soon to be added). FRES companies are mostly installing SHS, but the Mali venture (known as Yeelen Kuxra or "New Light") had also established nine solar/diesel mini-grids as of the end of 2013 (FRES, 2013).

FRES data indicate that by August 2015, it had about 33,500 customers; 29,500 SHS units and 4,000 mini-grid customers in higher density rural towns (Nijland, 2015). This number is expected to grow to 100,000 by 2020 (FRES, 2013 and undated). System components are mostly imported from Europe and to some extent from Asia (EUEI PDF and Practical Action Consulting, 2015). However, local employment is created in assembly, installation and maintenance of SHS and mini-grids, plus in producing support

[10] However, Mutemeri (2016) refers to a number of 1,251 field agents. These sales reps are paid on a commission basis, on average earning between 15,000–20,000 Kenyan Shillings (US$146–194) per month. For many, this is not necessarily a full-time job. Those who treat it as such, however, may earn considerably more (Maritz Africa, 2015).

structures (frames, etc.), control panels, and battery boxes. At the end of 2014, the number of direct and indirect jobs totalled 337 (Nijland, 2015) (table 16).

FRES data for Mali and South Africa reflect more than a decade's worth of operations; in contrast, operations in Burkina Faso, Guinea Bissau and Uganda are more recent, and there may be efficiencies, productivity gains, and other learning curves yet to be mastered that could influence the outcome as FRES scales up operations there. This seems to be borne out in calculating installed capacity per employee ratios (which are lower for the newer operations but higher for the more established ones, and average 10 kWp for all FRES ventures). The customer-to-employee ratios are less conclusive.

Finding qualified local staff in rural areas is a major challenge for FRES operations and, since 2004, it has sent trainers to all of its locations to ensure standardized installation and maintenance practices. In January 2015, FRES initiated a new train-the-trainers programme for selected staff. The participants are intended to serve as future focal points for ongoing local training, pass on their knowledge to additional local technicians as they are recruited (Service, 2014).

Table 16. FRES customers, stores and employees, 2014

Countries	SHS capacity installed (kWp)	Customers	Employee		Customers per employee Capacity (kWp) per Employee*
			Direct	Indirect	
Mali[1] (Since 2001)	902	6 314	54	18	88 12.5*
South Africa (Since 2001)	1 317	18 065	96	23	152 11.1*
Burkina Faso (Since 2008)	342	3 365	30	7	91 9.2*
Uganda (Since 2010)	544	3 482	53	8	57 8.9*
Guinea Bissau (Since 2011)	279	2 041	6	42	44 5.8*
Total	**3 384**	**33 267**	**239**	**98**	**99** **10.0***

[1] In Mali, FRES also installed mini-grids with a combined generation of 825 MWh.

Note: Ratios in the final column are the author's calculations.

Source: Nijland, 2015

5.4.4 Some preliminary conclusions about labour needs and intensities

The various solar programmes and ventures that were outlined above permit some preliminary conclusions regarding labour needs and intensities in distributing, installing and maintaining distributed solar products, i.e. lanterns and home systems.

The work of Mills (2016), referenced in chapter 4, suggests that global solar lantern sales may involve some 170,000 people. It is estimated that Bangladesh's SHS programme alone, which is the largest in the world, may have provided employment for some 127,000 people. Installations in other countries are still far more limited, but extrapolating from Bangladesh's experience, they may have required fewer than 100,000 workers. Solar start-ups selling and installing a range of solar equipment are still relatively small. Table 14 above suggests that they only have a few thousand regular employees, with larger numbers of independent sales agents (who may, however, only derive part of their livelihoods from such sales).

Calculations by Mills (2016) suggest that sales of one million solar lanterns may require some 17,000 workers. This translates into about 59 lanterns per worker. Among the implementing partners of Bangladesh's programme, implied labour requirements vary widely, ranging from 13 to 33 SHS per worker (which is probably a reflection of the different scales of operations). Similarly, among solar start-ups, Mobisol data indicate that there is one job per 60 units sold, but for FRES, the ratio is 1 to 99, and for M-KOPA it is 1 to 147. Of necessity, these ratios are very rough, based essentially on snapshots of ventures that are scaling up and changing rapidly. Their business models vary widely, as do the scales of operations, and the length of time they have been in existence. The population densities of different rural areas also influence the nature of the distribution networks needed (a factor that may limit economies of scale). Reliable conclusions about the labour intensities of distributed solar energy are still hard to draw.

5.5 Rural renewable energy deployment: bioenergy

Biomass can be used in a variety of ways to generate energy services; biofuels for transportation, biomass power, and biogas, which itself can be used in power plants or for household cooking purposes. This section briefly considers the employment aspects of selected examples.

5.5.1 Biofuels

Chapter 3 discussed a number of large-scale biofuels projects, whose output is principally destined for urban or export markets and driven by their prerogatives, so that the benefits for rural communities are likely to be limited. However, biofuels projects can in principle also be oriented much more towards the needs of rural areas. In addition to growing feedstock for the express purpose of energy production, rural projects can use crop and forest residues, animal wastes, as well as by-products from food processing and food wastes.

Concerning dedicated feedstock operations, outgrowers and similar contracted smallholder arrangements can avoid the negative impacts that result from outright land acquisition for biofuels plantations. Smallholders can improve their negotiating position in relation to biofuels investors by organizing farmer associations (Sulle and Nelson, 2009). This is a conclusion supported by the experience of sugarcane outgrowers' associations in Kilombero and Mtibwa, in east central and northeastern United Republic of Tanzania, respectively (Matango, 2006).

Prospects can be further improved by building local supply chains and downstream linkages (Action Aid Tanzania, 2009). For instance, **KAKUTE Ltd.**, a venture established in the country in 1995, has been involved in a series of projects and efforts to develop local value chains related to jatropha, developing jatropha-based products and technologies such as cookstoves, lanterns, biogas (from jatropha seed cake), and soap (KAKUTE, undated). A pilot project was undertaken to promote micro-enterprises at the village level, training women's groups to establish and manage commercial jatropha nurseries, soap making and market development, and training youth in jatropha oil processing. Working with 17 local women's groups, KAKUTE trained over 1,500 people. More than 400 hectares of jatropha was planted on marginal lands donated by the local communities involved (UNDESA, 2007; LAMNET, undated).

5.5.2 Biomass power

In India, **Husk Power Systems (HPS)**, which was founded in 2007, has been a success story. The company has installed 84 mini-power plants in the state of Bihar, providing electricity to over 200,000 people. According to the company, a single one of its 25–50 kW plants provides electricity to 200–600 households and shops, and provides four full-time jobs and five to 10 part-time jobs. Women mostly fill part-time jobs. The plants built so far have thus created some 350 full-time jobs and provide part-time employment to 420–840 persons. Each plant on average saves about 42,000 litres of kerosene and 18,000 litres of diesel per year. By reducing communities' reliance on these polluting fuels, the plants help to reduce indoor air pollution and improve rural residents' health. There are additional (unquantified) economic development impacts, since the electricity generated by HPS plants allow local businesses to stay open after dark and makes it possible for children to study at night. HPS creates additional employment through its livelihood programmes (such as an incense stick manufacturing programme which largely employs women) (Husk Power Systems, undated).

5.5.3 Biogas

Biogas can be used in a variety of ways; as feedstock for electricity production in larger facilities, or for cooking and lighting in small household-scale plants. The SNV Development Organisation (undated) explains that: "A family in possession of a few heads of cattle can generate sufficient gas to meet their basic cooking and lighting needs and use the residue of the process, bio-slurry, as a potent organic fertilizer to enhance agricultural productivity. The technology is suitable for both households and small and medium-sized enterprises."

A report by SNV offers a glimpse into the various ways in which biogas is used in rural settings in addition to household use. In Honduras, biogas is used for electricity generation benefiting coffee farmers. In Peru, rural power production is based on biogas generated from cattle waste. In Uganda, manure and invasive water hyacinth are processed into biogas for battery-charging purposes and for agro-processing (rice milling). In Mali, a biogas-powered multi-function platform (MFP) replaces diesel use (SNV and FACT Foundation, 2014).

