SMART VILLAGES

New thinking for off-grid communities worldwide

The Smart Villages Initiative: Findings 2014-2017

Smart Villages

We aim to provide policymakers, donors, and development agencies concerned with rural energy access with new insights on the real barriers to energy access in villages in developing countries—technological, financial and political—and how they can be overcome. We have chosen to focus on remote off-grid villages, where local solutions (home- or institution-based systems and mini-grids) are both more realistic and cheaper than national grid extension. Our concern is to ensure that energy access results in development and the creation of "smart villages" in which many of the benefits of life in modern societies are available to rural communities.

www.e4sv.org | info@e4sv.org | @e4SmartVillages

CMEDT - Smart Villages Initiative, c/o Trinity College, Cambridge, CB2 1TQ

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Summary

In the Smart Villages concept, the provision of sustainable energy services to rural communities, in turn enabling the connectivity made possible by modern information and communication technologies, can have a catalytic impact on the lives of villagers when appropriately integrated with other rural development initiatives. Smart villages provide many of the benefits of 21st Century life to rural communities, and reflect a level of rural development consistent with achieving the Sustainable Development Goals.

The aim of the Smart Villages Initiative over the period 2014-2017 has been to identify the framework conditions necessary for the provision of energy services to villages to enable the livelihood opportunities, provision of services (healthcare, education, clean water, and sanitation) and empowerment embodied in the Smart Villages concept.

This report summarises the findings and recommendations arising from the work of the Smart Villages Initiative over the three years, which has included a series of 26 workshops and capacity building events in six regions (East and West Africa, South and Southeast Asia, South America, and Central America, the Caribbean, and Mexico) involving frontline workers (entrepreneurs, NGOs, development organisations, villagers and civil society organisations), policy makers and regulators, the finance community, and international experts in science, engineering, and the humanities. These workshops in the regions have been complemented by competitions, webinars, impact studies, media and Forward Look workshops, and reviews of the literature.

Strong support has been expressed for the smart villages concept throughout the engagement activities, not least for its ambitious vision for rural development, and its concern to take an holistic, village-level approach in which energy access initiatives are closely integrated with other development initiatives. Only through such integration can the full development benefits of energy access and synergies with other sectors be realised. This is essential as attainment of most of the Sustainable Development Goals in rural communities relies on energy access.

Three core chapters of the report (Chapters 5 to 7)—on energy access, on the effective use of that energy to support development, and on cross-cutting issues—identify the main findings and conclusions arising from the activities of the Smart Villages Initiative and provide links to the wealth of underpinning information that has been amassed. Recommendations are presented at the end of each of these chapters. Key points are summarised in the following paragraphs.

At the village level, the development agenda and associated actions should be driven by the villagers, mentored and supported by development bodies, NGOs, etc. However, all players—villagers, entrepreneurs, NGOs, civil society organisations, policy makers and regulators, development organisations, financiers, researchers, etc.—have important roles to play. They need to achieve much better levels of coordination and collaboration if smart villages, and consequently the Sustainable Development Goals, are to be achieved.

Nationally, clear, supportive, coherent, and stable policy and regulatory frameworks which bring together the interests of the relevant ministries should be put in place. They need strong political backing, the necessary resources and actions to deliver them, and to be based on careful analysis of the realities, not just wishful thinking. A stronger sense of urgency is needed across the board to achieve the Sustainable Development Goals by 2030.

Substantially enhanced rates of financing are needed, not just for energy access but for all key components of village development. Access to private sector funding at affordable interest rates is essential, and requires innovative approaches to risk mitigation and to building the confidence of the private sector to invest in order to maximise the leverage of government and donor funding. Ways need to be found, for example through project bundling, to reduce the transaction costs of the developers and their financiers for the large numbers of village-level projects that are required to supply and productively use off-grid energy. Where subsidies are used, they should be well targeted and time limited.

Governments and government bodies should continue to invest in increasing awareness of the opportunities arising from modern technologies to supply and use energy, in building skill levels across all relevant value chains, in providing support and advice to entrepreneurs and small businesses, in setting and policing quality standards, and in university research which responds to the needs of, and is well linked to, frontline delivery.

In respect of energy provision to villages, the focus has been on local generation, in particular solar home systems and mini-grids. Big reductions in the costs of solar home systems, improvements in the efficiency of domestic appliances, and innovative business models using pay-as-you-go approaches have made it possible to provide basic levels of electricity to households in off-grid villages at prices that many can afford. Costs of solar home systems will continue to reduce, extending the range of households that can afford them and the level of services they can support. The lessons from the successful commercial deployment of solar home systems in East Africa, and the government-led scheme in Bangladesh, should be disseminated to other regions where progress in home-based electricity supply has been slower.

The main motivation for the step up to the levels of electricity services that mini-grids can supply is to support the establishment of productive enterprises in villages. In general, the revenues generated by mini-grids do not match their costs, and there has not yet been widespread scale-up from pilot plants to extensive deployment. Actions are required (and identified in Chapter 5) to reduce costs and increase revenues so that subsidies can progressively be reduced and the deployment of mini-grids can be substantially accelerated. Effective community engagement and ownership is essential to the viability of mini-grids.

Progress on dissemination of clean cooking technologies has lagged behind that of electricity access. The health impacts of traditional cooking methods are a major concern: R&D programmes should be stepped up to develop improved cookstoves capable of achieving the low levels of emissions necessary to significantly reduce health impacts. Initiatives on clean cookstoves should aim to establish an effective ecosystem of players along the value chain, and put in place systems to enhance product quality. Cookstove designs should be tailored to local cooking customs and methods; and as for other energy access issues, the concerns and contributions of women should carry equal weight to those of men.

In order to maximise the value derived from energy access in enabling productive enterprises in villages, and to create and capture more value from agricultural value chains, key players (including the relevant government ministries) need to work more closely together to analyse market opportunities and barriers, and to put in place initiatives to address them. Micro-enterprise zones in villages, providing local enterprises with key services, have been successfully piloted and should be rolled out more widely to nurture new enterprises and provide a supportive environment in which they can grow.

For farmers, more attention should be given to the dissemination of information and research findings on how to increase productivity and the value derived from agricultural products.

Initiatives on energy access for schools and health centres should be integrated with other related initiatives to tackle more general shortfalls in resources, staffing issues, etc., and to make the necessary investments in the energy-reliant equipment which can enhance the quality of education and healthcare in villages. This requires collaboration between ministries responsible for energy, education and health. The focus should be on the health and educational outcomes, requiring energy access to be addressed for the village as a whole. Attention should be given to the long-term sustainability of energy access initiatives for schools and health centres, requiring arrangements for operation and maintenance to be in place together with the necessary long-term financing, including for equipment replacement.

Smart villages can become more resilient to natural disasters provided that the various players responsible for the key components of the infrastructure of villages, including the villagers themselves, come together to identify the vulnerabilities and to develop the physical infrastructure and social capital of the village to address them. The opportunities provided by energy access and modern information and communication technologies should be used to develop the knowledge and skills of the villagers in respect of mitigating risks, and to support the sharing of knowledge and experiences between rural communities.

Chapter 1: Introduction

This report presents the findings of the Smart Villages Initiative over the period 2014-2017. As explained in more detail in the next section, smart villages provide many of the benefits of 21st century life to rural communities, and reflect a level of rural development consistent with achieving the Sustainable Development Goals (SDGs). Building on the catalytic impact of sustainable energy services, in turn enabling the connectivity made possible by modern information and communication technologies, residents of smart villages lead healthy and fulfilling lives, achieve their development potential, earn a decent living, and are connected to the outside world.

The aim of the Smart Villages Initiative over this three-year period has been to identify the framework conditions necessary for the provision of energy services to villages to enable the livelihood opportunities, provision of services (healthcare, education, clean water, and sanitation) and empowerment embodied in the Smart Villages concept. Such framework conditions include policies and regulations, the business environment, access to finance, and development of skills. As noted in the International Energy Agency's 2016 World Energy Outlook (IEA 2016) in respect of access to sustainable energy services, 'countries can make a major difference with good policy choices and political will'.

New insights into the challenges and opportunities have been generated by a series of engagement activities in six regions (East and West Africa, South and Southeast Asia, South America, and Central America, the Caribbean and Mexico) which have brought together the key players in the provision and use of village energy for development to discuss the issues. A core component of the engagement programmes has been a series of 26 workshops and capacity building events in the six regions involving frontline workers (entrepreneurs, NGOs, development organisations, villagers, and civil society organisations), policy makers and regulators, the finance community, and international experts in science, engineering, and the humanities. These workshops in the regions have been complemented by competitions, webinars, impact studies, and media and Forward Look workshops.

Taken together, these workshops and events, augmented by a series of literature reviews, have provided a rich source of information and bottom-up 'views from the frontline' on which this report draws. Annex 1 provides a listing of the engagement events. Reports, policy briefs and presentations from the workshops, together with a book of essays and a set of technical reports addressing key topics, are available on the Smart Villages website www.e4sv.org. Throughout the report, links are provided to this underpinning material.

In respect of approaches to the provision of electrical services to rural villages, the main focus has been on local solutions generating power at the level of the individual household/enterprise or village, rather than through national grid extension which is often more costly or geographically impracticable. An evaluation in 2011 by the International Energy Agency of how best to achieve universal electricity access by 2030 (IEA 2011) concluded that 70% of the required new connections in rural areas should be made with local solutions off the national grid (of which 65% would be mini-grids and 35% stand-alone off-grid solutions—typically solar home systems). An important theme of this phase of the Smart Villages Initiative has been an evaluation of the role of entrepreneurs in providing energy services and in establishing productive enterprises made possible by energy access.

The activities of the Smart Villages Initiative have been undertaken in collaboration with a range of partners. Of particular note have been the partnerships with the national science academies and their networks around the world. Collaboration with Practical Action has also been valuable in providing access to the organisation's wealth of hands-on experience of rural development.

The opening chapters (2 to 4) of the report set out a vision for smart villages, review the current status of rural villages in the developing world, and summarise the policy context. Chapters 5 and 6 then summarise what has been learned from the Smart Villages programme in respect of the opportunities and challenges of providing sustainable energy services to rural communities, and the issues around reaping the development benefits of such rural energy access. Key crosscutting issues are addressed in Chapter 7. Taking a step back, Chapter 8 reflects on the actions necessary to make smart villages happen. The main body of the report is completed by Chapter 9 setting out final conclusions.

As indicated above, Annex 1 provides a listing of the engagement events. Annex 2 summarises the links between rural energy access (a key focus of Sustainable Development Goal 7) and the other Sustainable Development Goals: energy access is a prerequisite for achieving most of the Sustainable Development Goals.

Chapter 2: The Smart Villages Vision

The proportion of the world's population living in cities has increased from 30% in 1950 to 54% in 2014, and is projected to increase to 66% by 2050 (United Nations 2014). Africa and Asia are urbanising faster than other regions but for now are still mainly rural. However, because of overall population growth the absolute numbers of people living in the countryside has been rising slowly and is anticipated to peak in a few years' time at 3.4 billion, declining only slightly to 2050 (United Nations 2014).

So the living conditions and prospects of rural populations will remain a key global concern for decades to come. Growth in rural economies will be a major factor in the overall economic growth of developing countries (Ravallion 2008; IFAD 2016), and the development of rural communities will play a central role in achieving the Sustainable Development Goals (discussed in Chapter 4). While the world's rural population is currently around half of the total, it accounts for 70% of the world's poor. So if the central missive of the Sustainable Development Goals, to 'leave no one behind', is to carry weight, the development of rural villages must be placed 'centre stage'.

Cities too will remain important drivers of development and poverty reduction (UN Habitat 2011). Economies of scale and agglomeration in cities result in higher productivity and hence higher wages (Duranton 2014). Increased efficiency results from concentration of economic activity. Such economies may be generated internally by firms (they can set up large plants giving internal production efficiency gains), may be shared by firms in the same industry (for example, they share a common skilled labour force and suppliers), or may be more generally available to producers in a large urban area (good infrastructure, efficient finance, specialised services, etc.) (Struyk and Giddings 2009). Concentration effects may take the form of physical flows (for example, the transfer of goods and materials between companies) and knowledge flows, the latter resulting in innovation and the diffusion of innovations. Congestion may counter economies of agglomeration beyond a certain scale.

In addition to the prospect of jobs and higher wages, cities are attractive to villagers in offering better healthcare and education, a wider range of entertainment and cultural opportunities, and the prospect of escaping social norms perceived to be limiting.

But the reality for many people who migrate to the cities in search of a better life falls far short of expectations. In 2014, globally 30% of the urban population lived in slums and informal settlements, 55% in sub-Saharan Africa. Problems are particularly acute where there is 'over-urbanisation' or urbanisation without growth (Struyk and Giddings 2009). And environmental problems continue to grow in cities: for example, in 2014 around half the global urban population was exposed to air pollution levels at least 2.5 times higher than maximum standards set by the World Health Organisation (United Nations Economic and Social Council, 2016).

A key underlying proposition of the smart villages concept is that technological advances, if effectively integrated with other rural development initiatives, can create new possibilities to increase incomes, provide services, and empower communities that substantially enhance the quality of village life. This will shift the balance of opportunities, and hence distribution of populations, between villages and cities (van Gevelt and Holmes 2015). New technologies provide sustainable and affordable power, in turn enabling modern information and communication technologies (ICT) to connect villagers to the rest of the world and its knowledge base, helping to overcome the barrier of distance.

Farming will continue to provide the bedrock of livelihoods in many rural communities. In smart villages, agricultural productivity will be substantially increased providing food security and surpluses that can be sold. This will be made possible by a range of modern agricultural practices including energy-enabled precision irrigation and fertiliser application, access to weather forecasts and better advice on crops and farming techniques, early diagnosis and treatment of pests and diseases, and mechanisation. Equally important will be capturing more of the agricultural value chain through post-harvest processing, creating higher value products, avoidance of post-harvest losses through refrigeration, drying, etc., and through ICT connectivity getting better prices for products in markets. There will be a trend from subsistence farms supporting single families towards larger, more productive and commercial farms.

As incomes from farming rise and levels of village level activity in agricultural production and processing increase, new opportunities will arise for local service industries. Developments such as distributed manufacturing and 3-D printing will enable new rural industries to be established, and in some cases, smart villages in a particular area will host clusters of rural enterprises in strategic areas of dynamic competitive advantage (for example, as promoted in India by the Ministry of Micro and Small Enterprises since 2006 (Bhattacharyya 2014) and more recently by the National Rurban Mission: www.rurban.gov.in). Connectivity will enable local crafts to find markets and, with improved infrastructure, development of tourism in some areas. Installing and maintaining energy services will provide further possibilities for local entrepreneurs and for employment.

The rural connectivity made possible by modern ICT can go some way to reducing that component of the efficiency differential between cities and villages that derives from information flows. For example, specialist services requiring only a flow of information (legal, financial, marketing, etc.) can be as easily accessed (and potentially produced) in a village as they can in a city. Web-based recruitment platforms can connect producers with people with needed skills wherever they may be. The developing world may follow the path of many developed countries where people increasingly source goods via the internet rather than through face-to-face interaction in markets in towns and cities. And the developed world may follow the lead of some developing countries where 'mobile money' is circumventing the physical constraints of accessing banking facilities for remote communities.

Energy access and ICT will enable smart villages to provide substantially enhanced services such as healthcare, education, clean water, and sanitation. Health centres will be lit, and will have refrigerators to preserve vaccines and medicines, facilities to sterilise equipment, and essential diagnostic equipment. They will also be connected, enabling telemedicine and access to specialised expertise located in cities. Also important to improving the health of villagers will be the reduction in indoor air pollution, a major cause of ill-health and death, through clean cooking technologies. And waterborne diseases will be reduced by the provision of clean water and sanitation made possible by energy for water pumping, treatment, etc.

Similarly, schools will have lighting, as will households, enabling children to do their homework. Schools too will have internet connections, providing access to the world's knowledge base, opportunities for distance learning, and richer sources of learning materials to supplement face-to-face teaching. They will provide the enhanced levels of skill development and education, including through lifelong learning, necessary to establish the capacity to take advantage of the opportunities to increase incomes outlined above.

Education and connectivity will empower rural communities, enabling them to take a more active, informed, and influential role in governance processes at local, regional, and national levels. They otherwise typically have little influence over policy making (Cheong et al 2013). Empowerment also flows from the development of the social capital of the village in the form of local governance structures and community spirit, which enable villagers to come together to address issues and to continue to push ahead along the sometimes difficult development road. Alongside the establishment of appropriately designed physical infrastructure, social capital supports increases in the resilience of villages to natural disasters and economic shocks.

Such social capital can also encompass the undertaking of a stewardship role for the local environment, building on more sustainable farming practices and improved resource efficiency (for example, reduced collection of firewood through the use of more efficient improved cookstoves), and aided by technologies to monitor key environmental indicators such as forest diagnostics, water quality, soil conditions, and landscape changes.

Through the provision of modern energy services, smart villages potentially have a transformative impact on the quality of life of villagers by alleviating the drudgery that is pervasive in many lives in rural communities. For example, household appliances and mechanisation of crop processing can save much time and effort, freeing up villagers' energy for other things. The availability of radio, TV, and the internet enables villagers to access information and enjoy entertainment; accessing much of what is available to city dwellers (of particular value to the young, and noting the increasing tendency in the developed world to consume music, films, etc. in the home rather than public places). Public lighting, including for community buildings, can be provided at night so that people, particularly women, can enjoy social interaction without fear of danger.

A final thought is that villages and cities are interdependent: for example, cities provide markets for the food, water, fuel, etc. produced in the countryside. That interdependence is likely to increase and needs to be recognised by taking an integrated approach to development across the spectrum of habitation sizes from villagers through towns to cities. Information interconnectivity will be substantially enhanced through ICT, and needs to be complemented by improvements in physical interconnectivity in transport systems, in particular, so that goods produced by rural communities can get to key markets in cities.

SMART VILLAGE CASE STUDY – TERRAT

Smart Villages Case Study: Terrat Village, Tanzania

Located in the Manyara region in Tanzania, the Maasai village of Terrat exhibits many of the characteristics of a smart village. The village has a thriving economy and is rapidly growing, with around 1,250 households. Development in the village has been driven by the Institute for Orkonerei Pastoralists Advancement (IOPA)1. In its present form, IOPA is a limited company with 1,084 Maasai members. Its objective is to bring about positive social, economic, and cultural transformation. Currently, IOPA remains dependent on donor financing but expects to become self-sufficient by diversifying economic activity and finding new ways to enable energy access.

Modern electricity access is provided by three biodiesel generators, totalling 300 kW capacity. The generators run on biodiesel made from Jatropha, which is processed in-house. There are plans to convert the glycerine by-product into soap for commercial sale and for the waste material from biofuel production to be used for biogas generation. The generators currently provide electricity to 189 households in the village, as well as to schools, a health centre, a church and a mosque, and a range of productive enterprises (e.g. shops, tea rooms, light manufacturing, agro-processing). Electricity from the generators also powers eight boreholes providing 40,000 litres per hour of water for domestic use, livestock, and milk processing.

Electricity access has helped transform Terrat and the livelihoods of villagers. An important economic activity in Terrat is the processing of surplus milk into higher-value dairy products, such as cheese, yoghurt, butter, and ghee, and their export to niche national and regional markets. This has turned out to be a successful economic activity with daily processing capacity being between 1,000 and 2,000 litres per day and the milk economy accounting for approximately 400 million Tanzanian shillings (US$230,000) per year. Women play a key role in milk processing and there has been resultant progress in gender equality in Terrat.

For other businesses in Terrat, key improvements include significant cost reductions. For example, grocery shops, bars, hairdressers and tea rooms were previously powered by individual diesel generators using fossil fuel. With electricity from the biodiesel generators, these businesses have reduced their daily electricity costs by up to 95% per day. The biodiesel generator scheme has resulted in expansion of existing businesses and the creation of new ones involving both capital investment (e.g. in milling and welding machines) and investing in labour (e.g. hiring more staff).

Terrat has benefitted from significant improvements in education, environmental sustainability, food security, health, and general quality of life outcomes. For example, children can read at night time with bright electricity-powered lights. Furthermore, IOPA runs a library, an internet centre, a video/TV producing centre, and a radio channel that is able to provide information

1 IOPA was established to promote and advance dry land pastoralism as well as enhancement of the Maasai pastoralist culture, identity, and dignity, and the right to self-determination for the Maasai Indigenous Peoples: http://www.orkonerei.or.tz/

and entertainment to an audience of approximately two million people. In summary, urban aspirations appear to be increasingly met as a result of electricity: '…because we were in the dark and now we are in the light, like other people in Arusha [a nearby city].' As a result, the youth of Terrat are less inclined to migrate to the city in search of a better life.

Chapter 3: Rural villages in the developing world: current status

Following the ambitious vision of smart villages outlined in the previous chapter, this chapter provides a more sobering snapshot of current levels of development of rural communities in the developing world. It begins with an overview of some key development parameters for rural villages: levels of poverty and hunger, healthcare and education, and access to clean water and sanitation. Subsequent sections (3.2 and 3.3) discuss access to electricity and to clean cooking technologies. A final section (3.4) focuses on the connectivity of villages through modern information and communication technologies, and enabled by energy access.

3.1 Some key development parameters for rural villages[2]

While the number of people living in **poverty** halved over the ten-year period between 2002 and 2012, one in eight people continued to live in extreme poverty[3] in 2012. Most of them lived in developing countries, where 85% of the poor lived in rural areas and 15% in urban areas.[4] Sub-Saharan Africa remained the worst place for poverty: 43% of the population lived in extreme poverty.

The proportion of the global population suffering from **hunger** has declined from 15% to 11% over the last 10 years, leaving around 800 million hungry people, nearly all in developing countries, and mostly in rural areas. The problem is particularly acute in sub-Saharan Africa (where half the adult population face food insecurity[5] and one quarter severe hunger) and South Asia (food insecurity 25% and severe hunger 12% of the adult population). Chronic malnutrition in children leading to stunted growth affected one in four children under age five in 2014 (158.6 million children in total, of which 57.3 million were in sub-Saharan Africa and 63.9 million in South Asia).

Poverty and hunger are closely connected. The UN Food and Agriculture Organization (FAO) estimates that an additional US$265 billion needs to be spent each year over a business as usual scenario in order to eliminate hunger and poverty by 2030. Of this, nearly 70% (US$181 billion annually) needs to be spent in rural areas, reflecting the reality that poverty and hunger is predominantly a rural problem.

Health systems tend to be weaker in rural areas and rural populations carry a disproportionate burden of disease and early death; they are generally the most disadvantaged within low- and medium-income countries (WHO 2016). For example, a recent study of 73 countries found that children living in urban areas (including those living in slums) have better health outcomes than children living in rural areas (Fink et al 2014). Under-five mortality rates are higher in rural areas than in urban areas in most countries (median values of 84 deaths per 1000 live births in rural areas versus 61 deaths per 1000 live births in urban areas).