The construction of household or village biogas digesters is a labour-intensive process requiring masons and technicians. Employment is not always formal, but could be casual or involve cooperatives at the community level. A joint report by World Wildlife Fund (WWF) India and the Council on Energy, Environment and Water (CEEW) found that when a typical family-type biogas plant is installed, nearly 30 per cent of the total cost is spent on providing wages to local workers. Following construction, O&M activities provide employment to local technicians (WWF-India and CEEW, 2013).

Worldwide, China, followed by India, has built by far the largest number of household biogas digesters. From about 400,000 in 1975, the number in China went up to just under four million in 1984 (a lack of maintenance skills, however, prevented the government reaching an ambitious goal of 20 million). But by 2006, the number had risen to about 18 million (IRENA, 2012), and with the help of generous subsidies by 2011 it soared to a total of 42.8 million systems (SNV, 2012). This implies close to five million units constructed per year. For this period (2006–2010), ILO offers estimates that biogas digester construction in China created close to 90,000 direct and indirect jobs (table 17). These figures suggest that on average, one FTE job is required for 55 digesters per year. China's goal is to install 80 million household units by 2020 (Raniger, Mingyu and Renjie, 2011). Thus, it is anticipated that recent employment levels will be maintained for a number of years.

Table 17. Employment effects of biogas digester construction in China, 2006-2010

Types of jobs	Direct jobs	Indirect jobs	Total
Construction	4 500	6 600	11 100
Non-metal mineral products	13 100	35 100	48 200
Electronics, machinery and equipment, manufacturing	2 400	8 700	11 100
Metal smelting and pressing	500	2 100	2 600
Technical service industry	3 400	3 500	6 900
Residential service and other services	2 400	7 700	10 100
Total	**26 300**	**63 600**	**89 900**

Source: ILO, 2010

India constructed 150,000 biogas plants from April 2010 to March 2011, with a cumulative total of 4.5 million units installed (SNV, 2012).[11] WWF India and CEEW (2013) refer to a 2012 estimate that the installation of one 2-cubic metre biogas plant generates about 30 man-days of employment. This means that one FTE job is required to build 12 plants per year (a lower rate than China's 55, but not directly comparable as it excludes indirect employment). At this rate, the 150,000 plants constructed in 2010–11 would imply a total of 12,500 direct jobs. Including supply chain employment, a 2010 joint report by the Ministry of New and Renewable Energy (MNRE) with the Confederation of Indian Industry (CII) estimated the number of jobs in the biogas sector at 85,000, and anticipated that eventually some 200,000 jobs could be created (MNRE and CII, 2010).

Outside of China and India, SNV has for the past quarter of a century been one of the most important promoters of biogas plant construction in a wide arc of developing countries. By 2014, SNV-supported programmes had installed more than 600,000 biodigesters worldwide, benefiting about three million people (SNV, 2012). The pace of installations appears to be accelerating. As recently as the beginning of 2010, the number of small digesters stood at 300,000, and, by the end of 2012, it was about 505,000 (SNV, 2010; 2013). By far the most active SNV programmes are in Nepal (with about 268,000 plants by end of 2012) and Viet Nam (152,000), followed by Bangladesh (26,000) and Cambodia (19,000). Unfortunately, SNV does not offer information about the employment impacts.

In **Viet Nam**, a total of 500 technicians and 2,000 masons were expected to be trained in 2007–2012 under the country's biogas programme. In addition, some 7,000 training courses were organized for biogas users (Verbist, Ton and Phlix, 2013). According to IRENA (2016), more than 150,000 digesters have been installed since 2003. Employment creation is estimated at four construction jobs per digester. **Cambodia's** National Biodigester Programme (2011) is providing employment to 450 persons (370 farmers and

[11] A large number of India's scale plants face quality issues, the main reason being the lack of appropriate skills among installers and training for users. Apparently, many plants become non-functional within a year or so of construction.

80 technicians). There are 66 biodigester companies in the country, which by the end of 2014 had built more than 20,000 biogas plants, with the expectation of another 9,000 in 2015 (Climate Investment Funds, 2016).

SNV started supporting biogas activities in **Nepal** in 1989, and the country's Biogas Support Programme (BSP) was initiated in 2013 with support from UNDP. The programme relies on a private-public partnership to disseminate biogas plants, which are financed through subsidies, loans and micro-credit (UNDP, 2012b). Employment figures vary in the available literature, but it is clear that the programme has provided training opportunities for many poor rural youth to become biogas masons. SNV (2010) refers to "at least 9,000 people [who] have obtained employment from different organizations, especially biogas companies and appliance workshops." UNDP (2012b) mentions a figure of about 2,000 biogas masons employed through BSP. But the full employment effects are larger than that. The BSP has facilitated the emergence of a private biogas industry encompassing at least 55 construction companies, 15 biogas appliance manufacturers, and 80 financial institutions. By the end of 2005, there were 11,000 direct and indirect jobs (ADDCP, 2009). No newer comparable figures seem to exist. Further, UNCTAD (2010) refers to an additional 65,000 jobs through spin-offs (but does not explain how it arrived at this figure and what it entails).

Skills and workers' rights are central to BSP's work. The programme conducts biogas construction training for masons, who are subsequently certified by the Council for Technical Education and Vocational Training. Skilled masons are encouraged to become entrepreneurs and are given the authority to employ trainees. Working with enterprises in the private sector, BSP is also emphasizing the importance of protecting workers' rights for masons (a minimum wage, which is specified in bids has been integrated into a company code of conduct, and is used to assess companies' performance (UNDP, 2012b)

Biogas digester construction has clearly generated many thousands of jobs in a range of Asian countries. Biogas still plays a much smaller role in Africa and Latin America. But there are a number of efforts to raise the biogas profile. For instance, the Africa Biogas Partnership Programme (ABPP), funded by the Dutch government, focuses on reaching out to 22,000 smallholder coffee farmers in Kenya, Uganda and the United Republic of Tanzania (SNV, 2015). Programmes in these and some other African countries (Benin, Cameroon, Rwanda, Zambia and Zimbabwe) have to date supported the installation of nearly 60,000 biodigesters (Hivos, 2015).

5.6 Rural renewable energy deployment: small-scale hydropower

Large-scale hydropower projects require many more people during construction than smaller projects, but much of the workforce may be drawn from outside the location in question. Large projects can also be highly destructive and thus displace rural populations or cause loss of livelihood resources. The boundaries between small- and large-scale are not globally agreed. The *World Small Hydropower Development Report* (UNIDO and ICSHP, 2013) uses 10 MW as a cutoff, but some national governments, like those of Canada, China and India draw the line at a much higher level.

According to Small Hydropower World (undated), by far the largest installed capacity of small hydropower worldwide is in China and specifically in East China (40.5 GW out of the global total of 75 GW). East Asia also has the largest remaining small hydropower potential (34.8 GW), followed by Southern Asia (14.5 GW), South America (7.7 GW), Western Asia (7.3 GW), East Africa (6.1 GW), Southeast Asia (5.4 GW), and Central Asia

(4.7 GW). But relative to total potential, the largest undeveloped resources in the developing world are in sub-Saharan Africa and in Asia outside of East Asia.

Employment data for the small-scale hydropower sector are scarce. Worldwide, a rough calculation suggests that there may be some 209,000 jobs. China officially puts the number of jobs at 126,000 in the sector, but for many other countries there are no robust figures. In rural areas, small operators may be employed under informal arrangements. Another difficulty is that it is hard or impossible to distinguish between large- and small-hydropower projects in certain segments of the supply chain (IRENA, 2015b).

This section surveys a small number of experiences with regard to small- and micro-hydropower projects. In Nepal and Sri Lanka, these are supported by multilateral development agencies. Examples from Guatemala, Honduras and the Philippines are drawn from the realm of commercial projects. For Nepal, we also discuss impacts of improved water mills. Off-grid hydropower projects directly serve rural energy needs, but grid-connected projects, too, provide local employment opportunities during construction and in O&M.

5.6.1 Nepal

Two successive UNDP/World Bank programmes – the Rural Energy Development Programme (REDP), which was implemented from 1996 to 2010, and the Renewable Energy for Rural Livelihood (RERL) from 2011 – have provided support for micro-hydropower (10–100 kW) (in addition to support for SHS, biodigesters, and improved cookstoves) (UNDP, 2012b). By late 2011, a total of 555 micro-enterprises had been established in REDP/RERL programme areas, of which 323 were micro-hydropower projects (MHPs).

A typical MHP requires two operators. Running the growing number of MHPs required 24 FTE jobs in 1998, rising to 618 in 2010, and 323 for the first half of 2011 (IRENA, 2012). Employment has continued to climb since then and, by 2014, the cumulative number of MHPs stood at 423. At two jobs per MHP, this implies a total of 846 FTE jobs created to date. These MHPs provide electricity for more than 94,000 households (UNDP, 2014). This translates into one job per 111 households.

Given the two programmes' objective of increasing equitable access to energy services for the poor, women, and socially excluded groups, an important element is active community involvement and ownership of local projects (in addition to supportive district-level and national structures). Therefore, REDP/RERL included training (in running MHPs, planning, and book-keeping) for personnel and community representatives. As of mid-2011, a total of 34,050 people, including 15,000 women, had received training. Of these, some 2,596 people received technical training (IRENA, 2012). The REDP/RERL programmes also put strong emphasis on local enterprise development. Thus, the turbines, penstock pipes, and accessories for the MHPs are locally fabricated, and electronic load-controllers are locally assembled, although the generators are imported (IRENA, 2012).

In addition to the electricity generated by MHPs (which is mostly used for lighting), improved water mills (IWM) are another important source of energy access in rural Nepal, which are used mostly for agricultural processing activities such as grinding and hulling, but also for electricity generation. Nepal has at least 25,000 traditional water mills (Eagle, undated), but IWMs are more efficient. Nepal's Centre for Rural Technology (CRT) argues that IWM installations have brought about dramatic socio-economic improvements and rural employment. The number of IWMs keeps climbing – from 6,349 in December 2010 to 8,493 in late 2013 (serving about 450,000 households). According to a survey carried out in 2012 these installations employed 7,572 persons in operations; about one person per installation. Each IWM provides 53 households with energy services. In addition, service centres and kit manufacturers for IWM together provided employment for more than 750 workers in December 2010. The CRT study points out that IWMs serve as important hubs in the value chain of various products in the rural economy, and have promoted cottage industries and employment (Kapali, 2014).

5.6.2 Sri Lanka

In Sri Lanka, two projects (Energy Services Delivery, 1997–2002, and Renewable Energy for Rural Economic Development, 2002–2011) provided access to energy for some 175,000 households through on- and off-grid hydropower, SHS, wind and biomass. Each of the grid-connected mini-hydropower projects built employed 8–11 local people during a construction period of about 18 months. Once completed, each project employs 3–4 people for operations and maintenance. This O&M figure also holds for off-grid village hydropower projects. Over a period of 15 years, grid-connected projects reached a combined capacity of 152 MW (with an average plant capacity of a little more than 2 MW), while smaller off-grid projects collectively ran to less than 2 MW (and a per-plant capacity of just 10 kW) (UNDP, 2012c). Skills development was an important aspect; the project succeeded in building the capacity of professionals and organizations specializing in renewable energy, and provided training for local youth in various aspects of renewable energy, creating a skilled workforce that could be readily tapped by companies. The World Bank (2013) reports that 742 off-grid enterprises benefited from small hydropower development.

5.6.3 Philippines

A number of projects in the Philippines make for an interesting contrast with those in Nepal and Sri Lanka, given that they are at the upper end of what is typically defined as small hydropower. An 8 MW plant in Antique, Western Visayas, employed about 1,000 workers for the construction (three years), and for building access roads and terracing around the facility. Most of the jobs went to people from the local community. But management, engineers, and accountants were brought in from elsewhere in the Philippines. After completion, the plant provides 30 permanent full time jobs (Greenpeace Southeast Asia, 2013). It was estimated that a similar sized facility, the 7 MW run-of-river Tudaya 2 project in the Davao region of Mindanao Island, would employ some 400 people during the 14-month construction phase (Philippine Information Agency, 2012). Information for plants operated by Hedcor in Luzon indicates that smaller capacity facilities tend to require more labour per MW of capacity, with a range of 1–4 jobs (table 18).

Table 18. O & M workforce at Hedcor hydropower plants, Philippines

Plant name	Capacity (MW)	O&M workforce	Jobs per MW
Ampohaw	8.0	8.0	1.0
FLS	5.9	10.5	1.8
Bineng[3]	4.5	8.0	1.8[3]
Lon-oy	3.6	6.1	1.7
Bineng[1]	3.2	9.0	2.8[2]
Lower Labay	2.4	5.4	2.3
Bineng[2]	2.0	3.0	1.5[4]
Bineng[2b]	0.75	3.0	4.0[1]

Note: Jobs per MW at Bineng plants in descending order.
Source: Hedcor, undated.

5.6.4 Guatemala and Honduras

Both countries offer examples of small existing hydropower facilities whose capacity was expanded. In Guatemala's rural municipality of El Rodeo, an existing 400 kW plant was upgraded to 1.1 MW. This took place under a policy by the state-owned utility Instituto Nacional de Electrificación (National Institute of Electrification – INDE) to promote the connection of remote small hydropower plants into the national grid. The turbine and other equipment for the plant were purchased from an Italian-owned company manufacturing in Guatemala. Construction materials (wood, steel, cement, etc.) were purchased domestically. Construction employed 96 workers hired from the local community from 2008 to 2009. The O&M workforce at the hydropower plant comprises 14 persons: one manager, three engineers, and 10 operators and administrative personnel (IRENA, 2012).

In Honduras, the capacity of a run-of-the-river hydroelectric project in the department of Intibucá was raised in phases from 1.4 MW to 13.5 MW over a period of five years. As with the El Rodeo facility in Guatemala, electricity generated by the plant is fed into the national grid. Two local communities with about 1,200 inhabitants gained grid connection as a result of this project. From 2004 to 2008, more than 100 workers from the community were employed when the plant was constructed. The plant's turbines were purchased from an international supplier. Construction materials were sourced in Honduras, thus providing employment within the country. The O&M workforce comprises 83 workers (or six employees per MW of capacity): four managers, seven technicians, and 62 workers. In addition, specialized contractors are hired as needed for construction and installation tasks (IRENA, 2012).

6. Downstream employment impacts

Beyond the direct employment impacts of renewable energy deployment considered in the previous chapter, this chapter discusses downstream impacts; the economic and employment benefits that may arise when access to modern energy is improved or provided for the first time (Practical Action Consulting, 2012; Wilcox et al., 2015). It also specifically discusses the impacts on agriculture, communications, education and health.

6.1 Residential and productive uses of energy

A basic distinction concerns residential and productive uses of energy as described below:

- **Residential uses of energy** improve the quality of life and offer daily conveniences, and reduce household drudgery. Reducing the time spent on, for example, gathering fuelwood or other physically demanding household activities frees up time that can be spent on other pursuits, whether they be more leisure or income-generating activities (paid work). However, the shift in time use does not always translate into greater productive activity. Sometimes, free time is simply used to increase leisure and for social activities.

- **Productive uses of energy**, the use of electricity or mechanical power; can help enterprises improve their productivity, the quality of their products and services, thereby increasing sales and profits. This enables them to create new jobs and earning opportunities or improve existing earning activities that would not be possible without energy access. However, such opportunities depend on enterprises' access to capital (for expansion), adequate demand for such products and services, on the amount of capital to be invested, and other factors.

Productive uses require energy systems with greater capability than residential uses, such as provided by mini-grids (or by grid access). Higher tier electricity access (i.e. greater voltage) tends to be more conducive for employment generation. Most PV systems in rural areas lack the voltage to power machinery, and thus are mostly restricted to lighting purposes (Wilcox et al., 2015; MFAN, 2013).

In the context of the productive use of energy, UNDP distinguishes between "demand pull" and "supply push" conditions as the two principal pathways in which energy access can enable downstream employment. On the one hand, **demand pull** characterizes a situation in which the energy needs of an existing rural enterprise or of an entire rural industry stimulates the provision of improved energy services (replacing more expensive, less reliable, or insufficient sources of energy). Provision of new (renewable) energy thus secures existing jobs and enables the creation of new ones. On the other hand, **supply push** means that after energy access has been secured in a particular area, it helps stimulate economic activity and employment in rural enterprises and value chains (UNDP, 2012a).