Opportunities for **education** are consistently lower in rural communities than they are in the cities. In 2013, 59 million children of primary school age and 65 million adolescents of lower secondary age were out of school: the majority

2 United Nations data sources: http://unstats.un.org/sdgs/indicators/database/ and http://unstats.un.org/sdgs/metadata/

3 I.e. with an income of less than US$1.9 /day on a 2011 purchasing power parity basis.

4 Using the Multidimensional Poverty Index (MPI) developed by the Oxford Poverty & Human Development Initiative, and based on a survey of 105 MPI poor countries (Alkireet al 2014).

5 Food and Agriculture Organization et al (2015): Food insecurity: people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life.

were girls. Most of these children and adolescents lived in rural villages in low- and middle-income countries. While 75% of young people in developed countries achieved minimum proficiency in reading and/or mathematics, in developing countries the proportion was only 5%.

One third of the world's population still does not have adequate **sanitation** facilities: in 2015, 2.4 billion people did not have improved sanitation facilities[6], among which 946 million people had no sanitation facilities at all and defecated outside. Nine in 10 people who practise open defecation live in rural areas (Purvis 2015). While 82% of city dwellers use an improved sanitation facility, only 51% of the global rural population has access to such facilities. This leads to high risks of contamination of drinking water sources and the spread of diseases such as cholera, diarrhoea, dysentery, hepatitis A, and typhoid. In sub-Saharan Africa, due to population growth, the numbers of people without access to sanitation have actually increased since 1990.

Better progress has been made on improving access to **clean water**: 91% of the global population uses an improved water source—one that protects water from external contamination—up from 76% in 1990. But still 663 million people do not have access to an improved source of drinking water. As with sanitation, progress in rural areas trails behind urban areas: eight out of 10 people without improved drinking water sources live in rural areas (Purvis 2015). Moreover, 319 million people in sub-Saharan Africa do not have access to clean water, the most of any region.

3.2 Electricity access

Table 1 presents the findings of the International Energy Agency's World Energy Outlook in 2016 (IEA 2016) on electricity access[7]. It shows that in 2014 nearly 1.2 billion people in developing countries remained without access to electricity. It is estimated (World Bank Independent Evaluation Group 2015) that a further one billion people have chronically inadequate or unreliable electricity supplies.

Of the 1.2 billion, just over half live in sub-Saharan Africa. Most of the remainder are in developing Asia, with India accounting for around half of the Asian total. Rural electrification rates are much lower than those for cities, and amounted to just 19% in sub-Saharan Africa. While the absolute numbers of people without electricity in Latin America are relatively low, these residual populations are located in particularly remote and difficult to access regions.

6 From WHO/UNICEF website https://www.wssinfo.org/definitions-methods/: An improved sanitation facility hygienically separates human excreta from human contact.

7 The IEA uses an initial threshold for electricity access of 250 kWh per year for rural households and 500 kWh per year for urban households, assuming five people per household.

Region	Population without electricity (millions)	National/ Regional electrification rate %	Urban electrification rate %	Rural electrification rate %
Africa	634	45%	71%	28%
• North Africa	1	99%	100%	99%
• Sub-Saharan Africa	632	35%	63%	19%
Developing Asia:	512	86%	96%	79%
• China	0	100%	100%	100%
• India	244	81%	96%	74%
• SE Asia	102	84%	94%	74%
• The rest	166	66%	84%	56%
Latin America	22	95%	98%	85%
Middle East	18	92%	98%	78%
Total Developing Countries	1185	79%	92%	67%

Table 1: Electricity access in 2014 (IEA 2016)[8]

The current rate of progress on electricity access in developing countries falls far short of that which will be required to achieve universal access by 2030—the target set by the Sustainable Development Goals discussed in the next chapter (Sustainable Energy for All 2017). Based on the way in which governments see their energy sectors developing in coming decades (i.e. taking account of policies and measures in place, and new ones announced) the International Energy Agency in its 2016 World Energy Outlook (the 'New Policies Scenario' in IEA 2016) projects that 784 million people will remain without access to electricity in 2030 (619 million in sub-Saharan Africa and 166 million in Developing Asia). In this scenario, 1 billion additional people gain access to electricity over the period to 2040, but population growth, particularly in sub-Saharan Africa, outstrips the rate of new connections required to achieve universal electricity access.

8 Link to IEA energy access database: http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/

The proportion of the rural population without access compared to the urban continues to rise.

If universal electricity access is to be achieved in countries that currently have low rates of access (less than 50%), the annual rate of new connections needs to be increased from two million, which was the average over the period 2000 to 2010, to 14.6 million over the period from 2015 to 2030 (World Bank Independent Evaluation Group 2015).

In its 2011 World Energy Outlook (IEA 2011) the International Energy Agency projected that $48 billion needs to be spent annually on electricity access in order to achieve universal electricity access by 2030. A major part of this would need to be spent in sub-Saharan Africa. This is roughly the same as what the energy poor currently spend annually on lighting in the form of batteries and kerosene for lamps (typically paying very high prices for their lumens of light)—$40 billion (Granoff and Hogarth 2015).

The rate of investment in electricity access in 2013 was $12.7 billion (of which 37% was from developing country budgets, 45% from multi-lateral and bilateral aid, and 18% from private finance (IEA 2015)).

This figure of $48 billion may also usefully be put in context with the current annual expenditure of the global energy sector of $1800 billion, and annual fossil fuel subsidies in 2015 of $325 billion (IEA 2016)[9]. Taking a broader view, global investment in 2012 related to achievement of the three targets of Sustainable Development Goal 7 was $400 billion: one third of the rate estimated to be needed over the period to 2030 (SEforALL, 2016).

There is some debate about the veracity of this figure of $48 billion. Some argue that basic levels of universal electricity access can be achieved more quickly and substantially more cheaply (Practical Action 2016, Craine et al 2014, Power for All 2014). In contrast, Bazilian and Pielke (2013) argue that the IEA's definition of electricity access is not sufficiently ambitious (equating to 50-100 kWh/year per person: 0.5% of that consumed by the average American, 1.7% of the average Bulgarian or South African), and to achieve a level of access and consumption equivalent to current levels in South Africa and Bulgaria would require 17 times the annual rate of investment projected by the IEA.

Most of the current expenditure on electricity access is for national grid-based approaches rather than local solutions. For example, off-grid projects accounted for just 2.5% of the World Bank's funding of the electricity sector over the period 2000 to 2016 (World Bank Independent Evaluation Group 2016) – 'support for off-grid electrification was low and sporadic' (World Bank Independent Evaluation Group 2015). A review in 2016 of major electricity access initiatives in sub-Saharan Africa (EUEI PDF 2016) indicated that most were focused on grid-connected power rather than local power generation.

The average duration (preparation, planning and implementation) of grid-based projects funded by the World Bank is nine years. If this were to continue, low access countries would each only benefit from two to four World Bank projects by 2030. In contrast, off-grid solutions can be implemented on much shorter timescales.

More positively, some countries have demonstrated that, with political will backed by appropriate policies and investment, major increases in electricity access can be achieved quickly (van Gevelt and Zhang 2017): universal electricity access having been achieved in China over a period of three decades starting from a low base, and transitions from low access to higher access status being achieved in two decades in Indonesia, Lao PDR, and Vietnam (World Bank Independent Evaluation Group 2015). And with a view to the issue of climate change, in the scenarios for universal electricity access examined by the International Energy Agency in its 2011 World Energy Outlook (IEA 2011), global emissions of CO_2 increased by less than 1%.

3.3 Clean cooking

Table 2 summarises the 2014 figures for reliance on traditional biomass for cooking in developing countries (IEA 2016): 2.7 billion people in developing countries continued to rely on traditional use of biomass for cooking, 40% of the global population. Developing Asia, and in particular China (453 million) and India (819 million), accounted for the major part; but at 81% the proportion of the population relying on traditional use of biomass for cooking was highest in sub-Saharan Africa (corresponding to 792 million people). Worldwide, 84% of the households dependent on traditional use of

9 Of such subsidies in 2010 only 8% reached the poorest 20% of the population (IEA 2011) biomass live in rural areas (EUEI PDF 2014). The rural-urban gap for clean cooking is close to 60 percentage points—three times the gap for electricity (Sustainable Energy for All 2017).

Region	Population relying on traditional use of biomass for cooking (millions)	% of Population relying on traditional use of biomass for cooking
Africa	793	69%
· North Africa	1	0%
· Sub-Saharan Africa	792	81%
Developing Asia	1875	50%
· China	453	33%
· India	819	63%
Latin America	65	14%
Middle East	8	4%
Total Developing countries	2742	49%

Table 2: Reliance on traditional biomass for cooking in 2014 (IEA 2016)

Most of these 2.7 billion people burn the biomass on open fires (the 'three stone fire') or in traditional cookstoves which create high levels of indoor pollution, resulting in some four million premature deaths each year from respiratory and cardiovascular diseases, and cancer (World Health Organisation 2014). This is nearly 5% of the global disease burden, making it globally the single most important environmental risk factor. Domestic biomass burning is also a substantial contributor to outdoor air pollution-related deaths, responsible for around 0.4 million premature deaths annually ((World Health Organisation 2014). Through the role of women and children as the primary collectors of firewood, there are risks to their health and safety and substantial calls on their time.

There are additional significant impacts due to the collection of firewood in respect of deforestation: over half of all wood harvested worldwide is used as fuel. It has been estimated that in 2009 27 to 34% of the woodfuel harvested was unsustainable, though with large geographic variations (Bailis et al 2015). The burning of this woodfuel resulted in 1.0-1.2 Gt of CO_2 equivalent greenhouse gas emissions in 2009[10] (1.9-2.3% of global emissions), with roughly equal contributions from CO_2, black carbon, and CH_4/CO/volatile organic compounds.

The rate of deployment of clean cooking technologies is not keeping pace with population growth (Sustainable Energy for All 2017). In the International Energy Agency's 2016 'New Policies Scenario' referred to above, overall numbers of people still reliant on traditional biomass for cooking in 2030 only fall by 200 million (14%), reflecting a continuing struggle to keep pace with population growth. Clean cooking receives

10 After accounting for uptake by the fraction of woody biomass which is sustainably harvested.

rather less attention than electricity access (Sustainable Energy for All 2017): for example, a review of major energy initiatives in Africa in 2016 (EUEI-PDF 2016) identified significantly fewer initiatives for clean cookstoves than for electricity access.

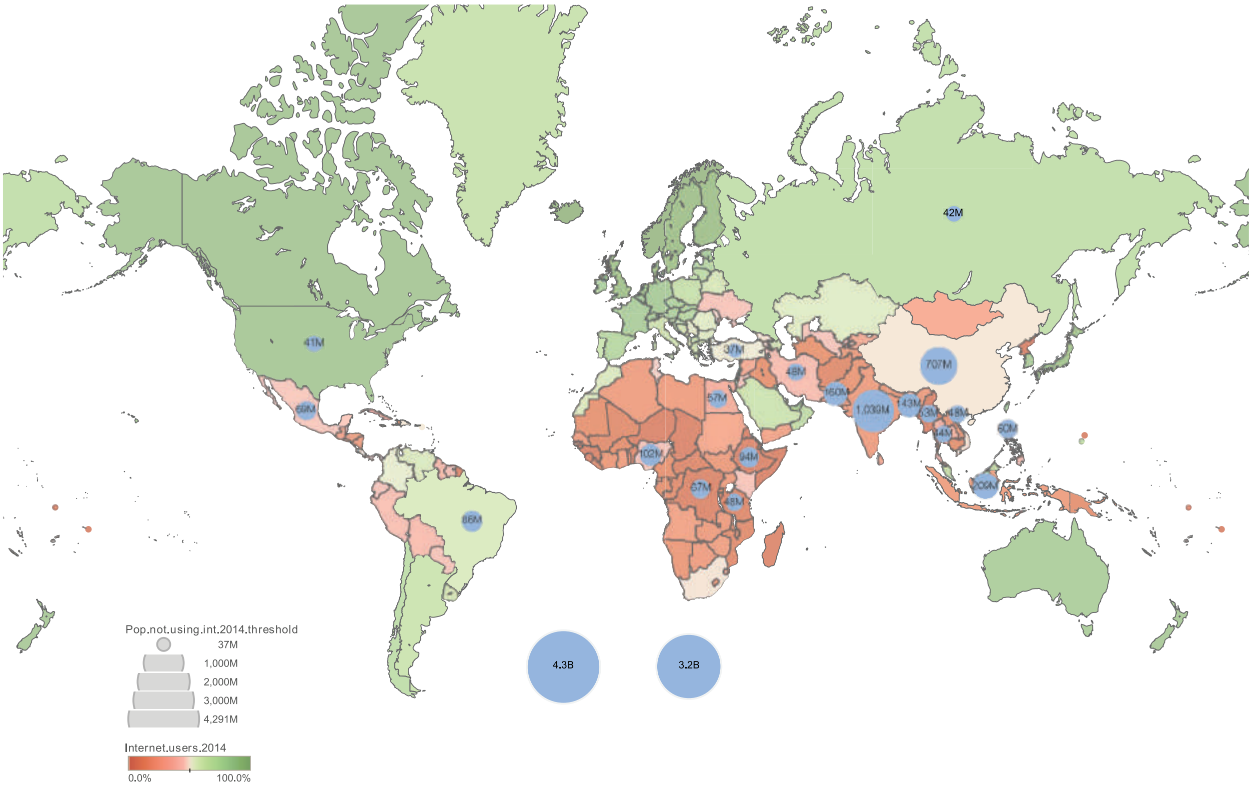
The International Energy Agency (IEA 2014) has estimated that the cost to achieve universal access to clean cooking technologies by 2030 would be $4.5 billion per annum. This is one tenth the annual cost of achieving universal electricity access, making clean cooking the cheapest form of energy poverty to tackle (Granoff and Hogarth 2015). But in 2013 (IEA 2014) the global spend on the deployment of clean cooking technologies was just $400 million, i.e. one tenth of the rate needed to achieve universal clean cooking, and one hundredth of that required to achieve universal electricity access.

3.4 Connectivity

Chapter 2 has outlined the development benefits that flow in smart villages from being connected to the outside world by modern information and communication technologies (ICT), in turn enabled by electricity access. This section summarises the current status and trends in respect of the connectivity of rural communities in the developing world and shows that major investments in ICT are still required if the development benefits inherent in smart villages are to be delivered.

The International Telecommunication Union (ITU) has developed an integrated benchmark of the level of ICT development in countries across the world: the ICT Development Index (IDI). It highlights the digital divide between developed and developing nations; the average IDI for developed countries (7.40 (out of 10)) is nearly twice that for developing countries (4.07). Africa is the region with the lowest IDI at 2.48 (ITU 2016).

Over the last 10 years there has been a steady growth in individuals and households using the internet, approaching 50% globally in 2016, but with a wide disparity between the developed world (around 85%), the developing world (40%), and least developed countries (10%) (ITU2016). Figure 1 from World Economic Forum (2016) maps the levels of internet access across the globe: there is a fairly close alignment between lack of access to electricity and to the internet. The barriers to greater internet use fall into four categories (World Economic Forum 2016): infrastructure; affordability; skills, awareness and cultural acceptance; and local adoption and use, which is often an issue of the lack of local content.



Map based on Longitude (generated) and Latitude (generated) and Latitude (generated). Details are shown for Country.Code. For pane Latitude (generated): Color shows sum of Internet.users.2014. Details are shown for Country.Code. For pane Latitude (generated) (2): Size shows sum of Pop.not.using.int.2014.threshold. The marks are labeled by sum of Pop.not.using.int.2014.threshold.lower and sum of Pop.not.using.int.2014.threshold.upper. Details are shown for Country.Code and Pop.not.using.int.2014.threshold.

Figure 1: **Map of the levels of internet access across the globe** [WEF 2016, p7]

Increases in internet access in developing countries have been driven by a rapid rise in ownership of smartphones[11] and associated mobile broadband access. In the sample of developing and emerging countries covered by Poushter (2016), smartphone ownership increased from a median of 21% in 2013 to 37% in 2015. Figure 2 from Poushter (2016) illustrates the wide range of levels of ownership of cell/mobile phones and smartphones over a sample of developing countries. Levels of smartphone ownership remain low in least developed countries, and while levels of ownership of cell/mobile phones which are not smart are generally high, there are still many people in developing countries without them. Levels of fixed broadband subscriptions remain very low: around 10% (mainly urban) in developing countries and 1% in least developed countries (ITU 2016).

11 From Poushter (2016), defined as a cell/mobile phone that can access the internet and apps (for example an iPhone or an Android)

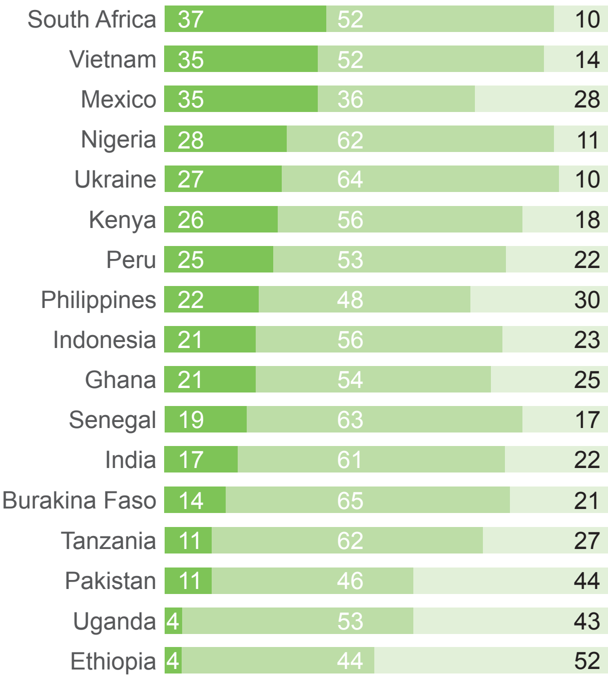


Figure 2: **Ownership of smartphones (dark green), cell/mobile phones but not smart (light green), and no phone in a sample of countries** [Poushter 2016, page16]

The proportion of the population covered by mobile broadband networks reached 84% in 2016 globally, but was only 67% in rural areas (and much less in developing countries), and there is typically a 20 to 40% points difference in access between rural and urban populations (ITU 2016). There is also a gender gap in cell/mobile phone and smartphone ownership, men having significantly higher levels of ownership than women in developing countries (ITU 2016; Poushter 2016).

The cost of cell/mobile (but not smart) phones has continued to fall rapidly, a basic package (100 SMS and 30 calls per month) now accounting for less than 5% of Gross National Income (GNI) per capita in developing countries (ITU 2016). Similarly, the cost of smartphones has decreased rapidly, but mobile broadband services are only available in 38% of the least developed countries. Where available in developing countries, the cost of a basic broadband package halved between 2012 and 2015, consequently accounting for 11% of GNI per capita in 2015. However, people in low-income countries pay substantially more, and for lower speeds and quality, than is the case in developed countries. Fixed broadband connections in least developed countries are out of the financial reach of most people: a fixed broadband plan with a minimum of 1 GB of data per month still corresponds to over 60% of GNI per capita.

Chapter 4: The policy context

The overarching policy context for rural energy access and the establishment of smart villages is provided by the '2030 Agenda for Sustainable Development' (United Nations 2015) which sets out 17 Sustainable Development Goals (SDGs) with 169 associated targets. The SDGs set a more comprehensive and ambitious agenda than the Millennium Development Goals that they replace. The United Nations positions them as being of 'unprecedented scope and significance' and reflecting a 'supremely ambitious and transformational vision'. With just 13 years to go (at the time of publication of this report in 2017) to the 2030 date for achievement of the Goals, time is short and the implementation of the necessary initiatives and mobilisation of the substantial required resources must be pursued urgently (see for example Stuart et al, 2016).

Unlike the Millennium Development Goals which did not explicitly address issues of energy access, the SDGs include Goal 7 on energy access, recognising (belatedly) the key role that energy services play in enabling the achievement of other Goals. As UN Secretary General Ban Ki-Moon said in 2012, 'Energy is the golden thread that connects economic growth, social equity, and environmental sustainability' (Ban 2012).

Annex 2 illustrates the ways in which rural energy access and the forms of rural development envisaged in the smart villages concept interrelate with the SDGs, and lends weight to the UN proposition that 'the interlinkages and integrated nature of the Sustainable Development Goals are of crucial importance' (United Nations 2015). Given that nearly 50% of the world's population and 70% of the world's poor live in the countryside, the pledge in the 2030 agenda that 'no one will be left behind' and the commitment to 'endeavour to reach the furthest behind first' are of particular importance to the Smart Villages Initiative, given its focus on rural development catalysed by energy access.

As the world's biggest development actor, spending more on development cooperation than the rest of the world put together (European Union 2016), the European Union and its member states will play a key role in actions to deliver the Sustainable Development Goals, and are committed to doing so (European Commission 2016). The European Commission's proposal for a new 'European Consensus on Development' (European Commission 2016) stresses the need for the European Union and its member states to work better together, using joint programming in partner countries. Recognising its potential contribution, and the need to access substantially larger funds, the private sector is recognised as a key and closer partner.

Reflecting the interconnectivity of the 2030 Agenda, the European Commission emphasises the need for policy coherence for development, ensuring that all policies in the EU and member states support development objectives. Eradicating extreme poverty and inequality is put at the centre of the EU's development endeavour. The development of sustainable energy services in developing countries is recognised as a key driver with cross-cutting transformational potential.

Established in September 2011, the SEforALL platform (www. SE4ALL.org) provides the key mechanism for the UN to deliver the three targets of SDG7: ensure universal access to modern energy services, double the global rate of improvement in energy efficiency, and double the share of renewable energy in the global energy mix. It aims to broker the partnerships and unlock the financing that will enable achievement of the three targets (SEforAll, 2016). It has established regional and thematic hubs, and has supported countries to develop action agendas and investment prospectuses necessary to deliver the targets at country level. With the World Bank, it has established the multi-tier framework for energy access (From ESMAP 2015) to track progress, recognising that energy access is a process of progressing to higher levels rather than a simple binary yes-no.

The European Union strongly supports SEforALL and the achievement of SDG7. Energy access is regarded as a key priority in poverty alleviation strategies and it is at the heart of EU development policy (European Commission 2015). It is seen as 'one of the most critical development challenges'. The EU's aim is to help 500 million people gain access to sustainable energy services by 2030. It is planned to make available €3.5 billion in funding for energy in developing countries over the period 2015 to 2030. With a strong emphasis on blending EU funds with private sector finances, the intention is to leverage this funding with €15-€30 billion of private sector loans and equity. Long-term partnerships focusing on energy have been established in bilateral agreements with 30 countries. Regional, continental and thematic instruments extend the geographic range of the EU's activities on energy access beyond these 30 countries.

Support is given to establishing enabling frameworks for modern energy systems through a range of initiatives, including the Technical Assistance Framework and the European Union Energy Initiative Partnership Dialogue Facility (EUEI-PDF). Such support includes advice on creating supportive policy and regulatory frameworks, capacity building, support for project development and finding funding, market development, and knowledge exchange.