Cabraal, Barnes and Agarwal (2005) argue against making too stringent a distinction between residential and productive uses, noting that, "any use of energy that contributes toward education, health, and gender equity should be considered a productive use of energy." Improvements in lighting, refrigeration, heating, and modern communications boost health and educational services. Access to modern energy also reduces the time spent (mostly by women and children) collecting fuelwood and performing household chores. The time gained "can be used on more productive activities, including the pursuit of educational, income-generating, and leisure activities. […] Generally, everyone agrees with the notion that healthy people are more productive" (Cabraal, Barnes and Agarwal, 2005).

Box 6. Investment and employment, DESI Power's EMPower partnership model

DESI Power is building and operating a number of rural power plants in rural India under its EMPower Partnership model. DESI Power installs hybrid power plants, which are locally suitable combinations of renewable energy technologies including biomass (for combustion, gasification, and charcoal), biogas, solar PV, solar thermal energy, and wind. The EMPower model is built on close cooperation between power generation, energy services, local micro-enterprises and farmers to develop appropriate technical and commercial solutions on the basis of local resources. The company's website offers information on what it calls the "performance metrics of a typical plant", some of which are presented in the table below.

Business activity	Investment (US$)	Direct jobs	Investment per job	Jobs for women (%)
Power plant	42 000	5.0	8 400	30
Mini-grid	7 500	2.0	3 750	30
Local business activities:				
Briquetting machine	9 000	2.5	3 600	50
Irrigation pumps	9 000	1.5	6 000	25
Rice huller	1 125	3.5	315	50
Chura mill	1 200	2.5	480	75
Flour mill	1 125	2.0	570	50
Fishery	3 000	1.0	3 000	–
Ice factory	10 500	5.0	2 100	30
Battery charging	300	1.0	300	75
Total, all businesses	**35 250**	**19.0**	**2 085**[1]	**45**

[1] Per job average value.

– = negligible.

Note: Original investment data in Lakh rupees converted into US$ by the author at a rate of 1 rupee = US$ 0.015.

Source: Adapted from DESI Power, undated

There are various ways in which energy access can translate into economic benefits and provide greater employment-generating opportunities. The following list provides a summary, and table 19 offers more detail, organized by type of energy use and energy technology.

- **More reliable energy supplies for existing businesses**. Economic benefits arise from the provision of electricity and mechanical power. This could simply mean avoiding situations in which existing, yet unreliable, energy supply cause problems, for example, blackouts or fluctuating voltage, which may damage appliances and other equipment. But there is also potential for productivity gains as presented in box 6 above.
- **Enabling new enterprises**. Where modern energy access becomes available for the first time, it may foster opportunities for new small businesses (restaurants, retail stores, mobile-phone charging, tailoring, weaving, carpentry/masonry, etc.). For existing local businesses, modern lighting allows extended opening hours (although this depends on sufficient demand), and thus enhances incomes.

- **Agriculture-related benefits**. Renewable energy can be used to enhance local agro-processing capacities, water-pumping and irrigation, which can boost productivity and raise agricultural yields. Food spoilage can be reduced through improved storage and refrigeration.
- **Communications**. Energy access makes available or improves communications (i.e. mobile phones), which in turn can facilitate economic transactions and assist in building rural markets.
- **Education and skill building**. Lighting expands the hours in the evening during which students can study in their homes. Electricity in schools enhances the educational experience. Better education leads to more skilled workers with the expectation of future income benefits.
- **Health and public safety**. Energy access can help improve the provision of clean water and sanitation, as well as better health care (cold storage for medicines, use of medical equipment requiring electricity). Another benefit is improved health through reduced indoor air pollution. Improved lighting improves public safety allowing people to be outdoors after dark, which may translate into greater economic activity.

Table 19. Economic development opportunities of renewable energy deployment

Type of energy use	Relevant technologies	New or enhanced economic opportunities
Lighting	Small solar, pico-wind, micro-pico-hydropower, biodiesel	• Extended business hours (higher incomes) • Extended hours for student learning (improved skills) • Creating new business opportunities
Cooking	Cleaner biomass stoves, biogas, solar cookers	• Sales and distribution of modern fuels and stoves • Time spent on fuel wood collection can be spent on other economic activities
Refrigeration	Larger scale solar PV and wind, micro- and pico-hydropower, biodiesel	• New markets for refrigerated products; reduced loss from agricultural and fishery spoilage (higher incomes) • Safe storage of medicines (better health translating into higher productivity)
Heating	Solar thermal water heaters, biogas, biomass	• Process heat for agro-processing, industrial processes • Improved comfort in commercial buildings and homes (higher productivity)
Information and communications	Solar PV, pico-wind	• Direct employment and income opportunities (Internet cafés, mobile-phone charging, radio stations) • Indirect benefits (improved business communications; access to real-time prices in different markets)
Irrigation	Pumps powered by biofuels, micro-hydropower, solar PV, wind	• Improved yields relative to rain-fed agriculture; higher crop production (greater income security; higher incomes) • Growing crash crops in addition to staple crops
Agro-processing	Biodiesel pumps, micro-hydropower, micro-grids, solar dryers	• Adding value by refining agricultural products; increased throughput and lower costs (higher productivity) • Less time spent manually grinding, pounding, etc.
Mechanical energy	Biodiesel pumps, micro-hydro	• Enabling welding and metal work • Improved carpentry • Time saved by mechanization (strengthened local economic base; productivity gains)

Source: Adapted from REN21, 2015; UNDP, 2012a

The benefits derived from energy access may be spread unevenly across rural communities. Practical Action Consulting (2012) cautions that in cases “where greater energy access increases automation and mechanization, this can make workers with less training and educational access redundant” . Since unskilled labour is typically provided by poor people, "greater energy access in enterprises can sometimes produce threats, at least in the short term, to poor people's ability to earn a living, displacing traditional employment opportunities." .

Another dimension that needs to be kept in mind with regard to downstream enterprises concerns the issue of whether an expansion of economic activity through energy access leads to an expansion in formal, paid employment or, as in other instances, continued reliance on members of the extended family. For instance, a study by Kooijman-van Dijk and Clancy (2010) focusing on Bolivia, the United Republic of Tanzania and Viet Nam concludes: "Employment opportunities as a consequence of access to electricity do occur but they consist mainly of flexible and unpaid involvement of family members, and real jobs are typically of a precarious nature …"

6.2 Impacts of electricity access on rural enterprises

How well do the points listed above hold up in practice? There is a substantial body of literature examining the economic impacts of energy access, much of it focusing on electricity access. However, a joint report by Practical Action Consulting, Institute of Development Studies, and TERI (Wilcox et al., 2015) indicates that 71 per cent of studies included in its literature review did not analyse employment impacts per se. The majority of the studies' objectives concentrated on assessing the creation of new enterprises, production increases, productivity, extension of operating hours, better product/service quality, and production costs. These obviously bear on the issue of employment, but only indirectly. In general terms, it stands to reason that positive developments with regard to income and poverty reduction are likely to translate into employment gains. Still, what emerges from the literature is that the linkages are often complex and influenced by factors beyond access to energy or electricity.

Concerning electricity access, a 2013 literature review concluded that, "there is some micro-level evidence on positive labor market effects of electricity use" . But the study also cautioned that, "results differ across time, across countries and in some studies across different segments of the labor force" (Mayer-Tasch, Mukherjee and Reiche, 2013). An earlier study (Maleko, 2005) examined micro-enterprises in three villages in Kilimanjaro, the United Republic of Tanzania, engaged in grain milling, furniture manufacturing, welding and tailoring. It found that, "the growth rate of microenterprises was noticeably higher in areas with electricity services than in areas without electricity services" . But it also concluded that the availability of electricity ended up creating more enterprises of the same kind, which led to market saturation rather than a sustainable expansion of economic activities.

In an assessment report of the work of FRES in a number of African countries (2013) refers to a general assumption that access to electricity can trigger a virtuous cycle of economic impacts. "Electricity use is expected to lead to more productive processes. Businesses and farms will grow using renewable energy, and this growth in itself will then increase demand for electricity, leading to a virtuous growth cycle profitable to both electricity providers and rural communities." The FRES report (2013) refers to multiple studies that have shown how electrification can stimulate micro-enterprise development, as long as other enabling elements such as finance and organized local markets are in place. The report notes that inadequate electricity supply is a major constraint to private enterprise development. Similarly, a 2009 enterprise survey in sub-Saharan African countries (Practical Action Consulting, 2012) referred to electricity as "the top elemental constraint on enterprise growth in 11 of the 30 countries surveyed, and second in nine more countries …,".

Among the rural businesses benefiting from electricity access due to the work of FRES in Mali, 70 per cent confirmed that they had gained from such access. About half cited the possibility to expand their business, while 10 per cent indicated the ability to operate for longer hours, and another 10 per cent said they were able to develop other small businesses. Two-thirds of FRES's small enterprise owners in Uganda indicated that business had improved. The most important reason others had not seen improvement was a lack of access to finance (FRES, 2013).

Among the potential benefits of energy access are productivity gains and the ability to operate a business for longer hours. Farmers and crafts people can process their products after dark and sell more during the day, shop owners can attract more customers to their shops in extended opening hours, and people can use savings to invest in their own small businesses (A.T. Kearney, 2014).

In Burkina Faso, a 2010 study by the International Fund for Agricultural Development (IFAD) noted that people using biodiesel-powered 'multifunctional platforms' have been able to extend working hours for farm-related activities (grinding cereals, de-shelling nuts, etc.) and support non-farm activities such as welding. Elsewhere in the country, tailors with access to electricity were found to work around 17 per cent longer hours per day than those without access. Similarly, small- and micro-sized enterprises in the service sector in Uganda with access to solar lighting work for about an hour longer, thus attracting more customers and increasing income. Still, positive outcomes depend on sufficient demand for products and services warranting longer opening hours (Mayer-Tasch, Mukherjee and Reiche, 2013).

6.3 Agriculture, communications, education and health

6.3.1 Agriculture

In the agricultural sector, energy access can provide a number of advantages, including improved processing, refrigeration, which reduces spoilage, water pumping, and others.

Kenya's tea sector is an example of demand pull. The sector consists of both large plantation companies and cooperatives of smaller-scale growers. According to UNDP (2012a), it employs some 800,000 people. Tea processing is energy intensive, and requires both thermal energy and electricity. The tea sector uses an estimated 1.3 million tons of fuelwood per year. Although most tea estates draw power from the national grid, reliability and supply costs are a problem, as is the fluctuating cost of diesel used for back-up generators. These problems have made renewable energy supplies an attractive alternative.

On the supply-push side, energy for agro-processing can improve the incomes for smallholder farmers. Farmers who sell only unprocessed crops typically receive only a portion of the price of finished products. As Practical Action Consulting (2012) points out, such processing can be done at the level of individual farms, but community installations (whether community watermills, multifunctional platforms, or mini-grids) offer economies of scale. In the Philippines, a coconut-processing cooperative involving some 200 families is an example of the successful use of renewable energy. This enterprise, which mostly employs women, has enabled employees to double their household incomes, and has made it easier for previously unemployed women to earn a regular income (Manapol et al., 2004).

Local processing and refrigeration of food helps reduce food spoilage. This improves small farmers' incomes and also generates additional local jobs. In India, for example, WWF-India and CEEW (2013) note that 100 solar food dryers with an annual processing capacity of 250 tons can generate 125 jobs. A project funded by the World Bank's "Development Marketplace" programme in cooperation with Solar Ice Company and Heifer Project International installed three solar icemakers in each of two rural communities in Kenya. With these icemakers, more than 100 farmers improved their ability to market milk, increasing their incomes, alleviating poverty, and contributing to food security (Erickson, 2009).

Renewable energy helps to reduce the drudgery of manual water pumping for irrigation and drinking water supplies (where mechanical or electric pumping is not available and where pumps are run with diesel, renewables provide a cleaner alternative). Typically, irrigation more than doubles agricultural yields compared with rain-fed farming. Renewable energy technologies ranging from solar PV systems, wind pumps to hydraulic ram pumps are available. Various types of PV pumping systems are in use across the developing world, typically consisting of a submersible pump, PV array, inverter, and a storage tank. Operating costs are very low, but high capital cost is the main barrier (IRENA, 2013).

In the Nalanda district of Bihar, India, solar water pumps were installed in 2012 to power 34 existing tube wells in 20 villages, inhabited by more than 3,400 families. The installed systems supply water to 1,600 acres of farmland. The project has created 45 direct and 80 indirect jobs (WWF-India and CEEW, 2013).

In Kenya, since 2009, the private company Grundfos has implemented more than 40 PV pumping demonstration projects (Grundfos Lifelink), benefiting about 100,000 people. Donors provided the initial investment, and user fees pay for water service. The projects also include training for community members (Meier, 2014).

In Ghana, since 2009, an EnDev project has supported efforts to improve productive uses of energy among small-scale farmers as well as in small-scale manufacturing, with irrigation (pumping energy provided by grid electricity and standalone solar PV) a major aspect. By 2015, the project had provided support for some 1,000 micro-, small- and medium-sized enterprises (MSMEs) creating approximately 3,000 employment opportunities (of which 417 MSMEs with 700 employees secured access to electricity for the first time) (EUEI PDF, 2015).

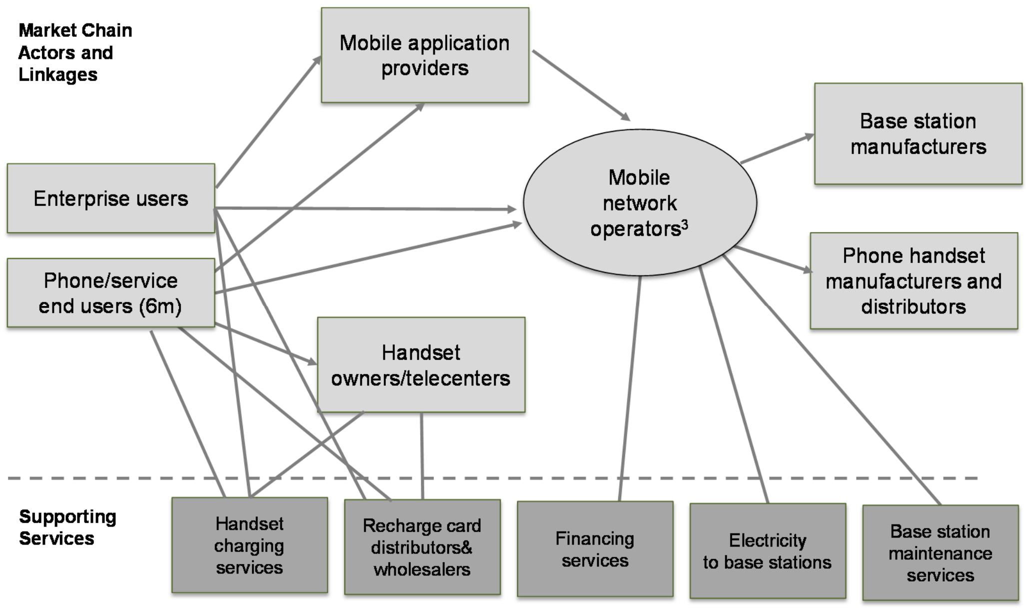
6.3.2 Communications

Energy access either improves, or makes available for the first time, mobile phone-based communications. Across the developing world, there are more than 640,000 off-grid mobile telecommunication towers (out of five million towers worldwide), mostly powered by expensive diesel generators. But solar PV offers an alternative source of power for telecommunications base stations as well as for charging hundreds of millions of mobile phones. Most mobile phone subscribers without grid access are in sub-Saharan Africa and South Asia. But in other regions, too, there are similar challenges. In the Caribbean and Latin America, 31 million people live without grid access, but have a mobile phone subscription (GSMA, 2013).