Support is also provided in the form of funds—grants, loans and risk mitigation mechanisms—for energy projects. There is a strong emphasis on leveraging this funding with other sources of capital. While much of this funding has been devoted to major infrastructure projects, such as national grid extensions/reinforcements and central power stations, there has been an increasing recognition of the value of local energy solutions for rural communities. For example, the ElectriFI initiative[12] provides grants to rural electrification projects to complement private financing, bridging potential financial gaps in order to make projects bankable. The aim is to provide the security investors and banks are expecting in order to boost investments. If investments are successful, the grants will be converted into loans at concessional rates, and the funds reinvested in new projects.

While the EU's activities on energy access range across the developing world, there is a strong focus on sub-Saharan Africa. The Africa – EU Energy Partnership established in 2007 as one of eight strategic partnerships within the Africa – EU Joint Strategy aims to provide access to modern and sustainable energy services to at least an additional 100 million Africans by 2020. Looking ahead, this partnership will have a stronger thematic focus on energy access, energy security, energy efficiency, and renewable energy.

12 http://electrifi.org/wp-content/uploads/2016/12/ElectriFI-Information-Sheet-English.pdf

Chapter 5: Providing sustainable energy services to rural communities

This chapter summarises the main findings and recommendations arising from the regional engagement programmes and supporting literature reviews in respect of the provision of sustainable energy systems to rural communities. It looks first at solar home systems and pico-solar lights (Section 5.1), then at mini-grids (Section 5.2), and in Section 5.3 at clean cooking technologies. Section 5.4 distils recommendations for policy-makers, development organisations and other key stakeholders.

The following Chapter 6 examines the use of energy in enabling the development of the various characteristics of smart villages summarised in Chapter 2. Cross-cutting issues arising in respect of energy supply and use are presented in Chapter 7.

5.1 Solar home systems and pico-solar lights

The performance and affordability of solar home systems (SHS) and pico-solar lights have made major advances over the last five years or so. Consequently, in many countries they now represent an attractive opportunity to provide a basic level of electricity services to households, generating substantial savings compared to non-electrified technologies such as candles and kerosene lamps. In practice, they can often offer a more reliable electricity supply for low energy appliances such as LED lights, phone chargers, and for solar home systems, radios, efficient TVs and small fans, than a grid connection which is all too often unreliable.

Pico-solar lights, typically costing $5-50, provide substantially better levels of lighting than candles and kerosene lamps[13]. A small solar PV panel (around 100 cm^2) which may be integral to the lighting unit or separate, together with a battery and charge controller built into the unit, when left in the sunshine during the day to charge up, can provide light for a few hours in the evening or up to two to three days for more expensive units. The latter may also provide a connection for mobile phone charging and in some cases to power a radio. LED lights, able to provide decent levels of light using 0.5 to 2 W of electricity, have been an important factor in the rapid rates of deployment of pico-solar lights in recent years. Around 20 million branded products have been sold worldwide by the 100 or so companies active in this sector, and about the same again of unbranded, generic products. The proportion of quality verified products is increasing, making up 75% of units sold in the first half of 2016 (GOGLA and Lighting Global 2016).

Solar home systems generate more power, generally from around 10 W up to 150 W for household systems, but ranging up to 1kW for small enterprises such as shops, or institutions such as clinics and schools. They comprise a solar PV panel, often located on a roof, together with a battery, charge controller and electrical connections inside the building. Smaller units can power two or three LED lights and a phone charger[14]. As the power (and cost) of the SHS increases, fans, TVs, laptops, and at the higher end, efficient refrigerators and sewing machines can be supported. Smaller systems run on DC

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13 A review by Lysen (2013) for the International Agency provides a useful overview. The Lighting Global website—https://www.lightingafrica.org/products/—gives a listing of quality assured products.

14 In 2014, US$150 would, for example, buy a 20 W Barefoot Power kit including five LED lights and a phone charger in East Africa, or a 20 W Grameen Shakti system with three LED lights and a phone charger in Bangladesh: https://www.ashden.org/solar (generally 12V); larger systems may include an inverter enabling AC appliances to be powered. It is estimated that 10 million solar home systems are in operation worldwide. A typical cost for a 100 W solar home system in Africa in 2015 was US$800-1000 (IRENA, 2016).

Families may spend $150 or more each year on kerosene for lighting and phone charging, so a pico-solar light offering these facilities can pay for itself in a matter of a few months. Solar home systems offer more services, which are sufficiently valued by households that they will divert household income to repay the cost of systems over, typically, one to three years. Initially, the better off families in villages without an electricity supply will adopt solar home systems. As prices continue to fall, the range of families that can afford them will expand, and well targeted subsidies for poorer families may be used to accelerate uptake in the interim.

Pico-solar lights and solar home systems provide household electricity supply and services at levels 1 and 2 of the World Bank/SEforALL Multi-Tier Framework (ESMAP 2015 and Annex 3). Global sales in the sector in 2014 were $550 million (van Gevelt and Holmes 2015), around 1% of the annual investment projected by the IEA as being required to achieve universal electricity access by 2030 (IEA 2011).

Key factors in the rapid progress made by pico-solar lights and solar home systems in recent years have been:

- Substantial reductions in the cost of pico-solar lights and solar home systems.
- Major improvements in the efficiency of appliances, for example LEDs for lighting and efficient direct current (DC) fans, radios, televisions, etc.
- Business models that get around the problem of the upfront costs of equipment through pay-as-you-go or pay-for-services approaches (often making use of mobile phone connectivity and/or mobile payment systems), which also help to build sufficient confidence for potential customers to make the purchase.

With regard to the first factor, as the manufacturing of solar modules moves down a steady learning curve (of increasing economies of scale and manufacturing efficiency), the solar industry has faithfully followed what is termed 'Swanson's Law' which states that for every doubling of cumulative shipped volume of solar panels, the price of these individual panels decreases by 20% (see Figure 3). Over a five-year period from 2009 the price of solar panels reduced by 75% (IRENA 2015b).

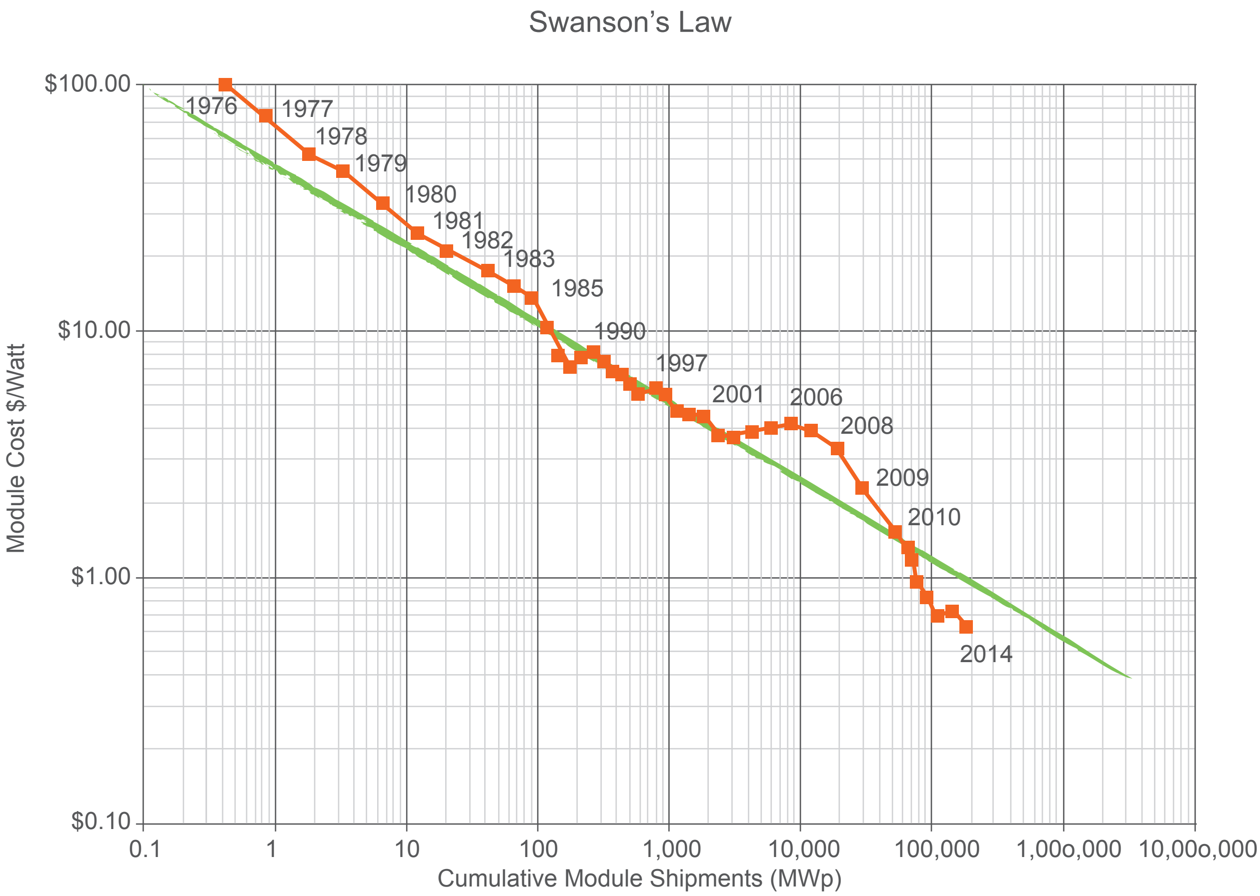


Figure 3: **Illustrating the reductions in PV panel costs over recent decades** (ITRPV, 2015)

This has been a major factor in reducing the cost of solar home systems. Reductions in the cost of other components have also made a significant contribution, including battery cost reductions (42% reduction over five years from 2009 (IRENA 2015b)), increased LED lighting efficiency, and increased manufacturing and sales volumes of the complete systems. Figure 4 shows the reduction in LED bulb price since 2010, and projections to 2040 resulting from increased efficiency and increased manufacturing volume.

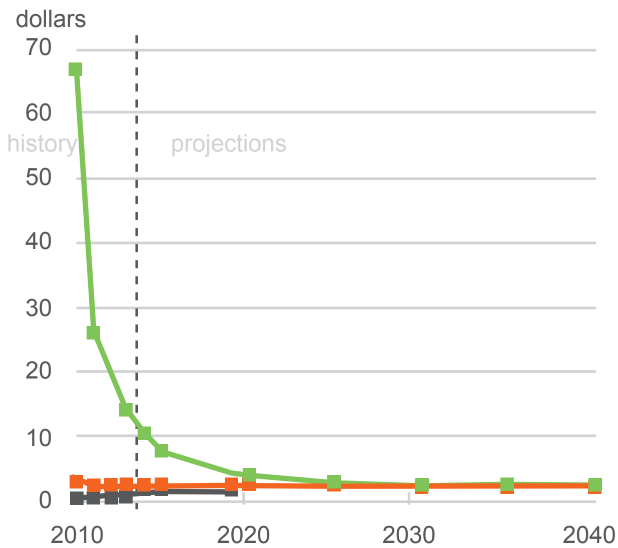


Figure 4: **Changes in the price of LED (green line), Compact fluorescent (orange line) and incandescent (black line) light bulbs in US Dollars (US Department of Energy 2014).**

Solar home systems can most readily supply DC power, and an increasing range of efficient DC domestic appliances are available (Kopek et al 2016). Table 3 illustrates typical power demands of available appliances.

Appliance	Power use (watts)
Small LED light (50 lumens intensity)	0.5
Radio	0.5
Larger LED light (200 lumens)	2
Small mobile phone charging to 50% for 2 hours	2
Tablet/efficient laptop to charge to 50% in 3 hours	10
Small LCD television (DC)	20
Ceiling fan	20
Fridge	40
Sewing machine	100

Table 3: Illustrative power usage of domestic appliances (from Gevelt and Holmes 2015b)

Around 20 companies are now active in the pay-as-you-go/pay-for-services SHS market, serving half a million customers, mainly in East Africa, and attracting an increasing share of the investment into the sector recognising the potential for higher margins (Lighting Global 2016). Modern ICT, particularly mobile phone connectivity, enables efficient payment systems substantially reducing transaction costs (and making use of mobile money where it is available such as in Kenya). It also enables the use and condition of the SHS to be remotely monitored, facilitating timely deployment of maintenance services, and provides the facility for systems to be switched off if customers don't pay (see box). These factors bring together the service provider and customer into deeper and long-term relationships, supporting the sustainability of the service. Analogous arrangements in which households pay off an upfront loan in instalments are used in some government-led/sponsored schemes such as that run by IDCOL in Bangladesh.

M-KOPA, a solar home system company in East Africa

M-KOPA (www.m-kopa.com), a company headquartered in Nairobi, Kenya, has installed solar home systems in 400,000 homes in Kenya, Tanzania, and Uganda. It markets 8 W and 20 W systems, each with embedded GSM and the facility for customers to repay the cost of the system through mobile phone payments. For the 8 W system, customers make a down payment of $35 and then pay $.50 per month for a year, after which they own the system. The 8 W system comes with a two-year warranty and includes two LED light bulbs, a rechargeable torch, a phone charger and a rechargeable radio. The larger 20 W system includes an LED flat screen TV and an aerial that provides free-to-air channels. Customers have access to a 24/7 customer call centre.

M-KOPA has now extended its range of products so that customers who have successfully completed their payment plan on the solar home system are given access to affordable financing to purchase an expanding product portfolio which includes energy efficient cooking stoves, smartphones and water tanks.

Also, particularly in East Africa and more recently West Africa, commercial companies are offering 'energy escalator' approaches in which households can readily move to higher energy systems when they have paid off their current system (see box).

Azuri Technologies and the energy escalator

Azuri Technologies is a commercial provider of pay-as-you-go solar home systems to rural off-grid communities across sub-Saharan Africa (www.azuri-technologies.com). Its entry-level PayGo solar home system provides eight hours of lighting each day and a mobile phone charger. After a small one-off installation fee the customer makes weekly or monthly payments over a period of typically 18 months, after which they can unlock the system forever or upgrade to a larger model. Azuri envisages a three-stage customer journey:

- starting with the basic model, substituting for kerosene and phone charging fees, and building brand loyalty
- upgrading to a larger system capable of supporting aspirational goods and services such as radio, TV, and fan
- and extending to supporting productive uses such as retail, refrigeration, and irrigation, increasing customer income and delivering increased revenue to Azuri.

Payments are made via scratch card and SMS, or can be fully integrated with mobile money services if available in the location. HomeSmartTM technology— a self-learning, artificial intelligence feature—enables appliances to be controlled throughout the day according to the level of insolation available in order to maximise their utility.

In South America, the developments in SHS technology have resulted in what are termed 'third generation' solar home systems that require one-third the amount of power of older systems to provide a given level of electricity services, resulting in cost reductions of 30–50%. Their weight has been reduced from 50 kg to six kg, making the devices more portable (an important consideration when deploying them in mountainous or rainforest regions where transport by road may not be possible), and they are much easier to install.

Currently, pico-solar lights and solar home systems mainly provide improved living conditions for households through better quality lighting, improved physical comfort (fans), more convenient and cheaper mobile phone charging, and home entertainment (radios and TVs). Through making light available in the evenings, they provide some limited opportunities to increase the output of domestic enterprises by extending working hours, while higher-end solar home systems can power electric sewing machines and food-making equipment, opening up new possibilities for domestic enterprises.

Looking ahead, as solar home systems become more powerful and affordable, and with improvements in energy efficiency and availability of DC equipment, a wider range of productive enterprises will come within the ambit of solar home systems. A recent report from GIZ (2016) highlights the large number of appliances now entering the market that are specifically designed for off-grid productive enterprises. Future research might usefully include a five to 10-year look ahead to explore the potential for village-level enterprises based on domestic solar home systems.

In some countries in East Africa and more recently in West Africa, pico-solar lights and solar home systems are making rapid progress driven by commercial companies. Companies such as Offgrid Electric, MKopa and Azuri are each adding around 10,000 new customers per month. Supportive framework conditions have included the wide availability of mobile money systems, VAT removal on solar products in Kenya, Tanzania and Uganda, adoption of international standards in Kenya and Uganda, and in Tanzania a clear overall electrification plan and the removal of kerosene subsidies (Diecker et al 2016). But there are a number of constraints to a further acceleration in their rollout of home-based electricity systems:

- The limited availability of affordable working capital discussed above: the companies carry the capital cost of the equipment over the customer repayment periods—typically US$250-1000 for a solar home system—which rapidly adds up to substantial amounts when customer volumes increase rapidly.

- The time and effort required to build reliable distribution networks for remote communities and to provide effective after-sales service in respect of operation and maintenance.

- The need to establish the required skill base for both technical and business capacities.

However, this success has not yet been replicated across sub-Saharan Africa. For example, in Rwanda we were informed by the Ministry of Infrastructure that it considered that the market-based approach to disseminating solar home-based systems was not working: fewer than 1,000 units are sold each month. Further investigation of the differentiating factors across sub-Saharan African countries would help to identify the framework conditions that need to be put in place in those countries that have not yet benefitted from the deployment of home-based electricity systems through a market-based approach.

In other regions, sales in India are high due in no small part to the size of the potential rural market, and **Bangladesh** stands out, given that four million solar home systems have been deployed mainly through a scheme run by the Infrastructure Development Company Ltd. (IDCOL), a government-owned financial institution, which draws on substantial support from the World Bank. Key factors behind the success of this government-led scheme were identified as:

- IDCOL has established a group of stakeholders with a strong sense of ownership of the scheme.
- Subsidised finance is provided to the partner organisations that deploy solar home systems to rural communities.
- Households repay system costs in instalments.
- There are effective technical standards and quality assurance systems: a committee has been established to license products and ensure that only they may be used within the scheme.
- Effective technical support is provided to the operation and maintenance of the systems: all households are given the telephone number of a call centre where they can report problems.

However, problems remain (for example, in respect of the reliability and maintenance of equipment), and there has been a proliferation of systems deployed outside of the scheme that are cheaper (attractive to poor families who cannot afford the IDCOL scheme systems) but have attendant quality problems. Nonetheless, it is considered (Sanyal et al 2016) that lessons from the IDCOL experience in respect of establishing supportive framework conditions may be transferred to other countries, including to East Africa to increase the availability of working capital, identified as the number one constraint in this region (Diecker et al 2016).

Experience in East Africa and Bangladesh indicates that both top-down, government-led and bottom-up, commercially-driven approaches can work. Looking beyond East Africa and Bangladesh, in other countries and regions covered by the workshops the rate of progress has been lower, and a more mixed picture of approaches emerges. Generally, NGOs and governments play a more active role in the dissemination of pico-solar lights and solar home systems than in East Africa. However, governments may be prone to top-down, 'one size fits all' schemes which fail to respond to the individual needs of households: a case in point being a scheme launched by the Peruvian government in 2016 to distribute half a million SHS—workshop participants in Lima expressed strong reservations about the efficacy of this initiative.

Approaches in different countries range from free distribution, to subsidies at various levels, to fully commercial. Free distribution spoils emergent markets for pico-solar lights and SHS, and generally leads to high levels of disused equipment: it is therefore to be avoided. Where subsidies have been provided, recurrent concerns are how to target them effectively at the poor and how to establish an exit strategy. In some countries in South America such as Bolivia and Chile, strong commitments to rural electrification driven by concerns for equality and citizens' rights have led to high levels of subsidy. For example, a government-led scheme to install 3000 125 W SHS in the Coquimbo region of Chile charged households $4 per month based on an evaluation of what they could afford, but the cost was $17.9 per month, the difference being made up with government subsidy.

Several other problems are evident in relation to access to affordable working capital, establishing distribution chains, supporting operation and maintenance, and building the necessary skill base, as identified above for East Africa.

Access to affordable financing is needed at all stages of the value chain, extending to end users. Effective distribution chains require the building of confidence and trust through face-to-face interaction: employment of local people can be helpful in this regard and contributes to increasing livelihood opportunities for villagers. Ecosystems of suppliers, spare parts, etc. need to be established along with an effective and financially viable system to support the ongoing operation and maintenance of systems which is crucial to their long-term sustainability. It is remarkable how many initiatives have failed on this point. Availability of spare parts is often a problem, and there were calls for more standardisation of components to facilitate procurement and stocking.

The technical training of local people in the maintenance of systems is essential, and householders need to be educated in how to operate the system to avoid recurrent problems of overloading, battery misuse, etc.(examples include adding additional power outlets in homes, connecting neighbours to the SHS, and using the batteries to start up engines in boats). Governments and development organisations can play an important role here in supporting awareness and training initiatives: it is inappropriate to leave all of this to private companies.

In all countries, there is a major and growing problem with **poor quality and counterfeit products**. This undermines customer confidence and can spoil the market for home-based systems. National governments need to set and vigorously enforce quality standards for products and for their installation, establishing the required institutional infrastructure and testing facilities. Care must be taken in how these arrangements are set up: for example, in Ethiopia a requirement for local testing of each product, whether quality verified or not, led to large quantities of products being impounded on entry into the country (GOGLA and Lighting Global 2016).

International standards and quality assurance frameworks such as those developed by Lighting Global[15] can play an important role (also, United Nations Environment Programme 2015). And there were calls for international action to stem the flow of counterfeit and poor-quality goods. Reliable hallmarking is needed at the customer level, and there is ongoing value in initiatives to educate householders in the issues around cost and quality. Barcoding is being used for pico-solar lights in EnDev initiatives in West Africa to help track quality problems.

Governments may exert influence through taxation regimes as, for example, in Pakistan where import duties are only exempted on equipment that meets quality standards. Where dissemination schemes are government-led, governments have more scope to control the quality of systems. For example, as noted above, in Bangladesh the IDCOL scheme only distributes solar home systems that have been certified by its quality control committee. However, governments may lack the institutional capacity to police and enforce standards.

Additional uncertainties faced by organisations deploying pico-solar lights and solar home systems are the lack of clear plans for the extension of electricity grids and the difficulties in discerning householders' willingness or ability to pay. Governments and electricity companies need to provide clear forward planning of grid extensions. Surveys and market testing can provide a better fix on the prices that can be charged for home-based systems: schemes need to be established to enable the effective sharing of such information by the private sector, governments, and NGOs.

Looking ahead, new business models were mooted, for example, where the marketing fo-

15 *Lighting Global quality assurance programme: https://www.lightingglobal.org/quality-assurance-program/*

cus shifts to the services provided by domestic appliances (lighting, cooling, TV, and radio, etc.) and the commercial emphasis shifts to sales of domestic appliances. The solar home system, as the enabling technology, becomes part of a broader package. In this scenario, white goods manufacturers may be drawn into the market. The example of M-KOPA given in the box above provides evidence of this shift to a broader concern with household appliances and services. Also, making use of the established distribution networks of domestic products and services companies is potentially attractive but may not be straightforward, and, consequently, some innovative thinking is needed.

If reliable in their repayments, households can build a credit history which can be leveraged to gain access to new loans. Evidence is building that this is an important motivation of households (Alstone et al 2015). SHS companies are also offering incentives and widening the scope of benefits, for example providing free hospital insurance for customers who pay on time, as in the case of PEG Solar in Ghana. The point was made in the regional workshop in Ghana that companies need to tune into the aspirational nature of West Africans.