UNDP (2012a) points to macro-economic studies, which indicate that a 10 per cent increase in the number of telephone subscribers in a country contributes 0.6 per cent to growth domestic product (GDP). In rural areas, mobile phones have become service delivery platforms for agricultural, health, financial, and educational transactions. They are thus helping to expand economic activity and build rural markets, and therefore create new jobs (IRENA, 2013). A number of mobile payment systems have emerged, among them: M-Pesa in East Africa; MTN MobileMoney in Benin, Cameroon, Cote d'Ivoire, Ghana, Rwanda, Uganda, and other African countries; Tigo Millicom in Ghana, Guatemala, El Salvador, Honduras, Pakistan, Paraguay, Rwanda, the United Republic of Tanzania; and Easypaisa in Pakistan, among others.

Data from Zimbabwe (figure 7) highlight the employment potential. According to UNDP (2012a) estimates, the country's mobile phone operators directly employ 1,400 personnel, which is relatively few people, although many of them are well-paid jobs. Rural and urban mobile telecentres employ another 150 people. At least 15,000 people are involved in retailing mobile recharge cards (although probably not full-time). There are also some 500 street phone vendors who offer call services to people who do not own a phone.

Figure 7. Zimbabwe mobile telecommunications sector market map



Source: Adapted from UNDP, 2012a, p. 37.

Constructing the mobile base stations and towers needed for a mobile phone system offers additional employment. The largest operator in Zimbabwe, Econet, was thought to build one base station per day, with each site requiring at least 300 person-days of local unskilled labour. Together with other operators, annual employment in the country has been estimated at 108,000 person-days (and rural wages of US$ 1 million, at US$ 10 per day) (UNDP (2012a).

Emerging experience in India suggests that there can be important energy access co-benefits from the spread of a renewably powered cellular tower infrastructure. As of early 2013, 150,000 of the country's then 400,000 mobile phone towers were either located in off-grid areas or in areas with unreliable grid supply. The government has mandated that 50 per cent of the rural sites be powered by renewables by 2015 and 75 per cent by 2020, up from just 9,000 in 2013 (IRENA, 2015a). This reduces the economic burden on the government, which has heavily subsidized diesel. Diesel demand by the Indian telecom industry had been expected to rise from 3.2 billion litres in 2011 to 6 billion litres by 2020, but the new rules would save more than 540 million litres annually (Tweed, 2013).

Uttar Pradesh is India's most populous state with 200 million people (three quarters of whom live in rural villages). The **Omnigrid Micropower Company (OMC)** has been operating there since it was set up in 2011 building hybrid micropower installations, with a capacity of 50 kWp or less each, combining solar, wind, and biogas.[12] OMC has explicitly linked its strategy to telecommunications infrastructure. Mobile telephone towers thus serve as anchor customers, but it is the combination of anchors, other local businesses, and rural households that have made for a commercially viable business model (Almqvist and Rao, 2015). OMC's micropower installations grew from 10 at the end of 2012 to an expected 100 by the end of 2015. Each site employs 12–15 locally recruited workers. The company aims to have 500 facilities by the end of 2016 and 3,500 by 2018, providing a projected 10 million people with access to energy (Tenenbaum, Greacen and Siyambalapitiga, 2014). In 2015, Omnigrid and SunEdison announced a planned joint venture to build 5,000 micro-power plants in rural areas (Krishna, 2015). Applying the present per-site employment rate, this could translate into 60,000–75,000 O&M jobs, not counting construction employment.

African countries face similar challenges and opportunities: in 2014, 145,000 of 240,000 mobile phone towers were located in rural off-grid areas. Only 4,000 relied on renewable energy (IRENA, 2015a).

6.3.3 Education and health

Education and health are two factors that, while less immediately related to economic activity than the other factors discussed so far, do have an impact on how well an economy performs. In general, a more educated and healthy population can be expected to be more productive and fare better economically.

The lack of adequate lighting and other forms of modern energy severely compromise the quality of the learning environment in rural schools in the developing world. Some 140,000 schools in Africa alone do not have access to the grid, and this disadvantage is reinforced in homes that lack access to energy.

According to one recent assessment referenced in UNEP's study (2014), children in homes with solar systems are able to do twice as much homework a day as children who only have kerosene lighting in their homes. Education and literacy are important precursors to future employment and wages. Findings concerning longer hours of study and higher educational attainment are replicated elsewhere (FRES, 2013). Similarly, a literature review on the impacts of energy access published by the Dutch Foreign Affairs Ministry (MFAN, 2013) concluded: "Eight out of 10 evaluations indicate that in households with electricity, children do study more at home and both school enrolment and number of years at school completed increased." Interestingly, however, better school performance was not so much associated with additional study hours at home, but rather with schools' access to electricity, "enabling the school to attract better teachers and to offer better education."

A FRES report (2013) found that: "Although the availability of electricity in households per se seems to have no significant effect on adults' and children's propensity to read and study (i.e., whether or not they wanted to study), once individuals choose to read or study, electricity was found to increase the time children spent studying by 77

[12] OMC's experience indicates that a 50 kW peak (kWp) PV installation plant with battery storage is able to power a range of small businesses, schools, health centres, two telecom towers, and over 500 homes (Rao, 2016).

minutes and the time adults spent reading by 27 minutes per electrified household per day, compared with non-electrified households."

More time spent studying and greater educational attainment is likely to translate into better economic prospects, higher incomes and better jobs.

Regarding health, World Bank macroeconomic data indicate that the level of electrification is very closely related to the health expenditure per capita and hence the quality of health care (FRES, 2013). Across the developing world, an estimated 1 billion people are served by health facilities that have no access to electricity. This puts severe limitations on health care. For example, health facilities cannot operate at night, and sophisticated medical equipment cannot be used. Another issue concerns the refrigeration of medical supplies. At present, rural clinics rely on some 100,000 kerosene vaccine coolers, but they lead to local air pollution and cause dependence on supplies that may not be reliable. According to IRENA (2013), off-grid renewable energy applications, such as solar vaccine coolers, are essential in improving rural health-care services.

6.4 Enabling factors

Some analysts, such as Kooijman-van Dijk (2012) and Rao (2013) argue that detailed understanding of the economic impacts of energy access (such as economic growth and income generation) need greater study, due to the complexities of causal chains. One difficulty, as Rao points out, is that regional or local case-specific studies make generalizations difficult. Also, most case studies cover very small numbers of households, and it is difficult to know whether micro-scale local circumstances are sufficiently similar across the developing world to enable wider conclusions to be drawn. Further, the needs and characteristics of different rural enterprises (such as fruit processing, flour milling, tailoring, etc.) vary in the degree to which they are likely to benefit from the provision of modern energy services (Wilcox et al., 2015).

There is broad agreement in the literature that **"**energy is a necessary, but insufficient condition". Among the additional enabling factors are availability of finance, knowledge and skills, and access to markets (which relates to location, physical access through roads, as well as appropriate social networks). The *Poor People's Energy Outlook 2012* (Practical Action Consulting, 2012) adds "access to resources, conducive regulatory environments, managements capacity, and other" to this list. Cabraal, Barnes and Agarwal (2005) argue that an even broader context is necessary as a frame of reference: "… energy in the context of failing schools, poor health facilities, and poor water supply will not lead to development" . Below, we consider some of these factors.

6.4.1 Knowledge and skills

Skills are an obvious enabling factor, and are particularly important with regard to electricity. In a study Wilcox et al. (2015) write: "Low skill levels and capacity act as a barrier to local people securing economic benefits through involvement in electricity provision. Knowledge of the benefits and possible productive uses of electricity is key in the take up of electricity access, and potential users also need the skills to operate and maintain electrical machinery. Finally, entrepreneurial skills are required to identify new opportunities created by electricity access, create new enterprises and find and access markets for the new products and services provided." Cabraal, Barnes and Agarwal (2005) agree that, "machines must be used by educated and healthy people to be effective in promoting development and improving income."

6.4.2 Access to markets

Access to markets is being identified as one of the key factors. Energy access may enable rural enterprises to expand their production or improve the quality of their products and services, but it will matter only if they are able to reach more customers, which typically means that they have to gain access to markets beyond their local customers.

However, a study for the Dutch Ministry of Foreign Affairs (MFAN, 2013) regards one of the key challenges as "the 'insular nature' of many small businesses; the 'constrained rural markets'; the lack of electrical equipment that enables a producer to make use of the power."