Necessary **technical developments**, requiring research and development, and more effective interaction between the research community and enterprises disseminating home-based solar systems, are summarised in the following paragraphs.

Batteries were consistently identified as the weak link in solar home systems and can account for up to half their cost. They have made rather limited progress in recent years in comparison to solar panels, but it is anticipated that significantly faster progress will be made in coming years, particularly in respect of battery technologies using lithium and sodium. A review of developments in battery technologies at the Forward Look workshop in Edinburgh concluded that incremental but significant improvements to existing commercial technologies are the developments most likely to find their way to wide-scale deployment in the market in the next ten years (see box); lead times for the radically new technologies under development may be longer.

Conclusions of the Forward Look workshop on 'Frontier Energy Storage Technologies', University of Edinburgh May 2016.

Progress in increasing battery performance will be incremental but significant over the next 10 years. Physical, chemical, and engineering research focuses on improving capacity, stability, safety and cost. Our understanding of materials systems at the atomic and molecular level will lead to gradual but substantial advances in all aspects of battery device design. Manufacturing learning curves, and scaling, and some manufacturing step changes introduced by the likes of the Tesla Giga factory, will provide major sources of cost reductions. Battery cost is predicted by many in the industry to reach below US$100 per kilowatt hour capacity by around 2020 [Lead acid batteries for a 12 volt system currently cost around US$ 125 per kWh capacity (IRENA 2016)].

The price of lithium ion batteries, taken together with their longer cycle lifetime, will make them competitive for off-grid solar home storage compared to the currently dominant lead acid batteries at some point in the near future, although the cycle life of lead acid batteries will improve. Lithium sulphur and sodium-based batteries are promising technologies in the short- to mid-term (two to eight years) for increased capacity and lower price, respectively.

The **environmental impacts** of redundant equipment from pico-solar lights and solar home systems are of increasing concern, particularly in respect of batteries: lead acid batteries may need to be replaced after just two or three years. Systems and system components need to be designed to be recyclable or reusable. Historically, batteries have not been designed to be recycled or easily repaired. This will become a much more important design consideration in future, and in particular for smart villages. For example, lithium recycling may become very important if lithium ion batteries take off.

The infrastructure and procurement chain requirements of recycling of lead acid batteries, and in the future other types of batteries, are in many cases too large for governments and businesses to achieve in the developing world. Engineers, entrepreneurs, and governments must work together to create new business models and new technical facilities that enable effective management of redundant equipment to avoid adverse environmental and health impacts. R&D is needed to develop recycling technologies that can be economically deployed at smaller scales, such as the Citrecycle technology for recycling lead acid batteries (www.citrecycle.co.uk) (Kumar 2015).

Balancing supply and demand through the day, avoiding overloading of circuits and components, and managing charging and discharging of batteries to maximise cycle life, require improved control systems. Intelligent control systems such as that incorporated in SHS by Azuri are becoming available. Remote monitoring approaches are also increasingly being used. For example, the BBOXX SHS is connected to a geosynchronous orbital satellite network which sends data back to the company on how the unit is being used, what the health of the battery is, temperature, and energy use patterns. This is very useful for monitoring the battery to replace it before it degrades too much, minimising system downtime.

To further reduce system costs, R&D on **new solar PV technologies** such as printable organic solar cells holds the prospect of significant further improvements and should be actively pursued.

Developments in solar PV technologies

'Third generation' solar PV technologies have been, and are currently, an area of intense active research. Improvements to the efficiency of mass produced silicon solar cells through clever engineering have meant that steady progress has been achieved, through the uses of 'back contact' solar cells or using 'n-type' monocrystalline silicon, for example. But 'third generation' photovoltaics include thin film technologies that would potentially provide a step-change improvement—either in efficiency or cost. These include Cadmium Telluride, organic, quantum dot, and Perovskite solar cells. Perovskite, quantum dot, and organic solar cells offer the promise of very cheap, solution-processable PV devices that could drastically reduce the upfront cost of panels by avoiding the sensitive and high temperature processing required to create high quality crystalline silicon.

Perovskite solar cells, made of a mix of a small amount of lead, halogens, and small organic molecules, have shown a remarkable rise in solar cell efficiency—from 3% up to 22% power conversion efficiency—in the last five years, but require much work still to attain sufficient stability to be competitive commercially (Cheng et al 2016). Organic solar cells have shown a more steady rise in efficiency (currently they are around 14% efficient), but have better stability than perovskites, and are already commercially available for certain niche applications, like indoor lighting (http://www.eight19.com/).

Just as important are further **developments in appliances** to increase their efficiency, reduce their costs, and improve their capability to operate with intermittent electricity supplies. Forward Look workshops (in particular in Cambridge in December 2015) have identified the significant headroom that exists for further improvements, for example, in refrigeration (see box for a brief account of the 'Sure Chill' technology), water pumping, and electric motors to drive mechanical applications such as grinding and milling.

Sure Chill refrigeration technology (www.surechill.com) provides accurate and 24/7 cooling, based on relatively simple technology, and requiring only an intermittent electricity supply. Cooling applied at the top of a vessel results in water at 4°C (when it is at its densest) falling to the bottom, providing a constant refrigeration temperature. Ice build-up at the top of the vessel results in an energy store (in effect acting as a battery that can be recharged indefinitely) that can last for around 10 days. It takes 12 to 15 hours to fully charge it. A further advantage is that temperature conditions across the refrigerator only vary by around 0.5°C, whereas the temperature variation across conventional refrigerators can be up to 5°C which can render vaccines ineffective by being made too cold.

'Plug and play' technologies provide for easier and more reliable installations. But while some progress has been made, further developments are required.

Technology development and manufacturing within developing countries brings added value and should be supported. If appropriately managed, national initiatives to build skills in the off-grid solar market can create the capacity for in-country assembly of pico-solar lights and SHS (Diecker at al 2016).

Linking together clusters of houses (typically 10 to 30) with DC connections ('DC nano-grids'), either with a central solar panel or with solar panels on each house, can provide opportunities for load sharing and can be more cost-effective for villages of an appropriate size. Advanced control systems are needed with intelligent metering to support variable charging through the day; to the extent that battery storage can be avoided, electricity services can be provided significantly more cheaply.

Such DC-based routes to electrification may become affordable more quickly than AC mini-grids and may progressively be able to support a wider range of applications. The review of DC appliances undertaken as part of the Smart Villages Initiative (Kopek et al 2016) and inputs to the workshops (see in particular the presentation by Prof Jhunjhunwala to the workshop in Patancheru in India) identify the efficiency savings that are possible by running a DC-only system powered by solar PV: for example, conversion losses in a 125 W SHS can be reduced from 45% if the appliances are AC to 7% if they are DC.

While concerns were expressed about 'AC lockout' (i.e., not being able to use AC appliances), the relative future roles of AC mini-grids and DC solar home systems/nano-grids are not yet clear. Further research is needed to help elucidate the issues.

5.2 Mini-grids

For the purposes of this report mini-grids may be defined as 'village-scale electrical generation and distribution networks either unconnected to, or able to operate autonomously from, the main electrical grid'. They occupy the middle ground between smaller home-based systems on the one hand and national grid connections on the other, as illustrated in Figure 5. Importantly, they are able to support a much wider set of productive enterprises than home-based systems. The mini-grids discussed in the smart villages workshops have typically ranged in size from five to 1000 kW, supplying a few tens to a few hundreds of households, institutions, and productive enterprises (Bahaj 2015).

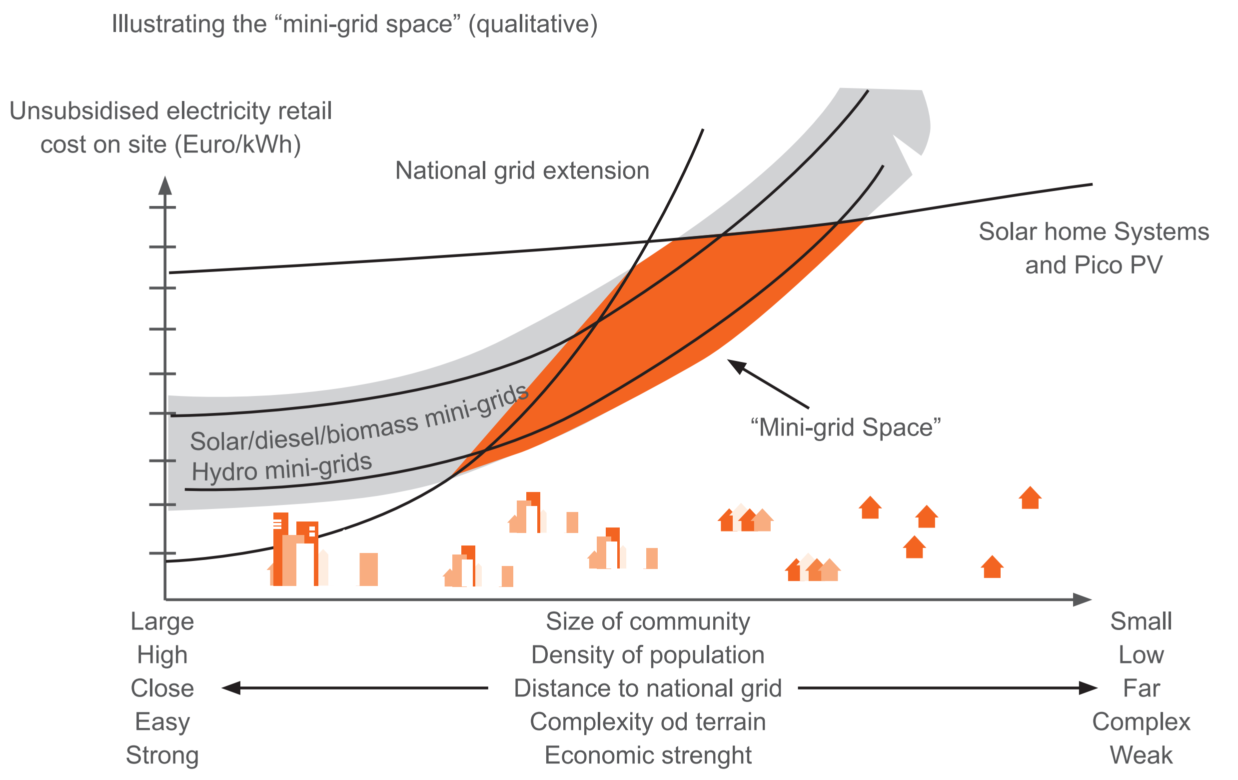


Figure 5: **Illustrating the mini-grid space. From RECP 2014** [figure 2 on page 18].

To date, mini-grids have mainly been based on micro-hydro generation in countries with hills/mountains and good rainfall (for example, Nepal, Pakistan, and Borneo) or diesel engine generation (for example, there are over 1000 diesel generators powering mini-grids in operation in Africa (RECP 2014)). The cost and price volatility of fuel for diesel engines is often a problem, and hybridisation of the diesel engine with solar PV is increasingly being undertaken.

Example of solar-diesel hybrid mini-grid: Bancoumana in Mali

A 33 kW solar PV field together with a 64 kW diesel backup generator and 3640 Ah/48 V battery pack provide power to nearly 400 households, small businesses, schools, health centre, and street lights in the village of Bancoumana in Mali, comprising 20,000 inhabitants.

Twenty per cent of the investment cost of $430,000 was provided by ACCESS Renewable Energy Ltd, which manages and operates the scheme, the remainder by the Malian Renewable Energy Agency and KfW as an investment grant. The tariff of US$0.30/ kWh, which covers the operating costs of the mini-grid, was determined by the regulator taking account of the interests of both the community and the operator. Households pay for their power consumption monthly and had previously spent $27 each month on kerosene, candles and batteries.

Planned next steps are to increase the number of connections, increase the solar and battery capacity, and improve the client management system by installing smart meters. It is intended to replicate the model in 50 further villages.

The International Energy Agency 2011 World Energy Outlook projected that standalone home-based, mini-grid, and national grid extension solutions would account for 25%, 45% and 30% respectively of new rural connections over the period to 2030. There has been much interest in mini-grids based on renewable energy sources, but apart from micro-hydro schemes (now a relatively mature technology), progress has so far been limited: pilot plants in many countries have not yet led to substantial scale-up. Nonetheless, it is estimated that five million households worldwide are supplied by renewables-based mini-grids (IRENA 2015).

A concern often repeated at the workshops was that there remains a lack of political commitment and supportive policy environments for mini-grids which would make them a more attractive proposition for the private sector. This is a generic problem for off-grid energy schemes and associated initiatives on public services and productive enterprises, and so is addressed in section 7.1. The need for effective community engagement and involvement was stressed in all workshops, and is discussed in section 5.2.3.

In general, mini-grids cost more than the revenues that they can generate through electricity sales. To ‘balance the books’ in future schemes, costs need to be reduced and/or revenues increased. Table 4 lists key factors that may reduce costs and increase revenues, which are discussed in more detail in the following sub-sections. The text draws not only on the workshops but also on a review of business models for mini-grids published in the Smart Villages Initiative’s Technical Report series (Safdar 2017).

Reduce costs	Increase revenues
Technical developments	Effective tariffs
Economies of scale and replication	Stimulate productive enterprises
Reduction in set-up costs	Increased load factors
Lower financing costs	Increased level of connections
Capital cost subsidy	Operating cost subsidy

Table 4: 'Balancing the books' for mini-grids

5.2.1 Reducing mini-grid costs

We may expect that future scientific and **technical developments** (particularly for solar panels and batteries) will reduce the costs of mini-grids. Discussion at the Forward Look workshop on mini-grids in Bangalore in July 2016 considered that technical developments could reduce the capital cost of solar PV mini-grids by 30 to 50% over the next few years, bringing generating costs down to US$0.15-0.20, comparable to unsubsidised grid electricity costs in India of US$0.15.

Optimisation of the design and operation of inverters and batteries can make an important contribution to this cost reduction. For many mini-grids, replacements of batteries are an important component of overall lifetime costs, putting a premium on their management to maximise cycle life (Alliance for Rural Electrification 2011). There were calls for the development of smart batteries that could predict failure. Hybrid ultra-capacitors integrated into mini-grid power storage systems can smooth loads, improve overall system efficiency, extend the life of the batteries, and make more usable watts available for daytime applications.

As the deployment of mini-grids increases, **economies of scale and replication** should lead to cost reduction. Currently, each mini-grid installation is unique, and there were calls for more standardisation and a modular approach. However, it was recognised that there is a tension here with the need to develop mini-grid projects in collaboration with local communities, responding to their distinctive needs.

Similar economies can be achieved by clustering of mini-grid projects in which a single management team is responsible for the operation of a set of mini-grids in the same area, and through a franchising business model (Safdar 2017). In both cases management costs can be reduced.

Set-up costs for individual mini-grid projects can be high. In the workshop in Nepal concerns were expressed that transaction costs for setting up micro-hydro mini-grids are too high, and there were calls for simplification of bureaucratic procedures to shorten project development periods. In sub-Saharan Africa it can often take three years to get the necessary licences for a mini-grid, separate licences being required for generation, distribution and sale, and for other issues such as land and water rights, construction permits and environmental impacts, each requiring interaction with different government agencies (African Union 2016; Mnzava 2015). Transaction costs should be reduced through standardised administration procedures for establishing tariffs and approving schemes (GVEP International 2011). Governments may usefully also set up web-based portals providing a single source of information on procedures, opportunities, etc., for private sector developers, reducing their costs of information gathering (for example in Tanzania: www.minigrids.go.tz).

It has been argued that individual projects are too small to absorb the fixed costs of isolated and bespoke transactions, and that there is value, as summarised in Table 5 and as proposed at the opening regional workshop in Southeast Asia, in bundling projects for investment purposes (UN Environment Programme 2015b). It was calculated that a portfolio of ten projects can reduce set-up costs by 30%. PWC (2016) argues for planning mechanisms that encourage standardisation and enable project aggregation, and proposes that unified funds are established to overcome current problems of fragmented funding and scattergun projects.

· Use of standardisation to reduce transaction costs and improve the viability of individual investments
· Unlock institutional capital by increasing scale of investment
· Reduce investor risk by diversifying across multiple projects
· Reduce costs through wholesale purchasing of equipment and services
· Increased ability to layer complementing forms of capital
· Collect aggregate data on project performance, increase the possibility of refinancing individual projects with lower cost capital
· Ability to attract carbon finance through credits given to the overall programme
· Take advantage of installations which are readily bankable to finance less bankable (but potentially more socially impactful) projects

Table 5: Benefits of project bundling

The cost of capital is a fundamental factor in the economic viability of mini-grids; **lower financing costs** can therefore have a big impact. In East Africa, interest rates for mini-grids are typically 18 to 25%. Such figures are broadly in accord with those quoted by RECP (2014) of 16 to 24% for debt and 20%+ for equity. They reflect the inherent risks associated with mini-grids, but also in many cases a lack of familiarity by the banking sector in investing in such projects, leading to a reluctance to lend; loans tend to only be for short periods. In Nepal, the point was made that the transaction costs for bankers in evaluating the viability of remote mini-grid projects are high.

Manetsgruber et al (2015) argue for a risk management approach in which risks are systematically identified and mitigated appropriately, potentially with support from governments and development agencies. This would have the effect of reducing interest rates.

For now, mini-grids generally require some form of subsidy: **capital cost subsidies** are preferred to operating cost subsidies which can become a long-term burden on governments (Glemarec 2012; GVEP International 2011). A typical micro-hydro mini-grid in Nepal requires a 32% capital cost subsidy. With heavily subsidised grid electricity in India the problem becomes more acute as mini-grid generating costs of $0.30-0.75 cannot compete with grid electricity at $0.045-0.075. Mini-grid subsidies need to be viewed in the context of such subsidies to grid-based electricity and to fossil fuels.

5.2.2 Increasing mini-grid revenues

Establishing **effective tariffs** which balance the need to achieve acceptable returns on capital against the ability of villagers to pay is a key challenge. Often governments set restrictions on the tariffs which can be charged; for example, universal tariffs in which everyone pays the same whether they live in a city or a village, and lifeline tariffs set at low rates for poor people who consume little power. Both may undermine the commercial viability of mini-grids. For example, in Indonesia, independent power producers can only charge the national tariff of $0.15 / kWh, whereas diesel powered mini-grids on islands generally generate at $0.25-0.30 / kWh. In India, restrictions on tariffs for rural customers have resulted in unreliable electricity supplies and poor financial health of electricity supply companies, leading to a proposal to charge more for a better quality service: a win-win for customers and suppliers (Ganesan et al 2017). Accenture (2015) expresses the concern that 'tariffs are deeply political and very rarely designed around commercial realities'.

We heard mixed messages about villagers' willingness and ability to pay. In East Africa concern was expressed that villagers overstate their willingness to pay compared to their ability to pay which brings subsequent problems for the sustainable operation of mini-grids. In West Africa the point was made that the ability of villagers to pay is often underestimated. In India the example was given of a solar PV mini-grid where villagers have been diligent in paying rates four times those which apply in cities. In-depth surveys of villagers' willingness and ability to pay are needed before projects go ahead.

A point made frequently at the workshops was that **stimulating productive enterprises** is very beneficial to the revenue streams of mini-grids, and should therefore be included in a broader package of measures undertaken in connection with electrification projects. The stimulation of such enterprises requires an integrated approach in which market barriers are identified and requisite investments in infrastructure, such as information and communication technology, roads, etc., are made. For example, in Uganda rural trading centres are being established that provide good customer bases for mini-grids.

Local businesses are often better able to pay for electricity than households (see box for example from Bangladesh). By increasing the productivity of existing businesses and catalysing the establishment of new ones, new sources of income can be brought into the village, increasing villagers' ability to buy electricity. The timing of productive use demands, which are typically during the day, is generally complementary to most domestic demand which is in the evening.

100 kW solar mini-grid on Sandwip Island, Bangladesh

The 100 kW solar mini-grid operating since 2010 on the remote island of Sandwip, Chittagong, was constructed to demonstrate the use of solar energy for grid quality electricity and to increase access to electricity for commercial and productive use in an off-grid area. The project was financed by an IDCOL loan (30%), a grant from the KfW Group (50%), and sponsor's equity (20%). Its cost was 56.78 million taka (around US$730,000). Distribution lines total 4 km.

Target customers are primarily businesses and institutions rather than private households. Whilst the scheme has had a very beneficial impact on local businesses (for example, 198 commercial shops are connected, many of which have been opened since the initiation of the scheme), only two schools are connected as most cannot afford it. Many of the businesses previously generated their own electricity from small diesel generator sets. Fans are the biggest single load on the system.

An unexpected challenge for the mini-grid has been the arrival of national grid electricity on the island. Other challenges include the difficulty of matching loads and the low income of households on the island, requiring the focus on commercial and institutional customers to achieve project viability. Operational challenges include the need for continuous support to ensure the smooth running of the plant, a lack of technical and administrative human resources on the island, the need for consumer education to optimise use, and the requirement for demand side management to achieve long-term reliable operation. Low-cost funding has been needed with long tenure, which is not typically available from commercial banks.

As discussed at the Nepal workshop, the Nepal Government's Alternative Energy Promotion Centre provides support to productive use alongside electricity access; it has established 2800 new micro, small and medium-sized enterprises (MSMEs) and upgraded 1300 existing ones. Support is offered through business development and financial assistance. Technical assistance is given to identify what is available in terms of markets and capacity in the area through business opportunity assessment, followed by facilitation of business plan development and business registration. Training is offered on business orientation, enterprise creation, business management, and skill development. Market linkages are facilitated. There is regular follow-up and monitoring for those moving to the next level. There is evidence that electricity access along with such business development support can have a significant positive effect: there has been a 20% increase in the income of MSMEs in renewable electricity system catchment areas.

From the literature (Yao and Barnes 2007; Bhattacharyya and Ohaire 2013), the success of the rural electrification programme in China (which reached close to 100% electricity access in 2016) was the ability to set tariffs which gave almost full cost recovery, made possible by the active promotion of the productive use of electricity from an early stage.

Increasing load factors enables more revenue to be generated for a given capital investment. This was illustrated in discussion at the Nepal workshop where it was considered that to achieve acceptable private sector commercial returns (18% with a 60% capital subsidy) load factors need to be at least 50% and up to 70% for remote villages (see box for Gorkha example). Here, productive uses of electricity are seen to be the key to higher load factors, as discussed in the preceding paragraphs.

The Gorkha mini-grid

Supported initially by the NGO Winrock International, a local entrepreneur obtained a loan for the construction of a 50 kW micro-hydro system in Gorkha, a mountainous region of Nepal. Rural enterprises that made productive use of electricity were subsequently set up, and through coordination of loads through the day (for example, baking late at night and operating mills during the day) a load factor of 75% was achieved. This led to increased revenue, and profits were reinvested to increase the capacity of the system to 100 kW. Key points made by participants regarding the success of this case were: the clustering of households in the Gorkha region, the homogeneity of the community, and the use of effective tariffs.

Discussion of this example at the Nepal workshop was just days before the major earthquake which hit Nepal in April 2015 with Gorkha as its epicentre, causing major damage to the village. At the time of the discussion there were further plans to again increase the system's capacity significantly: subsequent to the earthquake all attention has been on restoring the infrastructure of the village, illustrating the importance of resilience to natural disasters discussed in section 6.4 of this report.

In the discussion of diesel-PV hybrid mini-grids for islands at the Indonesian workshop, the point was made that diesel generators running at less than 30% of their peak load operate very inefficiently. There is therefore a premium on maintaining high load factors. Management of loads through modern control systems (for example, as illustrated by the Chottkei mini-grid in India described in Section 6.1) and tariffs can help achieve high load factors. IED (2013) provides a useful review of emerging technologies for load management. In Pakistan, linking of micro-hydro schemes in neighbouring villages provides opportunities for load sharing and management, improving the overall economics of the set of schemes.

The Smart Villages technical report on 'Making Smart Villages a Reality'(van Gevelt and Zhang 2017) provides the example of Thailand in which concerted attention was given to promoting productive use of electricity in villages as an integral component of the government's rural electrification initiatives over the period 1970 to 2000. As most villages had at least one or two rice mills and cottage industries, previously powered by diesel engines, the daytime load in villages increased significantly as they switched to electrical power. This improved the load factor—previously skewed towards evening use—and improved the rate of return, thereby allowing more villages to be electrified (Tuntivate and Barnes 2007).

Anchor loads—typically commercial companies with predictable and long-term electricity needs that are prepared to enter into long-term contracts—can provide a good foundation for building load factors (Safdar and Heap 2016; Schnitzer et al 2014). For example, at the off-grid business models workshop in Cambridge in January 2016, the business model of Cambridge Energy Partners was discussed in which an anchor load is initially established with a mining enterprise, and electricity distribution is then extended to adjacent villages in which economic hubs are developed to further enhance demand.

Another pervasive opportunity for anchor loads discussed at the workshops is presented by cell phone towers; for example, Accenture (2015) points to the 400,000 cell phone towers in

India, accounting for 30 to 50% of the operating expenditure of mobile network operators. For the mobile network operators, contracting for supply of electricity from a mini-grid offers a number of advantages: reducing costs, enabling them to focus on their core business, improving their ability to forecast their operating expenditures, and improving brand awareness through community engagement and partnership.

Schools and health centres may also constitute anchor loads, and several governments have established initiatives to achieve 100% electricity coverage for such institutions. In all cases, careful consideration needs to be given as to who is responsible for the operation and maintenance of the system: it may not be appropriate to distract headmasters and doctors from their main tasks, and operators of commercial and industrial facilities may well have other priorities.

Increasing the level of connections in a village (sometimes referred to as a process of densification) reduces distribution costs per customer. A commonly encountered problem (for example in East Africa) is that households do not opt into the mini-grid scheme as customers, in many cases because they cannot afford the connection charge. In this case, subsidies to the connection charge may be appropriate.

In addition, there is value in increasing the demand for electricity and hence the revenue from each customer. One approach is through 'bundling of services' in which the electricity provider also supports the sale of appliances (International Finance Corporation 2016). Also, charging schemes need to be enforced and a strong line taken on disconnection if households do not pay; for example, in Tonga electricity connections and metering are located outside the house so that disconnections can readily be made if necessary.

Prediction of customer uptake and demand for mini-grids is challenging. There is consequently a premium on technologies such as solar PV which lend themselves to incremental additions to capacity, in contrast to micro-hydro schemes where the capacity has to be committed at an early stage.

Operating cost subsidies are in many ways a 'last resort': for example, in the opening regional workshop for Southeast Asia, preference was expressed for supportive regulations and tax incentives as alternatives to long-term operating cost subsidies. They can become an unsupportable burden for governments, and are vulnerable to 'cliff edge' problems if supported by donors for fixed periods without regard to the subsequent viability of projects. While cross-subsidies are common for grid-connected customers, they are more difficult to set up for off-grid schemes (Palit and Sarangi 2015).

If they are used they need to be carefully designed and targeted (see box for example of Ghana) as they may otherwise be regressive, favouring wealthy people over the poor, and should provide for being phased out as they may otherwise be 'addictive' (Ahuja and Tatsutani 2009; GVEP International 2011; Pachauri et al 2013; Pueyo et al 2013).

Cross-subsidisation in Ghana

In Ghana, there is a policy of cross-subsidisation between urban and rural consumers; although it generally costs more to supply rural consumers than urban consumers, tariffs are the same in rural and urban areas. A 'lifeline' tariff applies to customers using less than 50 kWh per annum. Tariffs then progressively increase through bands: 50 to 150, 150 to 300, 300 to 600, and greater than 600 kWh per annum.

5.2.3 Community engagement

One of the strongest and most consistent messages from the workshops was the need for off-grid energy initiatives to be founded on close and extensive community engagement to ensure the support of villagers and so that the development path and energy schemes can benefit from, and build on, local knowledge, cultures, and customs. In the absence of such engagement and buy in, energy initiatives are likely to fail. Villagers should retain control of their development path and should be the main drivers of energy initiatives. The priorities of international development initiatives do not necessarily reflect those of villagers.

Such engagement takes time—typically six to 18 months—and needs to build trusting relationships, potentially by working through individuals and organisations that are already trusted by the community. The effort required should not be underestimated: we heard various formulations along the lines of projects being '70% social / 30% technical'. While village chiefs and elders will play an important role, and it is appropriate to identify and nurture champions within the village, care should be taken that there is a voice for the poorest and marginalised within the village, not just the powerful. Energy access initiatives should be seen as a mechanism to build the social capital of communities, and support may need to continue after project construction is completed.

There may be some initial scepticism from communities; they may have had bad previous experiences of technologies and interventions or, as sometimes experienced (for example in India), they may regard off-grid electricity as sub-standard—not 'proper electricity' like grid-supplied power. 'Seeing is believing' and successful demonstration projects can be persuasive. Also developers should be prepared to deal with resistance and problems (such as land ownership) which may arise at any stage of a project. Government-led initiatives may be necessary and appropriate to prepare the ground. For example, in Indonesia 80 young engineers have been recruited by the government as 'patriots' who will be deployed in remote areas to search for and progress local energy schemes with village communities.

Communities should have a stake in energy initiatives, possibly through 'sweat equity', for example, by providing labour for the construction of a micro-hydro scheme, or by providing some part of the initial capital investment. This creates more of a sense of ownership and villagers become active stakeholders in the project. For example in Pakistan, communities had to make commitments to capital generation, capacity development and certain responsibilities for organisation before being accepted into the Aga Khan Rural Support Programme. This has made an important contribution to the success of the Programme.

There are some examples of mini-grids being run effectively by village committees; for example, micro-hydro schemes in Pakistan and Borneo, and mini-grids in some island communities and remote villages in India. Generally, these schemes have been able to build on already strong community governance structures. On balance, the majority view expressed in the workshops was that villagers tend to lack the necessary business skills and discipline. Community-based ownership and management structures tend to be loose—financiers are uncomfortable with this, making it difficult to obtain loans for the initial capital outlay—and they may suffer from coordination failure: 'everyone owns it and no one owns it'. Village-level projects in India have failed because the village energy committees set up to manage the schemes were assigned roles that they were not adept to handle.

Hybrid models were proposed involving community ownership and private sector management. Safdar (2017) and RECP (2014) provide useful summaries of alternative operator models. The box provides an example of an NGO-run scheme in Tanzania where community participation has made a major contribution to the success of the scheme (Ahlborg 2015).

The Mawengi micro-hydro scheme in Tanzania

The Mawengi micro-hydropower scheme is located in the southern highlands of Tanzania. Initially, 260 users (including 30 commercial and six productive enterprises) were connected to this scheme, which was funded by donors but owned by a local NGO, LUMAMA. In this first phase there was low consumption for productive use (less than 30%); revenues were insufficient to cover operation, maintenance, and depreciation costs; and LUMAMA did not have the capacity to manage the service efficiently.

An additional problem for the project was caused by farming practices upstream of the hydropower plant which led to a build-up of silt that compromised the plant performance. Appealing to the upstream villagers was difficult as they were not connected to the energy output of the hydropower scheme.

By 2014 connections had risen to 1200, and maximum output was 260 kW. Concerted effort has been put into capacity building of LUMAMA, and the electricity scheme has been integrated with other development initiatives related to agriculture, business, education, land-use planning, and water conservation. Upstream farmers were being persuaded to move away from the riverbank to reduce siltation. A shift has been made to a pre-pay tariff structure and a balanced budget was achieved thanks to an increase in productive uses, in particular milling machines.

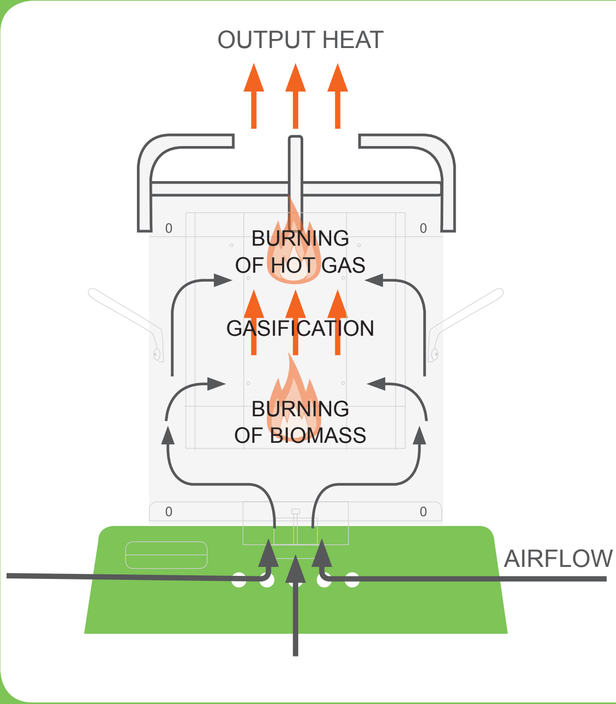
Local participation has been invaluable in protecting infrastructure, enabling collaboration around the common resources, capacity building, building trust between the community and LUMAMA, and preventing capture by an elite.

5.3 Clean cooking technologies

As discussed in section 3, 2.7 billion people in the developing world still rely on traditional biomass for cooking with profound impacts on their health, and on the environment through emissions of CO_2 and black carbon, and through contributing to deforestation. Cleaner cooking technologies involve a switch to cleaner fuels such as LPG or biogas, or continue to burn biomass but in 'improved cookstoves' which increase efficiency and reduce harmful emissions through enhancements to combustion and heat transfer processes (see box). The opportunities and challenges of adopting clean cooking technologies have been considered at several workshops in the Smart Villages engagement programmes (in particular, in Malaysia, Tanzania, Pakistan, Indonesia, Peru, Ghana, and India), and in a workshop in Myanmar focusing on the issues of clean cooking in Southeast Asia.

Improved cookstoves: how they work

As biomass heats up it releases a mixture of volatile gases, leaving behind a solid carbon-rich char. For efficient burning, sufficient air must reach both the gases (which contain around 75% of the energy content of the biomass) and the char. If not, there will be incomplete combustion reducing the efficiency and producing soot and smoke.



In improved cookstoves, the necessary contact of the air with the char and volatile gases is enhanced by raising the grate so that air can flow underneath the fuel, and through careful design of the combustion chamber so that air reaches all the burning areas. In some 'semi-gasifier' designs (as illustrated in the diagram[16]), the combustion of the char and the volatile gases is more clearly separated, each having its own air supply, in some cases supplied by a small fan.

Heat losses are reduced by insulating the combustion chamber, and heat transfer to the food is enhanced by ensuring good contact between the hot gases from combustion and the cooking pot or hotplate. A chimney may be used to take the combustion gases with any remaining smoke away from the kitchen area, and can also improve combustion by increasing airflow through the stove.

Typically, improved cookstoves reduce wood use by 20 to 60% compared to open fires.

The main focus of discussion at the workshops was how to establish the framework conditions necessary to progress the deployment of improved cookstoves. An estimate in 2009 (Legros et al 2009) indicated that only around one quarter of the 2.7 billion people relying on biomass for cooking used cookstoves that might be considered 'improved' (only 6% in sub-Saharan Africa). Figures provided by partners in the Global Alliance for Clean Cookstoves (2016) indicate that around 13 million improved cookstoves were distributed in 2015 and that there is a trend towards an increasing proportion of higher tier stoves as reflected in the World Bank's multi-tier framework for energy access (ESMAP 2015).

As observed in Chapter 3, the rate of progress in disseminating improved cookstoves has been slow. It is considered to be a rather neglected issue in comparison to electrification: for example, a review in 2009 revealed that only 2% of energy strategies in the least developed

16 *Diagram courtesy of Nguyen Hong Hanh, SNV, Vietnam*

countries addressed cooking (Havet et al 2009). This is an important omission given that cooking accounts for the major part—more than 90%—of energy consumption in the rural areas of many developing countries, and that it is estimated that universal access to clean cooking could be achieved for one-tenth of the cost of universal electricity access.

However, in recognition of this gap in initiatives on energy access, increasing attention is now being given to the deployment of clean cooking technologies. The Global Alliance for Clean Cookstoves (www.cleancookstoves.org) has been established, hosted by the UN Foundation, as a public-private partnership with the aim of spurring the adoption of clean cookstoves and fuels in 100 million households by 2020 (Global Alliance for Clean Cookstoves 2011). For example, in the ECOWAS region of West Africa targets have been set for the deployment of clean cookstoves (60% of population served by 2020 and 100% by 2030) and access to LPG (17% of population with access by 2020 and 32% by 2030).

A shift to cleaner fuels in the form of biogas was discussed in a number of workshops as summarised later in this section, and large-scale initiatives to deploy LPG were touched upon; for example, the dissemination of 54 million LPG packages in Indonesia, and current plans in India to connect 50 million poor households to cooking gas by 2019. In Peru, the government issues vouchers to poor households as a subsidy for the purchase of LPG, though uptake is limited by the LPG distribution network.

In respect of the motivating factors for clean cooking, the health issues are discussed later in this section. The impact of wood fuel collection on deforestation was considered in workshop discussions to be less clear-cut. While it is a major motivator for clean cookstoves initiatives in some countries, for example, Myanmar, views were expressed that there is limited evidence for it being a major factor in deforestation. Impacts are likely to be location specific, and more of a problem in arid areas than in greener areas like Southeast Asia. This is symptomatic of the fact that deforestation results from a range of causes, of which firewood collection is just one (EUEI PDF 2014). Nonetheless, the substantial reductions in fuel wood requirements arising from the adoption of clean cookstoves, together with sustainable management of forests, can make a useful contribution to reducing deforestation and biodiversity loss, and to climate change mitigation.

The conclusions and recommendations of the workshop discussions are summarised in the remainder of this section in relation to each of the following issues:

1. Responding to user needs and cultural norms
2. Increasing awareness
3. Gender issues
4. Financing of the cookstove value chain
5. Support to businesses operating in the value chain
6. Product quality, standards and testing
7. Health issues
8. Biogas.

5.3.1 Responding to user needs and cultural norms

The use of cookstoves is driven by socio-cultural factors. The designs of improved cookstoves and programmes to disseminate them should therefore be tailored to local cooking habits and be cognisant of other functions, such as providing light and repelling insects, otherwise their adoption and sustained use will be limited. A first step in any initiative to develop an improved cookstove should therefore be to properly understand local cooking norms and cultures. New designs will have a greater chance of success if they build on incumbent technologies. This need to develop locally appropriate designs results in a tension with calls for a more industrialised approach driven by considerations of improving quality and reducing price.

There is a need for a systems thinking approach in which the entire cooking system is considered. This may identify other ways in which fuel use can be reduced, for example by using solar water heaters or even simpler technologies like black polythene bags in the sunshine to heat or preheat water, or to change the ways in which food is cooked (Practical Action 2010, 2014). Such changes to long-established norms are likely to be more difficult to promote.

5.3.2 Increasing awareness

Householders lack awareness of the benefits of adopting improved cookstoves, so governments and donors should continue to invest in public awareness projects for householders to understand the health, environmental, and social benefits of using them. More research is needed in order to build a body of evidence about the positive effects of improved cookstove adoption, requiring collaborative projects between academia and other stakeholders. The arising evidence will be useful in sensitising stakeholders, including governments and development organisations, to the needs and opportunities for improved cookstove dissemination.

Consideration should be given to appropriate entry points for engagement with villagers. For example, in Kenya, a clean cookstoves initiative worked with a farmers' federation, and set up demonstration kits in each of five tea factories. In West Africa, radio broadcasts and schools are important channels for raising awareness, and community members are used as local champions.

A GVEP programme to support energy enterprises in East Africa (Clough 2011) concluded that SMEs working in the improved cookstoves value chain should pay more attention to marketing and identify what factors are important to potential customers in taking a decision on whether to invest in an improved cookstove. For example, in areas where wood and charcoal are purchased, the promotional message should probably focus on 'save money' and 'use less fuel'. Whereas, in areas where biomass is collected rather than bought, the message should put the focus on 'save time' and 'less smoke'.

5.3.3 Gender issues

In many cases, improved cookstove dissemination programmes are not targeted primarily at women, who have the main responsibility for cooking within the household and are most at risk from indoor air pollution. While this is changing, more needs to be done to engage women in order to ensure adoption and sustained use of improved cookstoves (which are a very 'gendered' technology). As they do not generally cook or collect firewood, men tend not to properly appreciate the benefits of improved cookstoves and may therefore oppose their purchase. And if information on how to use cookstoves is given to the men, often they do not pass it on. 'Middle women' are needed, not 'middlemen'.

Women's voices should be brought to the fore and they should be engaged from the start in interventions, including in the design of improved cookstoves. Women's groups and unions can play an influential role in promoting clean cooking solutions. For example, an improved cookstoves initiative in Lao PDR worked closely with the Lao Women's Unions, who set up steering groups in each of three provinces to act as a channel for communication with women in rural households.

Fuel wood collection can typically take up to four hours per day. As women generally undertake this task it reduces their scope to undertake paid work and therefore limits their economic position and influence in the household. It also reduces their leisure time and access to education. In contrast, it has been found in schemes centred on training women to manufacture and sell improved cookstoves that those skills open up new income-generating opportunities, for example as masons in the village, and as agents for mobilisation and training more generally in the community.

5.3.4 Financing of the cookstove value chain

Across Southeast Asia, most rural consumers are very cost-conscious; therefore, improved cookstoves need to be priced so that they are affordable. Table 6 gives some indicative prices for commercial improved cookstoves.

- Justa: US$60 (built by technicians in the home, mainly from brick)
- RETC: US$20 (users trained to make specially-shaped mud bricks and build stoves in their homes)
- Grameen Shakti: US$10 to 12 (built by technicians in the home, mainly from mud)
- New Lao: US$2 to 3 compared to US$1 to1.5 for Traditional Lao (produced by local artisans. The extra cost is paid back within two months through savings on charcoal)
- Greenway Grameen 'smart stove': US$23 (retail)
- Nishant Bioenergy 'earth stove': US$400+ depending on size (this is a large stove for food stalls and restaurants).

Table 6: Indicative prices of improved cookstoves[17]

Furthermore, stakeholders involved in cookstove dissemination programmes should develop financing mechanisms to support the uptake of improved cookstoves. Such financing mechanisms should be available throughout the value chain: actors at each stage need to be able to establish viable business models. This requires an evaluation of the financing needs of actors at each stage of the value chain.

For example, if entrepreneurs are to be motivated to invest in setting up manufacturing facilities, mechanisms to reduce their financial risk may be appropriate. If retailers are to stock improved cookstoves which are more expensive than traditional cookstoves they will need more working capital. One solution that has been successfully used is a revolving fund providing loans to manufacturers who can then pass on credit facilities to their retailers. Households may not be able to afford the upfront costs of an improved cookstove, and micro-finance institutions are often not interested in making loans for this purpose. In this case, financing may appropriately be provided to retailers who can pass credit to householders, who can then pay for their cookstoves in instalments.

Industry associations can also play a useful role. For example, in Cambodia the association of stove manufacturers has established a loan system whereby the association gives loans to mem-

17 *From Ashden website: www.ashden.org*

bers based on their requirements. Each member of the association contributes to the fund each month and can access it according to their needs. The loans can be used to expand production capacity or to improve the downstream supply chain.

Based on an extensive programme of support to energy SMEs in East Africa, GVEP (2013) concluded that capacity building is needed for financial institutions which otherwise may not have sufficient appreciation of the issues and opportunities inherent in the clean cookstoves value chain.

If cookstoves are given for free to households, there may be a lack of ownership and, consequently, they often fall into disuse. Workshop participants went so far as to call for government clampdowns on organisations giving cookstoves away: they spoil the market for incumbent players and potential entrants to the commercial value chains which are the key to sustainable deployment.

Well-targeted and time-limited partial subsidies for the poorest segments of rural communities or financing schemes to overcome the up-front cost hurdle have been shown to be more effective in practice. In Indonesia a government-led clean cookstoves initiative has provided subsidies to manufacturers at levels corresponding to their stove performance. Government support could also be in the form of reduced duties on the import of manufacturing machinery and materials that are not available locally.

5.3.5 Support to businesses operating in the value chain

In order to achieve the required substantial increase in the uptake of clean cookstoves, healthy value chains need to be established in which manufacturers, wholesalers and retailers can make decent profits. The creation of a thriving global market for clean cookstoves is a key aim of the Global Alliance for Clean Cookstoves (2011). But profit margins tend to be low, not least because the price of cookstoves needs to be kept low if they are to be afforded by poor households, and problems have been encountered in attracting new entrants into the market. For example, an initiative in Kenya trained 19 villagers in how to manufacture improved cookstoves but only two subsequently remained active as manufacturers, mainly because of low profit margins. In India, there is still a scarcity of companies selling improved cookstoves despite various initiatives on the ground.

Support needs to be provided to actors across the value chain, taking an integrated approach (see box for example of Lao PDR). Local cookstove manufacturers should be provided with managerial support in order to develop their business expertise, as many of them do not have the managerial capability to develop systems that can support the growth of successful enterprises. Start-up costs for manufacturing facilities can be prohibitive and governments should consider setting up incubators to help get new businesses off the ground. From their extensive experience of supporting energy SMEs in East Africa GVEP (2013) observes that well applied mentorship and coaching can substantially improve their capabilities and prospects.

Sustained and long-term support and training is also required to develop local stove-building expertise. Development of the supply chain should ensure that the necessary raw materials are available, and wholesalers and retailers need to be incentivised to stock improved cookstoves and to promote their use by consumers. Informal social networks can play an important role in such promotion.

Example of improved cookstoves initiative in Lao PDR

The initiative is being funded by the European Union over a four-year period 2013-2017. Key planned outcomes and progress to end 2015 are:

- 15 SMEs will be established producing 100,000 high quality improved cookstoves: in fact, 19 producers had been established by the end of 2015 (of which seven are managed by women), which had produced over 60,000 stoves.
- 150 SME retailers will be created and successfully promote improved cookstoves with more effective marketing strategies: by the end of 2015, 733 retailers had been established (of which 675 are owned by women).
- Lao Women's Unions in each of the five target provinces will act as effective promotional partners: at end 2015, Women's Unions in three provinces were active.
- Access to clean and efficient improved cookstoves will be improved: the stoves are available and delivered to retailers at 35-50,000 KIP (US$4.50-6.00).
- Five testing agencies operational providing independent quality labelling: three laboratories established by end 2015.
- National quality standard and trademark will be established: this was endorsed by the Ministry of Science and Technology in 2015.
- Multi-stakeholder partnerships will be established involving stove producers, retailers, financiers, and authorities: in place in each province and holding monthly meetings for consultation, problem solving and experience sharing.