The *Poor People's Energy Outlook 2012* (Practical Action Consulting, 2012) explains: "Most micro-scale enterprises sell to local markets. In rural areas with high occurrence of poverty, the local customer base is limited and customers have low expenditure flexibility. For new enterprise products and services, and also for increased volumes of production, saturation of local markets is a risk, and disappointing profits due to fast emerging competition in case of successful introductions of new products or services is a widespread phenomenon."

Similarly, Wilcox et al. (2015) write: "In the absence of adequate access to external markets, demand in rural areas is often constrained and unable to absorb additional production, leading to market saturation with new and newly electrified enterprises simply competing with existing and un-electrified firms for the same overall "pool" of value. In the absence of access to wider markets, the availability of additional labour freed-up by electrification is likely to simply drive down wages and the prices of goods and services produced informally so that even those able to use additional time productively may well not see any increase in incomes."

6.4.3 Location and equity

However, not all rural enterprises face the same dilemma. There are differences, and inequities, in their ability to take advantage of energy access. Kooijman-van Dijk and Clancy (2010) point out that "Modern energy access is not only generally gained earlier by households and enterprises with better financial starting positions and assets, but also in villages with better conditions for enterprise development such as larger concentrations of population and locations along roads" . They conclude: "Not surprisingly it is the wealthier members of communities who benefit most. They are already well placed to take up modern energy carriers and are already running enterprises".

6.4.4 Social networks

Kooijman-van Dijk (2012) argues that, "the stimulation of access to markets should focus on social rather than (only) physical access, as the social distance is at least as inhibitive as the physical distance." This relates to a point raised earlier, namely the danger that purely local markets are easily saturated. Social skills and networks are essential "to access new markets and business and technical skills to innovate products. Without such skills and networks, the impacts of modern energy services remain largely in the domain of comfort and flexibility of operation, with only small or no positive impacts on income generation for the typical rural entrepreneurs."

The *Poor People's Energy Outlook 2012* (Practical Action Consulting, 2012) concurs: "For poor entrepreneurs without social networks based in larger markets in towns or with middle or high-income customers, it is practically impossible to understand and serve external market demands, including trends and keeping up with latest developments and standards. For this reason programs supporting energy access to rural MSEs should always integrate a market demand-side element based on an assessment of the overall market system, and in particular demand volume and characteristics."

7. Conclusions

Renewable energy technologies are having an increasing socio-economic impact due to growing technical maturity and falling costs. Efforts to improve access to energy in the rural areas of developing countries are accordingly proliferating. Much of the available literature about existing initiatives and ventures focuses on technical aspects and financing questions, leaving the employment dimension comparatively unexamined. There is an uneven patchwork of data and information on job creation as well as on future employment potential. One handicap in any assessment is that many of the relevant projects and enterprises are still quite recent. Thus, with few exceptions, there is little in the way of robust data (and especially time-series or other long-term values) to draw upon.

This report has examined three ways in which the deployment and use of renewable energy translates into employment impacts in rural areas of the developing world:

- Conventional forms of biomass (gathering of fuelwood and processing, trading and retailing of charcoal.
- Large-scale wind, solar and biofuels projects (even though the energy generated itself is destined for urban or export markets).
- Decentralized, small-scale deployment of renewables at the household, village and small enterprise levels (solar PV, biomass and small hydropower; too little information is available for small wind projects). Solar PV projects are receiving by far the most funding and analytical attention in the literature, and this fact is inevitably reflected in this report.

7.1 Fuelwood and charcoal

The economic importance of fuelwood and charcoal in many developing countries is hard to overstate. Globally, the livelihoods of perhaps 30 million people, some 13 million of whom live in sub-Saharan Africa, depend on the fuelwood and charcoal supply chain. Rendering this supply chain more sustainable is a critical task, requiring: better woodland management and agroforestry practices; afforestation and reforestation efforts; improved energy efficiency in generating charcoal; and improved cookstoves. However, on the one hand, more efficient charcoal kilns reduces the amount of wood required per unit of charcoal produced, thus reducing the number of people needed to grow, gather and transport the wood. On the other hand, positive employment impacts are likely to emerge especially if they are accompanied by adequate training, micro-loans, and other support measures, such as secure land tenure and associations of charcoal producers, which would increase people’s bargaining power. This supply chain needs to be pursued with as much vigour as the deployment of modern forms of renewable energy.

7.2 Large-scale renewable energy projects

The employment impact of large-scale projects in rural areas can be ascertained from individual case studies and impact assessments. The extent and nature of employment depends strongly on the scale of deployment. While large-scale projects obviously employ more people overall than smaller ventures (on a per-unit of capacity basis), smaller deployments tend to require more people per unit of output. From an employment perspective, it is preferable to have a larger number of small projects rather than a small number of very large projects.

This report examined cases of wind and solar projects in Jordan, Kenya, Mexico and Morocco. In each case, rural areas can benefit from employment generation in construction and related activities (including induced jobs from the spending of construction wages). But these are temporary benefits, and residents of local communities can expect to be hired mostly for unskilled or low-skilled jobs, whereas more technically advanced jobs go to workers from outside the area in question. Jobs are much more limited during O&M than during the construction phase.

The experience with wind development in southern Mexico and with numerous biofuels projects in various countries also suggests that a broader livelihoods perspective needs to be employed in order to assess the economic impact on rural communities. Biofuels plantations in particular can occupy substantial stretches of farmland. Incomes derived by rural communities from leasing land to biofuels companies may be insufficient to offset the loss of food and income from the land. Contract terms are critical to the outcome, though rural communities are often at a disadvantage in negotiations with companies. Meanwhile, jobs on biofuels plantations are often seasonal and low skilled. Experience suggests that communities tend to fare better when farmer cooperatives enter outgrower arrangements (avoiding outright land acquisition by biofuels companies), and when communities manage to build local supply chains.

7.3 Decentralized renewable energy projects

Chapter 5 of this report examined the employment aspects of a range of solar, biomass, and small-scale hydropower projects. Generally, employment-related information for these projects is limited, but this is more the case for biomass and hydropower (and even more so for small-scale wind) than for solar projects.

A range of entities are involved in the funding side (national, multilateral and donor agencies, micro-credit organizations, and private investors) as well as on the operational side (NGOs, cooperatives, entrepreneurs, United Nations agencies, government entities, social enterprises, and commercial companies, which could be either established companies or start-ups). Presumably, the varying parameters, scales and institutional arrangements will impact employment generation, although more information is needed to reliably analyse differences in impact.

In the solar PV field, a state-directed, NGO-implemented, and international donor-funded programme in Bangladesh has been extremely successful in deploying SHSs and creating large numbers of jobs. As this report discussed, it offers a number of lessons for similar efforts elsewhere, although some factors of success are specific to Bangladesh and may not be easily replicable (for example, the country’s long track record with rural micro-credit organizations is fairly unique). The SHS programme succeeded due to strongly defined parameters, which emphasized commercial viability, and the quality control of equipment and installations.

The other major approach that is now emerging is found in a number of commercial start-ups operating under PAYG or FFS models. While the number of solar systems installed by these ventures is still far fewer than in Bangladesh, they are expanding fairly rapidly. Household affordability and commercial viability are as central to these efforts as they are to Bangladesh’s initiative. The major innovation is the use of mobile phone apps, which allow customers to make incremental payments and permit the companies to monitor the systems in use and offer troubleshooting as needed. To date, the PAYG approach is dominant among these new ventures, but more experience with both models will be needed before it is possible to judge which one is more suitable (and what impact it will have on employment creation).

Among small hydropower facilities, there is also a range of different institutional set-ups and driving forces. In some settings (such as in Nepal, which has a considerable number of micro-hydropower plants), the community approach is key, and this means that people from the community are involved both in decision-making and O&M. This is in contrast to other approaches that rely on a local entrepreneur to take care of these tasks. Employment information about these kinds of projects is scarce, but it appears that in the community approach, the necessary labour is shared, whereas an entrepreneur may rely either on family members or local workers. Elsewhere, especially at the upper end of the small hydropower field, commercial companies are key actors. They employ local workers during the construction phase, and a few during the operational phase. However, workers from outside the area often fill skilled positions.