5.3.6 Product quality, standards, and testing

The improvements to efficiency and cleanliness made by improved cookstoves result from more precise design of the combustion and heat transfer characteristics of the stove (see box for example of the 'New Lao' stove). This requires increased attention to quality control in the manufacture of the stoves and the establishment of standards and associated testing facilities. In the few schemes that have received carbon credits, it must be demonstrated that efficiency improvements are sustained over time. In such a scheme in Cambodia, the carbon credits go to support training, quality control and capacity building rather than to subsidise producers.

The New Lao Stove[18]

Many people in Cambodia cook on 'Lao' stoves, which burn charcoal on a grate fixed in a fired clay liner that sits in a metal bucket. Similar stoves are widely used across Southeast Asia, and in East and West Africa. Air for combustion comes through an opening near the base of the stove, and pot-rests allow a single cooking pot to sit on top. The stoves are made by local artisans and are very cheap but rarely last for more than a year.

The NGO GERES worked with stove users and artisans to improve the traditional Lao stove by increasing its efficiency and durability, while still using similar manufacturing techniques. The 'New Lao' stove uses slightly different dimensions to improve air flow; extra holes across the grate to give more uniform combustion; and tapered pot rests to provide a uniform narrow gap around the base of different sized pots, giving good heat transfer. Heat loss is reduced by tightly packing the gap between the liner and the bucket with insulating rice husk. This also reduces wear and increases the stove life to two or three years.

Tests show that the New Lao stove cuts charcoal use by an average of 22%. The stove has become very popular, and by January 2013 over two million had been sold.

Challenges to maintaining quality over time include that moulds wear out, raw materials may not be available to a consistent standard (and can be problematic if a new manufacturing location is adopted), and producers may relax standards if volumes increase. Most improved cookstoves are made by artisanal producers who may not be aware of the importance of quality assurance. Programmes aimed at developing the improved cookstoves value chain should provide technical support and training to producers to make them aware of the importance of quality and to help improve product quality. Ensuring uniform quality of the product is likely to have a positive impact on the uptake of improved cookstoves. Manufacturers that maintain good quality can brand their products to differentiate them and capture the associated added value (Clough 2011). Governments can exert pressure for quality by only allowing quality accredited producers to take part in government sponsored initiatives.

While there has been progress in developing standards and testing facilities for cookstoves, more needs to be done. Such standards are necessary to ensure the quality of products so that consumers have an idea of the performance of the products that they buy. These standards also help to ensure that there is evidence of their benefits to present to local and international stakeholders, not least to support access to carbon credits and results-based financing.

Testing methodologies need to recognise potential differences between performance in the laboratory and the home, and that the quality

18 Example of New Lao stove taken from Ashden website: www.ashden.org of manufactured products may deteriorate over time, requiring repeat testing and accreditation. While individual governments may usefully set standards for their country, there is value in an agreed set of international standards for clean cookstoves: interim standards have been developed by the International Organization for Standardization (ISO), and work is in train to develop new standards[19].

At the first regional workshop in West Africa it was suggested that governments should intervene in the cookstoves market to limit the availability and/or to phase out old cookstove technologies.

5.3.7 Health issues

As documented in Chapter 3, indoor air pollution from traditional biomass cooking and the use of kerosene is responsible for over four million premature deaths annually. This is more than the death toll from HIV/AIDS, malaria and tuberculosis combined. Levels of indoor air pollutants can be 100 times the recommended limits of the World Health Organisation. Women and children are the worst affected. Ill-health for children can have knock-on consequences for their education if they cannot attend school. There is a low level of awareness of these health impacts in both rural and policy communities (Practical Action 2016).

In addition, 300,000 people are killed annually through burns. As the main collectors of firewood, women are exposed to gender-based violence. Injuries, particularly to their heads and spines, are common and pregnant women are prone to complications (Global Alliance for Clean Cookstoves 2011).

Families may cook less nutritious food or not eat at all if they do not have enough firewood (Practical Action 2014). Conversely, improved cookstoves make bought wood and charcoal go further, potentially making it possible to afford two meals a day instead of one.

A major study by the World Health Organisation (2014) concluded that for several important health outcomes exposure to fine particulate matter needs to be brought down to low levels in order to gain most of the health benefit. LPG and biogas-based cooking can generally meet these particulate limits, but such clean fuels are not available to everyone living in rural communities. The WHO study also concluded that most of the improved cookstoves promoted in recent years have not come close to meeting these particulate levels in everyday use, though the use of a chimney can bring emissions down to broadly compatible levels. Research and development is needed urgently to prepare a new generation of improved cookstoves that meet the required particulate emission levels. More research is also needed to develop a stronger evidence base of the health impacts of improved cookstoves.

Given the interactions between clean cooking, climate change mitigation, deforestation, and health, a more integrated approach is needed bringing together the actors who otherwise tend to work in parallel and separately on these different issues. Given the values that are attached to avoiding greenhouse gas emissions, preserving forests (and the associated biodiversity), and protecting human health, and the money consequently spent to address these issues, a more integrated approach should aim to channel associated funding streams to support clean cooking technologies according to the contributions they can make.

5.3.8 Biogas

Domestic bio-gasifiers use a process of anaerobic digestion to convert manure and other organic waste into a biogas for cooking and a bio-slurry which can be used as a fertiliser. They can also

19 http://cleancookstoves.org/technology-and-fuels/standards/index.html contribute to reducing methane emissions. They are extensively used in villages in the developing world: for example, over 40 million had been installed in China by 2011 (Zuhzang 2013) and nearly four million in India by 2006 (Ali and Semwal 2014).

As indicated in the previous sub-section, cooking with gas can bring exposure to particulates and harmful substances down to guideline levels set by the World Health Organisation (WHO 2014). Where LPG is not available, bio-gas may offer an effective alternative gaseous fuel, particularly if domestic animals are kept which can generate sufficient digestible biomass. An example given for Latin America was that five to six cows or 80 guinea pigs should provide enough biogas to cover the cooking needs of a family.

The workshops provided evidence that bio-gasifiers continue to attract interest to provide a clean cooking fuel and a valuable by-product in the form of the bio slurry: 300,000 have been installed in Nepal; members of the Society for Biogas Promotion in Pakistan have installed 7000 units in the last six years and plan to install a further 125,000 units; an initiative in Kenya installed 3500 bio-gasifiers; the national bio-digester programme in Cambodia has installed 5600 units; and the government of Ghana has a policy to increase the use of domestic biogas in rural areas.

While emphasis is placed on the use of simple technologies and achieving low cost, concerns were expressed that the sustained operation of bio-gasifiers by households requires more active management and higher levels of skills than some other technologies. Cultural issues are important, particularly in respect of the use of human waste which is not accepted in some countries.

5.4 Recommendations on providing sustainable energy services to rural communities

This section summarises the key recommendations arising from the work of the Smart Villages Initiative in respect of the provision of sustainable energy services. The following three sub-sections cover, in turn, solar home systems and pico-solar lights, mini-grids, and clean cooking technologies.

5.4.1 Solar home systems and pico-solar lights

Recommendations in respect of the availability of affordable working capital, enhancing the awareness of villagers of home-based solar technologies, and developing the necessary technical and commercial skill base are covered in Chapter 7 on cross-cutting issues.

For governments and international development organisations key recommendations are:

- The reasons behind the successful experiences of the deployment of solar home systems and pico-solar lights in East Africa led by commercial companies, and in Bangladesh through an effective government-led scheme, should be evaluated and communicated to stakeholders in other regions with a view to accelerating deployment in those regions.

- The rapidly improving cost-effectiveness of home-based systems, together with business models that facilitate payment by instalments, are progressively eliminating the need for subsidies for all but the poorest households. To the extent that subsidies are still considered appropriate in particular situations they should be carefully targeted. Initiatives to give away pico-solar lights and solar home systems should be actively discouraged: they undermine the long-term sustainability of the sector.

- To tackle the endemic problem of poor quality products, international standards should be adopted at national level and testing schemes, regulatory regimes and facilities put in place to ensure that they are adhered to. Action is needed at an international level to stem the flow of counterfeit products.

- Technological developments will continue to play a major role in enhancing the affordability and utility of home-based systems. R&D programmes should continue to be supported on key system components (batteries, solar panels, control systems, plug and play, and recycling) and the further development of appliances to increase their efficiency, reduce their cost, and improve their capability to operate with intermittent electricity supplies. Increasingly, R&D should be undertaken in the developing countries where they will be deployed and R&D programmes should ensure effective collaboration between universities and the commercial sector.

- Solar home systems have the potential to support an increasing range of small-scale productive activities as the cost-effectiveness of supply and use technologies improves. A study should be undertaken to identify the opportunities for such productive activities and to quantify the values that need to be achieved in key parameters, such as cost and efficiency.

For companies and entrepreneurs in the business of providing energy services in poor rural communities, key recommendations are:

- Consideration should be given to opportunities to broaden the product/service offering to include domestic appliances and services such as insurance products which may hang off the development of household credit histories.

- Collaborative opportunities to work with organisations providing other products and services to rural communities in order to extend and reduce the cost of distribution networks should be explored.

- Possibly working through trade associations, consideration should be given to the value of standardisation of system components to mitigate problems experienced in the availability of spare parts in dispersed settlements.

5.4.2 Mini-grids

Recommendations on the stimulation of productive enterprises to enhance the economics of mini-grids are covered in Chapter 6, and on the need for political commitment and a supportive policy framework, and on the cost and availability of capital are covered in Chapter 7.

The following recommendations are aimed at governments, the private sector and development organisations:

- Recognising that provision of electricity to rural communities is inherently more expensive than urban electricity supply, it is all too easy to regulate tariffs for mini-grids in such a way as to exclude private sector involvement. Private sector companies running mini-grids should be able to set tariffs at a level which achieves a balance between affordability to villagers (and to governments/donors if subsidies are provided) on the one hand, and to generate revenues sufficient to meet commercial returns on capital on the other hand. Governments and the private sector need to come together in effective public-private partnerships if the much-needed scale-up of mini-grid deployment is to be realised.

- Community engagement is vital, and funding schemes should be set up in a way that provides the necessary time, flexibility, and resources. While a sufficient sense of ownership by the community is a necessary outcome of the engagement process, careful consideration should be given to the allocation of responsibility for the operation and maintenance of the system, and to its legal/financial ownership; the particular circumstances of the village will determine whether a commercial, community, or hybrid model is the most appropriate.

- Governments should streamline licensing and approvals processes which too often absorb substantial amounts of time and money, and should consider setting up 'one-stop shops' together with supporting information portals to help entrepreneurs set up mini-grids.

- Set-up and management costs can be reduced by bundling and clustering of mini-grid projects: regulatory arrangements should be supportive.

- Anchor loads can significantly improve the economics of mini-grids and may be provided by key village facilities such as schools and health centres, and by private sector entities such as mobile phone towers, productive enterprises, etc.; mechanisms should be put in place to enable these various interests to come together when mini-grids are being designed.

- Technological developments have the potential to substantially reduce the cost of mini-grids, and collaborative R&D programmes should be funded on key components such as storage and control systems.

5.4.3 Clean cooking technologies

Initiatives on clean cooking are undertaken by national governments, NGOs and international development organisations, and the private sector plays an important role in the manufacture and distribution of clean cooking technologies; the following recommendations are aimed at this set of players. A key concern is the need to rapidly scale-up the dissemination of clean cooking technologies. More people are in need, and progress has been slower, than for electricity access:

- The designs of clean cookstoves should be tailored to local cooking customs and methods. Women are key stakeholders and should be involved at every stage from design through to implementation of clean cooking initiatives.

- The health impacts of traditional cooking technologies are a key concern and, recognising the limited availability of LPG in many places, increased attention should be given to the wider use of biogas. R&D should be undertaken to develop improved cookstoves capable of achieving the low levels of emissions necessary to significantly reduce health impacts.

- Initiatives continue to be needed to increase the awareness of villagers of the advantages of clean cooking technologies and of the health impacts of traditional technologies.

- In order to enable scale up, support is needed to organisations working along the clean cookstoves value chain in respect of access to affordable finance and developing requisite business skills. Systems should be put in place to promote and sustain enhanced product quality, including standards and testing facilities.

Chapter 6: Reaping the development benefits of rural energy access

Whereas the previous chapter considered the issues associated with the provision of sustainable energy services to rural villages, this chapter focuses on the ways in which those energy services, when planned and implemented along with other development initiatives, can enable the creation of the various dimensions of smart villages outlined in Chapter 2. Sections 6.1 and 6.2, addressing the water-energy-food nexus and productive enterprise respectively, are concerned with increasing the incomes and food security of villagers.

Enhancing the provision of education and healthcare—two key services—in villages is the focus of section 6.3. Sections 6.4 and 6.5 examine two further dimensions of smart villages: increasing their resilience to natural disasters and economic shocks, and enhancing the opportunities for villagers to participate in governance processes at local and national levels. Section 6.6 summarises recommendations for policy makers, development organisations and other key stakeholders.

6.1 The water-energy-food (WEF) nexus

As discussed earlier in this report, increasing agricultural productivity and capturing more value at the village level will play a key role in achieving the development path envisaged in smart villages. Water for irrigation can play a major role in boosting agriculture production, and clean water and sanitation can lift the heavy burden of water-borne diseases in villages.

Water, energy, and food are intimately interrelated, as illustrated in Figure 6. Energy is needed for water pumping, purification, distribution and sanitation, and mini-hydro schemes are an important technology for local electricity supply. Energy is also needed for key inputs for agriculture such as fertilisers, to enable enhanced value addition to agricultural produce through post-harvest processing and effective storage to reduce wastage, and for transport to market. Enabling ICT brings the benefits of connectivity to the agricultural value chain, and agriculture can be a source of biofuels. In turn, water is an essential input to agriculture, boosting productivity through effective irrigation schemes, and sustainable agriculture supports effective water catchment management preserving the integrity of hydroelectricity schemes and village water supplies. The water-energy-food (WEF) nexus has therefore been the subject of increasing attention.

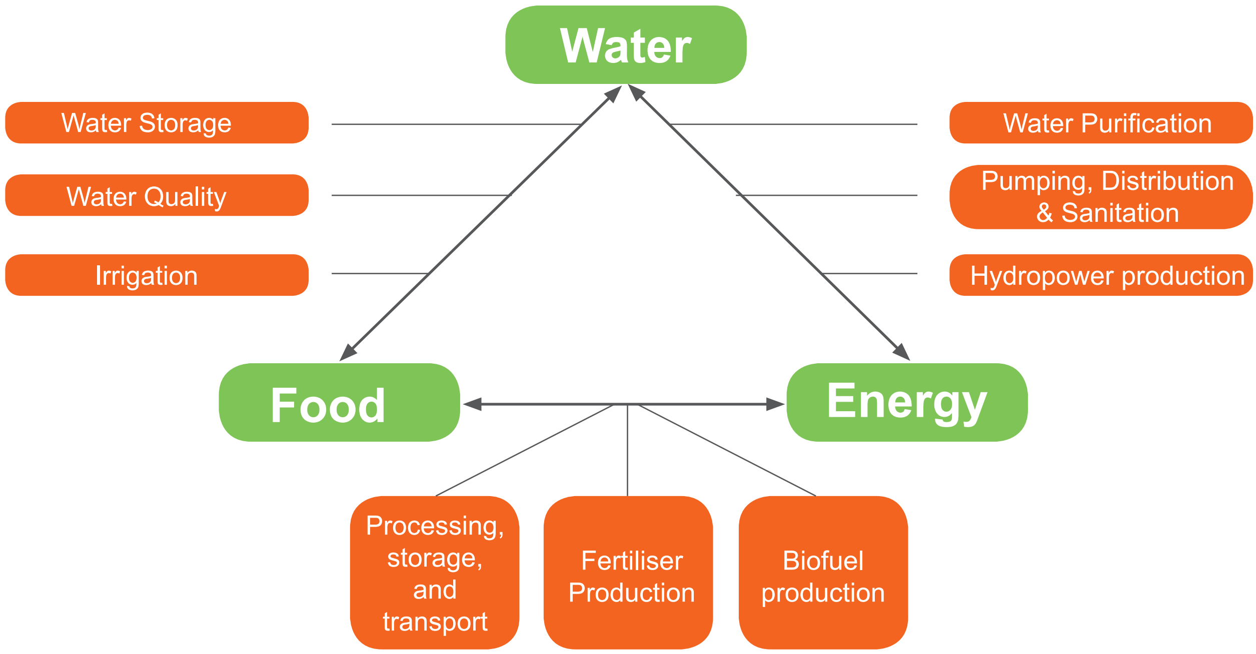
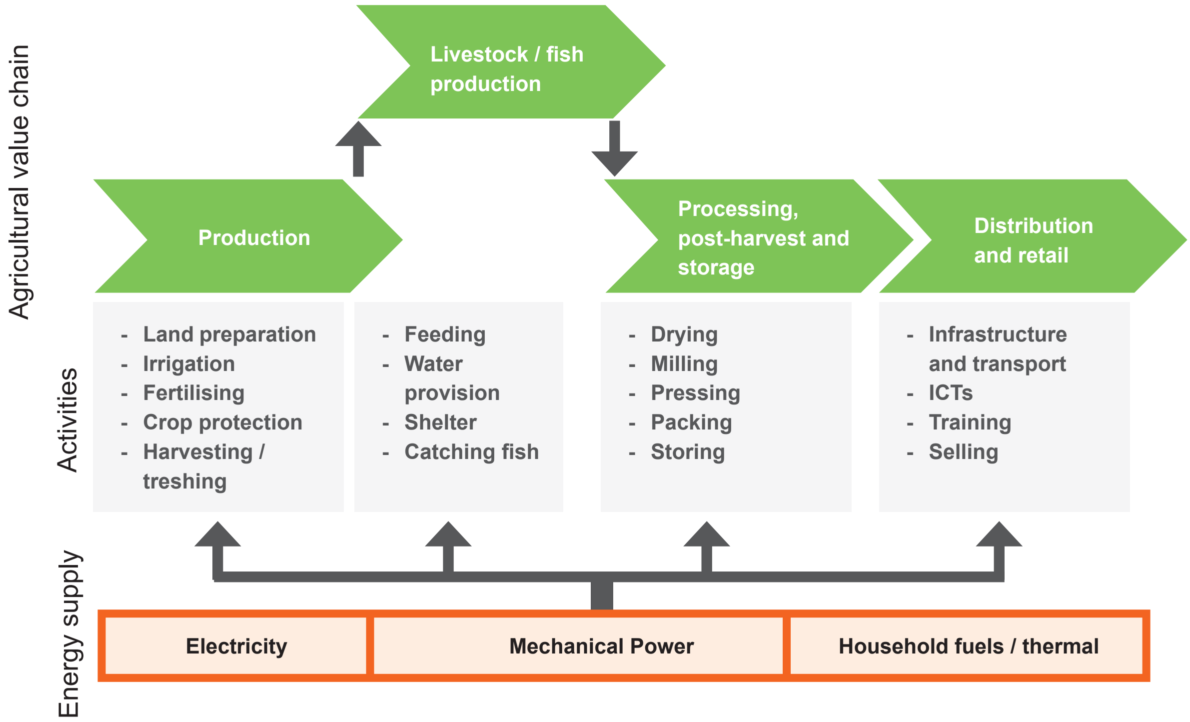


Figure 6: **The interrelationships between water, energy and food**

Energy inputs to enable activities in the agricultural value chain



Source: adapted from FAO, 2009 and GIZ, 2011

Figure 7: **Energy inputs to enable activities in the agricultural value chain (from Practical Action 2012b)**

The agriculture value chain accounts for 70% and 30% respectively of the world's freshwater and energy consumption (UN FAO 2014), and is responsible for 20% of the world's greenhouse gas emissions (UN FAO 2011). It employs 1.3 billion people in developing countries, corresponding to 72% of employment in the Least Developed Countries (Cheong et al 2013). It is estimated that 1.2 billion people live in areas of water scarcity (Hoff 2011) and one in eight people across the world remain chronically undernourished (UN General Assembly 2014). Global demands for water, energy, and food are projected to increase by 55%, 80% and 60% respectively by 2050 (UN FAO 2016; Stevens and Gallagher 2015).

Success in developing the WEF nexus in rural communities will therefore have a major and direct impact on achieving Sustainable Development Goals 1 on poverty, 2 on hunger, 6 on water and sanitation, 7 on energy access, 8 on economic growth, 10 on inequality and 13 on climate change, and a significant though less direct impact on achieving other SDGs. But climate change will make increases in agricultural productivity more difficult to achieve in future (UN General Assembly 2014), and mainstream agricultural development models are considered unsustainable (Best 2014). Consequently, the UN Food and Agriculture Organisation has pointed to the need for 'a profound transformation of food and agriculture systems worldwide' (UN FAO 2016).

The Smart Villages Initiative has held workshops to examine the WEF nexus in West Africa in August 2016 and in India in September 2016 (underpinned by a review of the literature: Safdar and Heap 2016). A workshop in the Philippines in June 2016 considered energy-water interactions in Southeast Asia. The interrelationships of water, energy, and food have been topics addressed in many of the other workshops.

Key findings and recommendations from the workshops are summarised below in respect of the following issues:

- Creating an enabling environment
- Taking an integrated approach
- Moving to a market-based approach
- Research and innovation, and project evaluation
- The role of cooperatives.

A final sub-section (6.1.6) presents some further considerations on the need to take a system view, the issue of building resilience to natural and economic shocks, and the challenges of making higher value products which are sold to international markets.

6.1.1 Creating an enabling environment

Policy makers, development organisations and other stakeholders need to create an **enabling environment** that supports the development of an effective ecosystem of players. High-level commitment and political will is required: historically, insufficient attention has been given to energy by the agricultural community.

Levels of awareness of technologies, systems, and business models available to progress an integrated approach to WEF systems are low; initiatives are required to increase awareness at the village level, of policy makers, and in the finance community. Concrete examples and demonstration projects can play a useful role. Similarly, as reflected in Best 2014, initiatives are required to build the skills and capacity of all players. There is a dearth of capacity to address the WEF nexus in the public sector. Smallholders need advice on finance and investment, and how to access markets.

Improved access is needed to finance at affordable interest rates for individual farmers, who may lack collateral and a good credit history, and for cooperatives. Financing schemes need to be streamlined, flexible, and tailored to the individual needs of farmers. They need to provide investment capital for agricultural machinery and harvest processing, not just for provision of energy services. More efficient banking systems are needed which take innovative approaches (see box). A particular concern in India, where high interest rates charged by the informal banking sector is one of the key factors that have led to high rates of suicide, was that affordable financing from the formal and regulated sector should be prioritised, particularly for the poorest farmers (otherwise benefits may just flow to those who are already better off). Bankers' concerns about payment defaults and equipment theft need to be addressed.

Consistent Energy in Nigeria

Consistent Energy is a Nigerian for-profit company set up by former bankers which provides loans on a rent-to-own business model for energy equipment and its productive use. They work with business associations and farming cooperatives rather than with individual enterprises, which reduces transaction costs. Clients make a 10% down payment before the system is installed, and pay in weekly instalments to fully pay off the system in 18 to 24 months. Agricultural pilot projects using solar power include a drip irrigation scheme, a grinding machine and a solar dryer.

6.1.2 Taking an integrated approach

Sectoral approaches are often compromised by competing objectives and fragmented government efforts, and fail to realise the potential synergies. **Integrated approaches** are required which bring together stakeholders across the agricultural, energy, and water value chains, together with WEF initiatives as a core component of rural development. Given the diverse range of stakeholders, such integrated approaches can be challenging (the required 'systems thinking' can be a turn-off for policy makers and practitioners: Best 2014), and new ways of cross-sectoral working need to be found, for example through techniques such as 'transformative scenario planning' (Kahane 2012). A particular concern is to ensure that there is effective cross-ministry cooperation (they often don't collaborate), and that sectoral approaches in key development bodies such as the World Bank are avoided. Donors that have too narrow a focus, for example concerned just with the welfare of children rather than the whole village, can cause problems.

Projects that involve local communities through participatory and bottom-up approaches that respect and build on local cultures have been shown to have the greatest chance of success. Strong local institutions are needed which can handle trade-offs as they arise. Local governments can be an appropriate focus for initiatives, but national governments should be engaged to support scale-up.

Experts need to be brought together with a common goal. There is a lack of communication and knowledge sharing between stakeholders: knowledge exchange platforms should be set up to support better communication.

6.1.3 Moving to a market-based approach

Concern was expressed by workshop participants that initiatives in the WEF nexus should move from 'charity' to a **market-based approach,** focusing on employment creation rather than energy access per se. Businesses need to see this as a new market opportunity (but the private sector currently tends to be put off by perceptions of high risk and low returns: Best 2014). Village entrepreneurs are key actors, but need to be made aware of opportunities and have access to affordable finance to purchase equipment. They can benefit from mentoring and business incubation initiatives (see box). Social entrepreneurs can also make an important contribution, balancing profit with doing good. NGOs need business partners and an exit strategy; they are good at working with local communities but are generally less able in respect of commercial activities.

ICRISAT Agribusiness and Innovation Platform

ICRISAT has established the Agribusiness and Innovation Platform (AIP) whose mission is to create, leverage, and aggregate programmes and services to promote agribusiness and enhance partnerships through entrepreneurship development, innovation, and value addition for accelerated agricultural growth (http://www.aipicrisat.org/). Key services of the Agribusiness and Innovation Platform are technology development, consultancy, funding, and mentoring. In India the platform had established 22 business agriculture incubators in agricultural institutes and universities. These incubators have trained 3,700 entrepreneurs and created over 200,000 jobs. Similarly in Africa, the AIP has established six incubators, which have supported 186 agribusiness start-ups and commercialised 58 agro-technologies.

There is no 'one size fits all' value chain: gap analysis is needed to understand the local context, the real needs of the community, and bottlenecks in the value chain. A common problem is a disconnect between villages and their potential urban markets (for example, Kagame and Amoaka (2015) point to the need in Africa for 'improved linkages to burgeoning urban consumer markets'). A key focus should be strengthening the agricultural value chain based on an integrated value chain development strategy, and considering the extension of the value chain backwards to suppliers and forwards to end-market requirements. Energy access issues need to be addressed at every stage of the value chain.

6.1.4 Research and innovation, and project evaluation

Much **research and innovation** fails to be communicated to, and taken up by, farmers: the problem of the 'death valley of impact'. More attention should be given to research dissemination and impact; one approach is to involve farmers in the research from the start (see box).

Farmer Producer Organisations in India

In India ICRISAT has supported the establishment of Farmer Producer Organisations which provide an entry point for farm interventions, encouraging interactions between farmers, research organisations, agribusinesses, and marketing experts (https://www.icrisat.org/tag/farmer-producer-organizations/). Fifteen FPOs have been established in the states of Telangana, Tamil Nadu, and Andhra Pradesh in India, mobilising 750 farmers. The Farmer Producer Organisations also enable farmers to work together in negotiating prices and sales in electronic markets for their produce, boosting their negotiation power.

Innovative use of ICT can establish research-extension-market linkages. Energy for agriculture start-ups must consider how end-users can be attracted—there has to be a 'pull factor' even for the greatest product—and early adopters can play an important role if their positive experience can be effectively communicated to others (see box). It is also found that villagers are more likely to adopt new technologies if they feel more financially secure.

Digital Green

Digital Green originated out of Microsoft research in Bangalore (http://www.digitalgreen.org/). It aims to support the uptake of innovative developments in the agricultural value chain through community-to-community knowledge transfer. Social workers train four to six people in the community to create seven- to ten-minute videos about their experience with innovative approaches, which are then shared with other communities. This helps to overcome the language barrier, given the wide range of local dialects in India, and by seeing a technique work for their neighbour, community members have the confidence that it could work for them too. Video projectors are powered by lithium ion batteries, overcoming the lack of reliable electricity supplies in many villages. The use of videos for knowledge transfer results in resource savings in terms of cost, time, and human resources. Digital Green has produced more than 2000 videos and reached 68,000 farmers.

Governments and development organisations should support the growing range of applications of ICT to support farmers and associated local enterprises, including weather forecasting, analysis of soil health, irrigation systems, precision agriculture, monitoring wastewater systems, and advance warnings of extreme weather events associated with climate change. Inefficient and expensive traditional extension services can be replaced by ICT-based approaches which provide for up-to-date and accessible knowledge sharing and information about best practices for smallholder farmers.

Reflections on design parameters for technologies suitable for adoption by villagers and SMEs pointed to the following:

- low upfront cost
- able to be built and repaired locally

- robust and easy to use
- short payback period.

An important area for innovative technologies is the effective use of waste from the agricultural value chain. For example, in West Africa the Fulwell Mill converts mango waste to biogas which can be used for fruit drying and cooking, and burns cashew shells to provide the heat needed for cashew processing with a surplus available for other agricultural processing needs. Process heat is an important dimension to energy access for the agricultural value chain.

Concern was expressed that more should be done on the **evaluation** of initiatives in the WEF nexus. A robust body of evidence needs to be developed on the value of taking a more integrated approach. Best (2014) also points to the need for more post-project evaluation which should overcome the inbuilt bias towards only reporting positive outcomes.

6.1.5 The role of cooperatives

By organising themselves in **cooperatives,** it has long been recognised that farmers can increase their chances of getting loans and exert more bargaining power when selling their produce. For a range of stakeholders, including the banking sector, it is better to work with organised groups such as cooperatives rather than with individuals as this reduces transaction costs. There are interesting parallels with the role of farmer-led cooperatives in Depression-era United States where they drove rural electrification, advised and financed by a federal government intent on boosting the rural economy and food security. As well as connecting farms, the cooperatives provided support with purchasing household, community and farm appliances and equipment, hinting at a potentially key role for cooperatives in bridging the gap between rural energy and productive uses (Best 2014).

6.1.6 Further considerations

Discussions at the workshops, and information on past experiences presented in the literature, point to the importance of taking a sufficiently broad **system view**. For example, the concept of ‘smart food’ discussed at the joint workshop with ICRISAT in India in September 2016 points to the need to consider nutrition security, not just food security, and to think about alternative crops to grains and rice, such as millets which are more tolerant to the unpredictable weather arising from climate change. Another example is provided by the opportunity arising from ICT and innovative mechanisms for managing loads in mini-grids, in which electricity for water pumping for irrigation is scheduled so as to complement electricity needs for other productive enterprises, as exemplified in the village of Chhotkei in the state of Odisha, India (see box).

The Chhotkei smart village

Chhotkei, Odisha, is a small, remote village situated amidst rich natural resources inside the hilly and scenic terrain of Satkosia Tiger Reserve, about 5km from its Gram Panchayat, Purunakote (http://www.smartnanogrid.net/SmartVillageNanogrid/). It is 65km from its district town, Angul, and 160km from the state capital, Bhubaneswar. Grid electricity has yet to reach Chhotkei, and lack of electricity precluded mobile phone communication as the village has no mobile phone tower to provide a signal. The nearest health centre is 35km from the village, which makes it difficult for the villagers to travel for their healthcare needs.

There was no electricity to set up microenterprises; the primary livelihood was rain-fed paddy cultivation once a year, and there was no irrigation system for lack of electricity. The lack of year-round agricultural activities and local employment compelled people to work as daily labourers in local and distant places.

The village has now been supplied with a 30 kW solar-powered Smart NanogridTM by the SunMoksha company (http://www.sunmoksha.com/) to meet the energy demands of 140 households, 20 streetlights, a temple, and three community centres. Together, these consume about 20 kW. The rest, 10 kW, has been set aside for day-time use by irrigation pumps and microenterprises such as poultry, stitching, rice-puff machines, provision stores, refrigerators, oil mill, welding machines, etc., to improve agricultural output, generate employment, and enable value-addition to agriculture. Power is supplied to the distribution boxes, spread throughout the village, through underground electrical cables to minimise losses. Fibre optic cables are used to communicate to these meters and controllers from the local server at the power plant control room.

Smart NanogridTM controls metering, billing, payment (prepaid/post-paid), alerts, and cut-off if bills are unpaid. There are differential tariffs for businesses, irrigation, and households. Smart NanogridTM schedules the demands of microenterprises, irrigation pumps, street lights, etc. The microenterprise load is scheduled to match the solar generation profile. The system switches off power supply if a consumer exceeds the maximum energy or maximum power allocated. Irrigation time and amount is designed to be controlled by measuring the moisture of the soil. These measures help manage demand to meet supply constraints.

Smart NanogridTM also manages customer information, technical support, continuous training, and local value-added services to consumers. The data on the local server is synced with a remote server on the cloud through a VSAT internet connection. Local consumers can get their usage information, payments made/due, and register complaints through a simple mobile app and energy card accessed from the intranet from WiFi hot spots spread throughout the village. The infrastructure created by Smart NanogridTM also supports tele-medicine, tele-education, tele-panchayat, smart agriculture, and smart water management, and they are being set up by SunMoksha as the next steps.

Consideration needs to be given to increasing the **resilience** of farmers to natural and economic shocks. One option is diversification, which can reduce the impact of climate shocks on income and provide households with a broader range of options when managing future risks (UN Food and Agriculture Organisation 2016). While options for on-farm diversification may be limited, off farm opportunities may be created both locally and through strengthened rural-urban linkages.

Incomes may be increased by undertaking post-harvest processing at the village level in order to sell **higher-value products**, which can also contribute to the needed structural change in developing countries. However, while recent growth in agricultural trade has been to a large extent driven by increasing trade in processed agricultural products, most low-income countries continue to have a very low share of processed products in their agricultural exports (Cheong et al 2013). Integration into international value chains can be challenging for village-level enterprises, given the need to meet quality and safety standards; but such integration, if appropriately managed and supported, can be the mechanism whereby village enterprises acquire the required knowledge. In the case of Africa, it has the advantage of access to technologies that other regions lacked at the same stage of their agricultural development; for example, cost-competitive off-grid solar power, mechanisms for mapping soil health, technologies for regulating water use, and mechanisms for providing farmers with access to accurate weather forecasts and price information (Kagame and Amoako 2015).

It is interesting to note the similarities between the challenges and prescriptions for success arrived at separately by the communities of practice addressing energy access, agricultural development, and clean water and sanitation. This too points to the value of those communities working more closely together in future within an integrated framework for rural development, as encapsulated in the smart villages concept.

6.2 Productive enterprise

The previous section on the water-energy-food nexus has touched on the key issue of stimulating productive enterprises in villages through energy access in respect of the agricultural value chain, and the enhanced opportunities for value creation at the village level through post-harvest processing. This section takes a broader view of the issues around productive enterprises, considering both farm-related and non-farm related opportunities.

A recurrent message from the workshops has been the interdependence of the economic viability of mini-grids and powering productive enterprises in rural communities which increase the incomes of villagers and create new jobs. Such enterprises play a central role in rural development, making an important contribution to the achievement of Sustainable Development Goals 1 on poverty, 8 on economic growth and productive employment, and 10 on reducing inequality. A key concern is to ensure that the interaction between energy access and productive enterprise leads to a positive and robust spiral of development. Diversification of the village economy is an important element of this.

An equally important message from the workshops is that energy access does not automatically lead to the development of productive enterprises: deliberate actions are needed to support the creation of new businesses and to increase the productivity of existing businesses. An integrated approach is needed. Section 7.4 discusses one aspect of this: the support to, and incubation of, businesses at the village level.

These conclusions of the workshops are echoed in the literature. Bruderle et al (2011) point to the common experience that economic activity does not automatically increase when electricity becomes available (with the consequence that assumptions about demand prove to be over-optimistic with negative consequences for the viability of the project): complementary actions are needed to stimulate productive activities (also Chaurey et al 2012; Manetsgruber et al 2015). Practical Action's Poor People's Energy Outlook 2014 usefully summarises the many ways in which energy access can support productive enterprises (Practical Action 2014). It is important to note that thermal and mechanical energy, not just electricity, both play an important role in productive activities (Bruderle et al 2013; Practical Action 2012b).

With regard to electrification options at the village level, Chapter 5 has introduced the thought that solar home systems can only support enterprises that have low power demands; for example, lighting to enable manual work to be undertaken over a longer period and so that shops can stay open longer, refrigeration to enable shops to offer cooled products, and at the higher end, sewing machines to increase the productivity of home-based garment production. Mini-grids are needed to support productive enterprises with higher energy demands, for example grinding and milling of crops, and power tools and welding for local manufacture.

A broad but useful differentiation may be made between those enterprises which provide products and services within the village, and those which sell products and services to customers outside the village. The second category brings new money into the village economy which is key to its growth (for example, van Gevelt et al 2016); the first contributes to increasing the level of economic activity within the village.

Examples of the first category discussed at the workshops included services such as shops, hairdressers, photocopying, and internet access, and local manufacturing such as welding and metalwork (stoves, security fencing, gates) and woodworking (furniture, window frames, boats, etc.). The local creation and provision of these services and products means that money circulates within the village economy rather than being spent externally.

Examples of the second category included:

- Processes to preserve and/or add value to harvests and catches such as cleaning rice, making cheese, drying fruit, milling maize, and freezing, smoking, and drying fish.
- New cash crops, aquaculture, and increased productivity of egg/chicken production.
- Provision of facilities such as hot water, lighting and internet connectivity needed to develop local tourism. Examples discussed at the workshops included homestays in Borneo and eco-lodges in Bolivia.
- Enhancing the income derived from handicrafts through increasing productivity, accessing new markets, and generating higher value products through a better understanding of what customers value (see box for example).
- Resources other than agricultural which can be harvested (for example, spring water, minerals) and processed locally (for example, bottling the water, creating craft products from the minerals, etc.)
- Looking ahead, the concepts and technologies of distributed manufacturing will provide opportunities for village level production, harnessing distinctive local attributes and sources of competitive advantage (for example, the cachet of a unique garment handmade in a remote village), to be integrated in global value chains.
- Provision of services based around flows of information rather than physical goods (and where the actors choose to live in the countryside rather than cities, as is increasingly the case in Europe, for example).

Basket weaving in Borneo

UNIMAS (the University of Malaysia in Sarawak) has supported a basket-weaving project in Borneo using traditional skills to produce high-end products that are sold outside the villages. The project is located in the village of Long Lamai, which is very rich in terms of traditional culture but poor in other respects. So the handicraft project, undertaken jointly by villagers and the university, is crucial. The aim of the project was to gauge the interest of the Long Lamai artisans to experiment with new materials and produce new contemporary rattan products. Artisans were very keen to work together and try new high-end handicrafts. Thirty new participants came to a second workshop, which was seen as a big success.

The new products use metallic threads, but pricing is a problem because of transport costs due to the remoteness of the village. Now the issue is how to make new products with local materials, such as combining rattan and bamboo. A collaboration with Tanoti Sdn Bhd, a local handicraft retailer and social enterprise based in Kuching, has been well received because the company's marketing and supply-chain expertise brings income to the community by promoting and selling to Europe, including France and Germany, as well as in Kuala Lumpur.

Long Lamai is now marketed as a 'Basketry Paradise'. The hope is to encourage the Penan artisans to stay in the village rather than move to the cities. If the project is successful, it will reduce urban migration of young people from rural areas. Even the men are now interested in participating so that they can take part in the economic activity. As a unique contribution, for example, they are proposing sourcing higher-quality raw materials (rattan) from the rainforest. Since one particularly prized area for rattan is three hours away from the village, the contribution that the men can make in carrying out the journey is useful. Given the limits to what can be sustainably harvested from the forests, consideration is also being given to growing rattan in the villagers' agricultural plots.

An important starting point for integrated initiatives on village-level energy access and productive enterprises is a systematic analysis of market opportunities and barriers. A concern expressed at the Ghana workshop was that too often, a silo approach is taken in which the various development communities focus only on their particular issues. Initiatives should carefully evaluate the activities within the village which might lend themselves to increases in productivity and where there may be spin-offs and new activities enabled by energy access. A bottom-up approach is needed, building on what is already there.

One relevant technique is 'participatory market mapping'[20] developed by Practical Action and discussed at the Nepal and Bangladesh workshops. It involves key players in value chains in a dialogue to better understand how a market system operates, to identify missing nodes and connections, and to locate barriers that prevent the market system from successfully delivering the desired outcomes.

In order to nurture new enterprises and to provide a supportive environment in which they can grow, it was suggested that micro-enterprise

20 See Practical Action website: http://practicalaction.org/consulting/market-mapping. Also, Franz et al 2015.

zones should be created in villages providing the necessary services (energy, connectivity, water and sanitation, etc.) and locating the SMEs in close proximity to each other, facilitating mutually beneficial interaction (see box for example). A similar idea is the 'Gram Kendra' concept[21]: centres within villages in India hosting commercial and light industrial activities alongside community facilities such as schools and health centres.

Business incubator in Mali

Based on an extensive study of the problems and solutions of rural electrification in Mali, GERES (a French NGO working on energy access) and AMEDD (a Malian NGO) have worked on the idea of a rural renewable electrification business incubator— a dedicated energy solution for rural businesses. The idea behind the incubator is to have a high quality supply of electricity, coupled with bioclimatic buildings and business service facilities. The goal at the start of the project was to have a proof of concept and establish ten rural businesses in the incubator that generate around 50 jobs for locals. Electricity supply is provided by a solar-biodiesel mini-grid. The results in the first eight months have been encouraging and five businesses have been established in the incubator. These include: a Jatropha oil unit, a bakery, a women's group engaged in the trade of juices and ice cream, an IT centre and a chicken brooder. These businesses have created 24 jobs and the incubator has had a strong demonstration effect in the surrounding areas.

On a smaller scale, the 'business in a box' concept pioneered by Coca-Cola through its Ekocenters aims to create business opportunities for its women franchisees to provide services to rural communities (see box).

Ekocenters

Coca-Cola partnered with Solar Kiosk, a German company, to develop solar-powered Ekocenters that serve as outlets providing a wide range of services aimed at improving living conditions and livelihoods in off-grid rural areas, especially of rural women. The Solar Kiosk is envisaged as a social enterprise that is a one-stop shop for high quality products and services, including solar products, fast-moving-consumer-goods, technology products, medicines, and tools. The kiosks provide important services to the local community such as mobile phone charging facilities, internet access, and clean water.

The business model is that the Ekocenter is franchised to a female entrepreneur from the local community. She is trained by Coca-Cola and partners, and she needs to generate an operating profit, reinvest and grow. The cost of providing clean water is borne by the charitable arm of the initiative.

21 *Video on the Gram Kendra concept: https://www.youtube.com/watch?v=7ZcHw4z0WVY*

More than 80 Ekocenters have been installed in seven different countries, located primarily in Africa, and they have empowered 450 women who are working in them. The centres have provided 50 million litres of clean drinking water to communities, which have consequently seen a marked reduction in water-borne diseases. They have a combined installed generation capacity of 250 kW.

6.3 Education and health

Provision of sustainable energy services, together with the modern information and communication technologies (ICT) that they enable, can transform the level of healthcare and education services provided in rural villages, closing the gap in service provision between villages and cities. But both health and education services in rural communities are typically starting from a low point.

In education, there are wide disparities in educational achievement between developed and developing countries, many children in developing countries only reaching levels of numeracy and literary skills substantially below their grade level (Robinson and Winthrop 2016). Dropout rates are high: in a sample of 32 countries, mostly in sub-Saharan Africa, 20% of enrolled children were not expected to reach the last grade of primary education (Education for All 2015). Globally in 2013 (but mainly in developing countries), 59 million primary-age children were out of school (United Nations Economic and Social Council 2016).

There are also wide disparities between educational opportunities in rural and urban areas: for example, in Nigeria 40% of rural children are out of school versus 9% of urban children (Robinson and Winthrop 2016). Schools located in rural areas of developing countries have tended to be the least favoured for funding (Jiminez and Lawand 2000). Globally, one out of every three children goes to a primary school without electricity (188 million out of 660 million). This rises to nine out of every 10 children in sub-Saharan Africa (UNDESA 2014). A representative sample of 16 Latin American countries indicated that 11% of primary schools in the region had no electricity, rising to 34, 46 and 57% in Panama, Peru and Nicaragua (where for rural schools the numbers were higher still: 46, 75 and 57% respectively) (Diaz 2015).

Data are relatively sparse regarding the status of electricity access in health facilities in developing countries. A World Health Organisation (2015) review obtained nationally representative data for 14 developing countries globally, 11 of them in sub-Saharan Africa. From these data, on average one in four sub-Saharan Africa health facilities had no access to electricity. Only 28% of health facilities and 24% of hospitals had reliable access (without prolonged interruptions in the past week). Rural health clinics without a grid connection often use diesel-powered generators which are expensive to run.

These data illustrate the challenges faced in meeting Sustainable Development Goals 3 (Ensure healthy lives and promote well-being for all at all ages) and 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all). SDG 3 sets targets for maternal mortality, ending preventable newborn and under age 5 deaths, ending epidemics, reducing premature mortality from non-communicable diseases, and universal access to quality healthcare and reproductive health services. SDG 4 sets targets that all children complete good quality primary and secondary education, gender disparities in education are eliminated, and youth have the skills needed for employment. By addressing the areas of the world where the underlying challenges are most acute, provision of sustainable energy services and ICT to enhance the quality of village-level healthcare and education has a key role to play in achieving Sustainable Development Goals 3 and 4.

This section reviews the experience of bringing sustainable energy services and ICT to health care and educational facilities in villages, summarising the benefits and the challenges, and how they may be addressed. It draws on two literature reviews undertaken as part of the Smart Villages Initiative (Welland 2017a and 2017b), and on presentations and discussions at the workshops. These have included a full day dedicated to education and healthcare at the closing workshop in Bangkok for the South and Southeast Asia engagement programmes, and a session at the opening regional workshop for Central America, the Caribbean, and Mexico.