With regard to biogas facilities, there is a similar spread of approaches, ranging from a state-directed approach in China to one focusing more on the communities' efforts, which are often assisted by international NGOs. There is a relative dearth of information about the employment implications, which makes it difficult to make reliable observations about which of these approaches is more beneficial with regard to employment generation. It is clear, however (for example, from the experience of India), that quality control and skills training are essential for biogas facilities to function reliably. The experience in a number of Asian countries shows that skill building and local enterprise development efforts are critical not only for setting up household- and community-scale biogas plants, but also for creating a local supply chain and downstream activities.

Across the various renewable energy technologies, mini-grid installations offer greater local employment opportunities than standalone household units do, which mostly focus on lighting and mobile-phone charging. In the first place, building a mini-grid involves greater scale and complexity, and requires appropriate wiring and other infrastructure within a given community, and more labour. But mini-grids also offer greater power and versatility than a household system, providing a broader array of energy services needed for agro-processing and other local enterprises and stores. Thus, there is greater scope for downstream employment. However, data gaps prevent reliable employment and livelihood assessments. Case studies of various types of mini-grids could shed light on this dimension.

Several dimensions are critical in interventions to provide or improve rural communities' access to energy. Table 20 offers an overview of the ways in which they impact employment generation:

(a) financing arrangements (sources of funding, types of financing);

(b) technologies and designs (material inputs and suppliers, scale of infrastructure, issues of imported versus local content);

(c) implementation approaches (distribution and retail, construction and installation);

(d) maintenance arrangements (including quality control).

Given the prominence of off-grid solar PV ventures in the field of energy access, table 21 offers more detail on this particular technology. It summarizes employment implications specifically for the growing variety of commercial solar start-ups, particularly, but not limited to, the countries of sub-Saharan Africa. These observations should be seen in tandem with the lessons that emerge from the experience in Bangladesh, where a more state-directed effort has proven successful.

Employment opportunities in rural areas are predominantly found in sales/distribution, installations, and O&M of standalone projects and mini-grids, since the bulk of equipment manufacturing takes place elsewhere in the world. This report has sought to marshal available information regarding such employment opportunities. However, as stated earlier, appropriate data are still relatively limited, and are only available on a project-by-project or an enterprise-by-enterprise basis.

It is possible to generate some approximate employment estimates; i.e. personnel needed per unit of capacity or sales, and this report presents a number of them for various projects and enterprises, mostly in the solar field. But at this early juncture, it remains to be seen how valid they are. Over time, labour efficiencies and productivities are likely to increase, as operations become more mature and learning curves are navigated. However, it seems unlikely that there will be massive productivity improvements, given that customers in rural areas are dispersed in relatively small and sometimes remote locations.

Thus, it is important to generate additional and improved data on employment in distributed renewable energy projects (mini-grid and standalone systems). As solar, hydropower and bioenergy ventures become more established and are scaled-up it will be critical to assess how labour requirements will change. Enterprise surveys and project evaluations can provide such insights but what is also needed is a better sense of future requirements for local skills, and for skills and capacity building. Ultimately, these data are as critical to success as is ensuring proper financing, and developing reliable and affordable products for people living in rural areas.

Table 20. Major determinants of employment generation in rural energy access efforts

Determinants of employment generation	Solar PV	Biomass	Small hydropower
Financing	• Micro-credit for SHS programme to create a commercially viable market; employment for micro-loan officers (Bangladesh) • Financing for commercial enterprise start-ups (PAYG and FFS models)	• Government or commercial financing for biogas digesters and biomass power plants • Subsidies, loans, and micro-credit for household- and village-level biogas digesters	• Multilateral development agency funding to support community micro-hydropower plants (Nepal) • Government funding or commercial project finance (debt, equity) for grid-connected facilities
Technologies and inputs	• Solar equipment (panels, lanterns, LEDs, etc.) is mostly imported, thus limiting domestic employment opportunities • Limited domestic assembly is taking place in some countries • Local employment in producing frames, mounting structures, accessories, etc., for solar systems	• Substantial employment in growing and harvesting of biomass, gathering of agro-wastes • Biofuels: issues of scale; plantations versus out growers); few jobs in feedstock processing • • Better local outcomes through farmers' growing cooperatives and development of local value chains • Biogas: manufacturing appliances offers substantial employment • Charcoal: cutting/gathering of wood entails substantial informal labour	• Larger, more complex turbines and generators are typically imported, thus, limited domestic employment • Smaller turbines, penstock pipes, and accessories for micro-hydropower plants may be locally fabricated or assembled (need for enterprise development programmes)
Implementation approaches	• Considerable employment in distribution, retail, and installations of household- or enterprise-level SHS • Different last-mile distribution models to reach remote customers (reliance on existing stores vs. sales agents working on commission) • Additional labour requirements for building mini-grids (construction, power lines)	• Biogas: building household and village-scale plants is labour intensive (need for masons and technicians), but employment may be informal • Biomass power: employment at rural enterprises (such as sugar mills and other agro-processing) • Charcoal: large-scale (but informal) employment in processing, transporting, and retailing	• Considerable, but time-limited employment in construction activities (including infrastructure, access roads, watershed management and terracing) • Project development for larger facilities requires some highly skilled external labour • Grid-connected plants require additional labour for building transmission lines/stations

Determinants of employment generation	Solar PV	Biomass	Small hydropower
Maintenance arrangements	• Bangladesh: employment for quality control inspectors, village technicians • FFS: emphasis on energy services, thus great importance given to reliable equipment (after-sales service jobs) and training of local technicians • PAYG: emphasis on equipment sale, but reliability and after-sales service (trained local technicians) still important	• Biogas digesters: adequate construction-related training and servicing needed to ensure plants remain functional • Charcoal: no maintenance activities required, but management of woodlands (including afforestation/reforestation) requires substantial amounts of labour; plus: employment opportunities for improved cook stoves (may be imported)	• Management and engineering jobs may be filled by external labour • Smaller scale plants require fewer operations personnel than larger plants (but more jobs per unit of capacity installed) • Some initiatives (Nepal) are characterized by strong community involvement (shared responsibilities and work/training needs) • Elsewhere, entrepreneurs or commercial enterprises play key role (fewer jobs but FTE)

Source: Author's elaboration.

Table 21. Typologies of off-grid enterprise models and employment implications

Typology	Description	Implications for employment
Standalone systems		
Distribution:		
Retail	• Network of franchise shops	• These are likely to be located in market towns and be smaller in number; limited employment (but likely FTE)
Direct marketing	• Independent (village-level) sales agents working on commission; “last-mile” distribution	• Larger number of agents than under franchise shop model, but may not be FTEs
After-sales service:		
Full service support	• Company technicians visit customers' homes for servicing	• More people needed than under service centre model; ease of servicing arrangement may gain greater number of customers (and thus contribute to growing employment over time)
Service centre	• Customers required to travel to authorized centre for maintenance	• Fewer technicians needed than under full-service support model
Sell only	• No explicit service/warranty commitment	• No dedicated staff for servicing; customer trust likely limited, clouding prospects for longer term sales and employment
Payment options:		
Upfront payment	• Off-the-shelf purchase; no financing	• Limiting the range of households able to afford equipment, and thus capping employment prospects
FFS	• Customer pays daily or weekly fee for energy (lighting, charging), but does not own the equipment	• Well-functioning, reliable equipment is key, putting a premium on adequately trained staff; but lack of ownership may limit longer term customer loyalty
PAYG	• Customer pays regular fees toward ownership of the equipment	• Tailored to customer's ability to pay (enabling a growing market, and employment); “energy ladder” (buying more powerful systems over time) supports employment generation over time
Mini-grids		
Institutional set-up and management:		
Community-managed	• Responsibility shared by community members (with agreed costs, shared maintenance costs, etc.)	• Community members may be designated to serve on management boards; maintenance tasks may be shared among residents (part-time)
Entrepreneur	• Responsibility rests with a local entrepreneur (delegated or self-initiated)	• Entrepreneur and local hires are likely to be FTEs
Commercial business	• An outside (larger) business builds and operates the mini-grid	• Depending on the complexity of the facility, jobs may go to workers from outside the community, though training may be provided for locals

Source: Author's elaboration.

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www.ilo.org/strengthen

International Labour Office
Development and Investment Branch
4 Route des Morillons
CH-1211 Geneva 22
Switzerland
Email: devinvest@ilo.org

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