Energy needs for health clinics include:

- Electricity for lighting to enable examinations, operations, and childbirth, particularly at night.
- Electricity for refrigeration to preserve vaccines and medicines, and for staff food where on-site accommodation is provided.
- Electricity for diagnostic equipment including microscopes, blood analysers, ultrasound, electrocardiographs, and (for larger clinics) X-ray machines.
- Electricity for water pumping and purification, and for sanitation.
- Electricity to support ICT and to enable the connectivity required for telemedicine [22] and e-health.
- Electricity for fans.
- Thermal energy for equipment sterilisation, hot water, space heating (in some climate zones), and for cooking.

Energy needs for schools include:

- Electricity for lighting to provide adequate levels of illumination in classrooms over longer periods, and to enable teachers to prepare lessons.
- Electricity to support ICT for the running of the school and to enable distance learning.
- Electricity for water pumping and purification, and for sanitation.
- Electricity for fans to help keep classrooms and offices at an acceptable operating temperature.
- Thermal energy for food preparation, water heating, and space heating (in some climatic zones).

From the literature reviews there are some distinctive issues for energy and ICT access for schools and for health clinics which are summarised below in sub-sections 6.3.2 and 6.3.3 respectively. There are some common issues which are discussed in the following sub-section 6.3.1.

22 Telemedicine is the use of telecommunication and information technology to provide clinical health care from a distance. E-health refers to the use of electronic processes and communication technologies in health care.

6.3.1 Common issues for schools and health centres

Health centres and schools in rural villages experience some common opportunities and challenges in respect of energy access and ICT: integration, costs, staffing, the value of connection, system sustainability, and information sharing.

In both cases, there needs to be **integration** with other related initiatives to tackle more general shortfalls in resources, staffing issues, etc., in schools and health centres, and to make the necessary investments in the equipment which will make effective use of energy access, for example laptops, smartphones and tablets in schools, and diagnostic equipment in health centres. In respect of ICT, as discussed in section 3.4, levels of connectivity in many rural areas remain low, and while the gap in mobile phone ownership between rural and urban communities is reducing, the gap in internet access is increasing (World Bank 2016).

The integration should extend to other village-level development initiatives. As an example, the box describes the Community Learning Centres in Nepal. Better integration is needed between ministries concerned with rural development: for example, effective cross-ministry working between those responsible for energy and for health could avoid the situation, sometimes encountered, where medical equipment is provided to clinics but no electricity to run it. Clear long-term plans should be developed for providing energy services to the education and health sectors, involving the ministries responsible for health, education, energy, finance, and the environment.

Community Learning Centres in Nepal

The Community Learning Centres (CLC) are operated by the National Resource Center for Non Formal Education (NRC-NFE). NRC-NFE is an NGO focused on addressing illiteracy and limited community development in Nepal. Nepal is faced with high rates of illiteracy and primary school dropouts, and limited socio-economic development, particularly in remote mountainous communities. CLCs are local educational institutes set up, managed and operated by the community to serve the community. They are multipurpose organisations catering for the educational needs of children, youths, and adults.

CLCs combine education with other community development initiatives, for example promoting income-generating activities, health care, environmental stewardship, information/technology dissemination, awareness raising, community development, and women empowerment activities. Each centre is planned and set up according to local needs and established using local resources and community input. NRC-NFE has implemented 21 CLCs in Nepal to demonstrate to the government and other organisations what these centres can achieve. The government has now set up 2100 CLCs of its own after seeing the impact that NRC-NFE CLCs have had.

NRC-NFE implemented a project called ‘Rural Connectivity for CLCs’ which seeks to address the challenges of irregular and intermittent electricity supply from the national grid (with daily blackouts of 10-15 hours) and the limits this imposes on community development. As part of the project, CLCs use solar energy to improve ICT-enabled connectivity and knowledge/technology transfer. The project also supports the establishment of community-based biogas plants and associated organic farming activities, and the development of a local skills base for community development; for example, the construction and operation of biogas systems.

The project activities include installation of a solar power system for the CLC and training of community members in installation and management of solar systems, learning centres, organic farming and biogas systems. The CLC therefore acts as an anchor for other community development activities. For example, it serves as a central charging point for rechargeable desk lamps, a distribution centre for water purification products, a community resource centre and library, and a training and information centre for establishing (subsidised) community biogas units.

It is important to think in terms of the overall outcomes of interventions to improve levels of health and education. In this respect, interventions on energy access need to be extended to the village as a whole in order to maximise the benefits. Lighting in homes means that children are better able to do their homework, parents are more likely to assist, and the savings arising from avoidance of purchasing candles and kerosene are often reinvested into education. Health outcomes are improved by avoidance of disease through access to clean water and sanitation, and the use of clean cooking technologies. Acute respiratory infections are the principal cause of school absence (UNDESA 2014). Improved cookstoves and pumped clean water make it less likely that children will be taken out of school to collect firewood and water.

There are strong interlinkages between improved healthcare and education. Improved healthcare means that children are less likely to miss school because of illness. And improved education can make children and their parents more aware of the benefits of health interventions, and of the actions they can take themselves to reduce the risk of ill-health.

Energy access and ICT do not necessarily on their own result in improved health and educational outcomes; there are many confounding factors. More research is needed to understand the interrelationships of the various factors and how they can be addressed in order to maximise the benefits.

Meeting the **costs** of energy and ICT access is often a challenge, and too often, even if upfront investment costs are covered, insufficient attention is given to meeting the costs of sustained operation and maintenance. Financing needs to be found also for the equipment that will be used to make effective use of energy access and connectivity, in particular for diagnostics, operations, and refrigeration in health clinics, and laptops and tablets in schools. Costings need to reflect the reality that 5-10% of equipment fails in most projects. More positively, the costs of renewable energy technologies and ICT are falling, and ingenious approaches are being developed to reap the benefits of distance learning and healthcare even where connections and electricity are intermittent.

In some cases, health centres and schools have been used as anchor loads in mini-grid systems that also provide electricity to other users in the village, such as businesses and households. This can help to share the costs with other users. To be viable as an anchor load a school or health centre needs to have a reliable source of funding for its electricity usage. If the anchor load is too dominant, problems of who gets first call on the electricity generated can arise. This problem may be alleviated if there are several anchor loads on the system.

An alternative approach to offsetting costs is to power productive enterprises (for example mobile phone charging) as a side-line. In both this case and for anchor loads, an important consideration is the distraction of already overburdened staff from their central tasks of teaching or health care. They may in any case not have the necessary skills or inclination. It may be more appropriate to put the running of such schemes into the hands of a community body or the private sector.

An integrated approach in which the energy, health, and education sectors come together in designing and implementing schemes for energy and ICT access can pay dividends, both in respect of finding the funds for the initial investment and subsequently meeting costs of operation and maintenance.

Staffing problems are commonplace in rural schools and clinics: it is often difficult to recruit and retain staff, particularly good quality staff, and absenteeism is high. For example, in village health clinics in Bangladesh doctor absenteeism rates of 74% have been reported (Chaudhury and Hammer 2003). Potential candidates often prefer jobs in cities to villages as they value the facilities available in cities, including the basic services and connectivity which may be absent in rural communities. Provision of key services and connectivity can help address the staff recruitment and retention problem. It also helps teachers and clinicians do their job better through access over the internet to knowledge resources, through internet enabled training packages, and by having light by which to undertake research, lesson preparation and other activities required of teachers and doctors.

The **value of connection** derives from having access to expert resources and the world's knowledge base, supporting health workers in diagnosis and decisions on treatment, teachers in lesson preparation, and schoolchildren in researching information for assignments, etc. Connectivity can increase efficiency and reduce costs, for example by allowing teachers to teach many more students, reducing the need for students' books, and replacing face-to-face medical referrals with smartphone or tablet based interactions with medical experts. Staff may need capacity building and training in the requisite skills to make effective use of the internet.

Lack of provision for the operation and maintenance of electricity supply systems is a frequent cause of their failure. **System sustainability** relies on adequate provision for financing, clear allocation of responsibility for operation and maintenance, and the local availability of the requisite skills. Funding formulas for schools and funding arrangements for health clinics often fail to make adequate provision for energy services which can therefore become a big drain on the school's or clinic's finances. Public-private partnerships may provide an effective model for the supply of energy services but must be set up so that the private sector partner can make commercial returns.

It is also important to get the initial design of the energy system right, ensuring that it is based on the needs and priorities of the school or clinic, rather than being technology led. End users and beneficiaries need to be involved in the design of the solution using a 'human-centred design' approach. Solar PV systems are often designed to meet the peak power demand of a clinic, assuming that all equipment is running at maximum capacity at the same time: substantial savings can be made by designing for more realistic patterns of power demand over the day.

The reliability of the energy system and the devices that use the energy is important for the long-term sustainability of the initiative: national quality standards and appropriate sourcing and tendering mechanisms can help. Staff members need to be trained in how to use the energy system so as not to overload it.

Theft and vandalism happen all too often: antitheft design approaches such as tamper-free mountings can help. So can the wider electrification of the village and its neighbours, which reduces the temptation for theft and for vandalism arising from jealousy.

There is a general lack of awareness and **information sharing** on possible solutions. Countries rarely implement mechanisms for learning from individual successful implementations within the country (unless implemented by the government) or indeed for sharing experiences between countries. There can also be a lack of institutional memory, so that countries do not learn from previous mistakes. Initiatives are therefore required which systematically record the experiences of electrification of schools and health centres, distilling lessons about reasons for success and failure, and which provide for information sharing within, and between, countries and the various relevant ministerial and sectoral interests.

6.3.2 Energy and ICT access for schools

Access to content for teaching can be provided via the internet through laptops, smartphones and tablets (increasingly favoured), and by more traditional media such as TV and radio. Web-based approaches can provide for learner-centred teaching which is beneficial, but use of the internet requires guidance and can result in challenges to traditional cultures that need to be addressed.

Teaching materials prepared centrally can provide a high-quality resource of particular value to inexperienced and/or overstretched teachers. However, they should not be used to replace teachers, rather to augment teaching resources and modes. Good quality software and programme materials need to be developed which are locally relevant and presented in local languages. Teachers need training in how to use them: particularly older teachers who may be reluctant to make the necessary changes to their teaching approaches.

In terms of pedagogy and group learning, a well-designed system using modern ICT will not result in less interaction among students, or between students and teachers. Indeed, the findings from interactive systems like Slate2Learn[23] are that use of these systems provides new and more innovative situations for students to interact with each other, in a group learning setting.

Schools equipped with energy services and ICT tend to experience reduced truancy and increased completion rates. Increased enrolment and better attendance is a stronger effect for girls than for boys. School meals and toilets (particularly for girls) are additional positive factors in encouraging enrolment and attendance. There is robust evidence of the positive impact of computers on learning when appropriately deployed to augment the learning environment (Diaz 2015).

For true 'smart' implementation in rural settings, children and families also have to be satisfied with the value of education, which means (in particular) the creation of suitable innovative employment or entrepreneurial opportunities for children graduating from school, in order to discourage their migration away from the village. There are also convergence opportunities in smart villages; for example, schools could carry out health screening as well as teach, or deliver life-skills training to adults as well.

23 For more information on Slate2Learn see: https://www.jbs.cam.ac.uk/faculty-research/centres/social-innovation/cambridge-social-ventures/our-ventures/slate2learn/

6.3.3 Energy and ICT access for health centres

The quality of electricity required for health centres has to be good in terms of the reliability of supply (to ensure that operations can be performed when needed and so that refrigeration is not interrupted) and the avoidance of voltage surges that could damage sensitive equipment and degrade its accuracy.

Telemedicine and e-health via the internet, and making use of smartphones, tablets, and laptops, can make a major impact by overcoming time and distance barriers in remote villages, and by providing access to scarce specialist care. For example, in sub-Saharan Africa one doctor has to meet the medical needs of between 5,000 and 30,000 patients (Meso et al 2009). An expanding array of innovative technologies is increasing the range of diagnoses that can be undertaken remotely and reducing the cost of doing so. More traditional technologies such as VHF radio can still play a useful role in enabling advice and emergencies to be communicated.

In the Dominican Republic, tele-medicine has been extended to X-rays and mammography. Health care workers manning the rural health centres where the equipment is located have relatively low levels of skills; the images taken locally are transferred to central hospitals by satellite links, where they can be evaluated by specialists and stored in a password-protected patient medical information system.

Technology adoption requires that health workers can find benefit in the supplied tool or solution to their regular workflow. Care must be taken to provide training to health workers that matches their needs: for example, telemedicine initiatives have failed to meet objectives because health care workers did not know how to operate basic phone functions.

Provided health centres in villages with facilities for telemedicine are embedded in an effective wider system, they can substantially enhance capability for early detection and action on outbreaks of diseases such as Ebola. They also provide the basis for monitoring progress in tackling more chronic contagious diseases. Through smartphones and mobile broadband, monitoring can be extended to homes for non-communicable diseases such as diabetes and cardiovascular disease. Training and education are needed both for medical staff and for patients in the benefits and limitations of telemedicine.

6.4 Increasing the resilience of smart villages

Rural villages may be at risk from a range of natural disasters depending on their location (for example earthquakes, volcanic eruptions, tsunamis, floods, droughts, hurricanes, and typhoons), and from economic shocks and epidemics. Climate change will increase the frequency and severity of weather-related natural disasters. Development benefits are hard-won but easily lost through such events. The characteristics inherent in smart villages can help rural communities increase their resilience to these risks, but attention is needed to ensure that the physical, social, and economic infrastructure of villages is developed appropriately.

The Sustainable Development Goals contain a number of targets relating to increasing the resilience of communities (both urban and rural): target 1.5 to build the resilience of the poor; 2.4 to strengthen the capacity for adaptation of food production systems to disasters; 9.1 to develop quality, reliable, sustainable and resilient infrastructure; 11.5 to reduce the number of deaths and economic losses caused by disasters; and 13.1 to strengthen resilience and adaptive capacity to climate related hazards and natural disasters in all countries. The Sendai Framework adopted by the UN in 2015 provides a focus for global action to reduce risks from disasters over the period 2015 to 2030, emphasising an integrated and inclusive approach, establishing guiding principles and priorities for action, and setting seven global targets (UNISDR 2015).

A recent World Bank report (Hallegatte 2017) focusing on how natural disasters affect people's well-being concludes that extreme natural disasters force 26 million people into poverty each year and result in a US$ 520 billion loss in consumption each year. Unless wide-ranging actions are taken to build the resilience of rural and urban communities, the more frequent and extreme weather events consequent on climate change will increase these losses in future. Disasters disproportionately affect poor people, who are typically more exposed to natural hazards and have limited ability to cope with them.

The opportunities and challenges to increase the resilience of rural communities have been discussed at two dedicated workshops: in Singapore in May 2016 focusing on Asia, and in Quito, Ecuador in January 2017 focusing on Latin America. A session on disaster risk reduction was also included in the opening workshop for the Smart Villages engagement programme in Central America, the Caribbean, and Mexico held in the Dominican Republic in November 2016. Key conclusions arising from the workshops are summarised in this section.

In smart villages, resilience at a general level is accumulated through progressing from a hand-to-mouth existence to a life that allows the accumulation of assets and savings which can support villagers in the immediate aftermath of a disaster, and enable lives and communities subsequently to be rebuilt. Smart villages also undertake a stewardship role for their local environment which can help minimise vulnerabilities to natural disasters such as droughts (for example, through effective forest management) and storms (for example, for coastal communities, by preserving mangrove forests).

With regard to the physical infrastructure of a village, energy access along with, and as an enabler of, modern information and communication technologies can improve resilience through:

- Providing opportunities for training and education at the village level, and the sharing of information, and hence the creation of skills and knowledge in villages on developing resilient infrastructure.
- Facilitating communication links and providing the means for advance warnings of natural disasters as well as enabling more effective disaster relief efforts.
- Improving health facilities and providing lighting, which can help rural communities during post-disaster periods.

To be effective in the event of a natural disaster, energy and communication systems together with other key infrastructural components such as roads and drainage systems need to be designed to be robust to anticipated events. However, it is not possible or economically feasible to resist all events, and a balance needs to be achieved between system reinforcement, prevention, and restoration. An integrated approach should be taken in order to build in the appropriate level of resilience when developing rural infrastructure and renewable energy systems. For example, a high-tech PV panel is often installed on a primitive house which will be destroyed in the event of a hurricane or earthquake. Countrywide resilience strategies should be developed; as an input, the World Bank has developed a tool to assess risks to natural disasters based on a municipal level analysis using historical records.

In the Ecuador workshop it was proposed that smaller, decentralised energy systems (in particular, solar home systems and mini-grids) are more flexible and easier to repair and reinstall after a disaster, and they reduce dependency on the grid system. These 'smart solutions' are especially important in remote areas with dispersed communities, which typically are the last to receive government assistance post-disaster since priority is given to densely populated areas.

It is helpful to map resources, in respect of facilities at risk and those which can be deployed in the event of a disaster, and to share that information with rural communities. Depending on the nature of the threat, infrastructure may appropriately include a disaster shelter and village notice board. Attention should be given to the maintenance of infrastructure, not just its construction.

It is important to recognise that while there are many methodologies and initiatives to increase resilience, the poverty of many communities remains a key problem. People tend to return to build their homes in risk-prone areas simply because they lack alternatives: 'you live where you can, not where you would like to'. In situations of poverty short-term needs, like finding enough to eat, take precedence over medium and long-term considerations of safety.

The social capital of a village is just as important as its physical infrastructure in building resilience. Communities that are empowered and competent in respect of building resilience, and that have the ability to come together to address problems in times of adversity, are more likely to withstand and recover from natural disasters. Such capacities depend on culture and circumstances; for example, migration can undermine social coherence. An example was given of Colombia where, following the destruction of housing by a natural disaster, community members rebuilt the houses collectively. A positive outcome of the process of reconstruction was the strengthening of social bonds, and the increase of capacity and resilience of the community.

Initiatives to build community resilience should involve villagers as equal partners, not just as recipients of knowledge and physical capital. Sufficient time needs to be taken to understand and respect community protocols, cultural beliefs and customs, and governance structures. If listened to, villagers will in turn be more likely to listen to 'experts', who should appreciate that local traditional knowledge can make an important contribution to increasing resilience (villages have in many cases had the adaptability and resilience to exist for many centuries).

Resilience should be part of everyday social discourse, and responses to relatively frequent, low-level disturbances can help build the capacity to build resilience to less frequent major events. There is value in initiatives to promote learning between regions, and to support the exchange of villagers' study teams to enable village-to-village learning. The 'sister village' concept in which villages are twinned, providing for social interchange and a welcoming place to move to temporarily in the event of a natural disaster, is a potentially attractive approach.

In advance of natural disasters, resources and vulnerabilities may usefully be mapped by governments and development bodies, and this information shared with communities. Individual villages need to be seen as part of a wider system with interconnected risks, in which actions to mitigate risks in one part of the system can have unintended consequences elsewhere. Diversity in the economy and of population centres, from villages through towns to cities with appropriate linkages, may enhance resilience.

The path to resilience is not linear: new vulnerabilities and opportunities may be generated by a wide range of factors. The devil is often in the detail. An integrated approach to policymaking is necessary to reduce the potential for unintended consequences of initiatives: all stakeholders need to work together. The finite length of projects to build resilience can be problematic in respect of the longer term sustainability of the measures introduced to villages. Sustainable business models and/or prior arrangements for handover to government institutions may be appropriate responses. Given the need to scale up from projects in individual villages to many hundreds of thousands of villages, there is a tension between standardised approaches and responding to the unique circumstances of each community.

6.5 Participation in governance processes

In setting out the vision of smart villages in Chapter 2 the proposition was made that, 'Education and connectivity will empower rural communities, enabling them to take a more active, informed, and influential role in governance processes at local, regional, and national levels.'

Drawing on a discussion paper and review of the literature undertaken as a component of the Smart Villages Initiative's activities (Welland 2017c), this section examines the opportunities and challenges in smart villages for increased participation and influence in governance processes arising from enhanced connections and education, in turn enabled by energy access. It takes as its starting point that the current low levels of internet access in rural areas of developing countries outlined in Chapter 3 are corrected, and that smart villages are well-served by the range of modern media, including TV, radio, internet, social media and the printed press. It considers in turn: opportunities to be **better informed** about the issues relevant to governance processes and decisions; the potential for villagers to exert more **influence**; and the possibilities for **enhanced service delivery** and **reduced transaction costs** arising from e-governance.

At present, villagers very often do not have access to the media through which information and debate associated with governance processes is conveyed. Politicians are more likely to make campaign promises to constituencies that can hear them, consequently favouring the better connected urban constituencies. And in the absence of the information necessary to make informed choices between political candidates, and to distinguish between the impacts of policies and other factors in determining outcomes, villagers are limited in their ability to exert rational control over government.

In principle at least, **better informed** electorates will make better decisions on who should represent them, and those representatives will be more likely to make decisions in the public interest. But it is important to be realistic about the extent to which people will seek detailed information on the many issues topical at any given point in time; it may typically be the case that individuals develop just a broad appreciation of what a particular party or individual stands for, and take a view on how that aligns with their own views and interests.

Simply making more information available will not necessarily reap the full benefits of a better informed rural electorate and hence better governance. It is necessary to look at the whole system, and to consider the contribution of education to enable villagers to understand how governance processes work and how they can input to them, to be able to distinguish between more or less reliable sources of information, and to be motivated to seek out alternative sources of information and views. To the extent possible, bias and censorship need to be eliminated from the media. Open political debates on TV and radio at local and national levels can be helpful in getting around the problem of literacy.

Research in India (Banerjee et al 2011) suggests that voters may well make substantial shifts in their choices as they become more informed. Data from Bangladesh and Kenya point to higher levels of political awareness when households are electrified (Barkat et al 2002; Lee and Miguel 2016).

In democracies, a villager's vote is a key mechanism by which they can **influence** governance processes and decisions: an important first step is therefore to ensure that villagers get the chance to vote, and that the voting system is fair and not corrupted. Mobile phones and video cameras have been used to good effect to report incidents at polling stations and to bring pressure to bear to avoid vote rigging (for example, Banerjee, 2015; Callen et al 2016). Remote electronic voting systems have the potential to overcome distance barriers, to encourage new voters to participate in elections, and to reduce the costs of voting for remote communities, but security issues remain undermining the trust necessary for their adoption (Gibson et al, 2016). The example of India shows that simple electronic voting machines used within a voting system which is efficient and trusted can result in high levels of voter turnout (Banerjee 2015).

Looking beyond the ballot box, ICT provides new opportunities for villagers to voice their concerns and demand accountability of elected representatives and their bureaucracies. 'Access to timely and reliable data about public sector policies, allocation of tax revenues and international aid provides people with the information they need to hold their governments accountable' (United Nations 2016). Rural communities often have lower expectations of service delivery and government performance than do urban communities; being better informed and having the tools to question government, and through being educated on their rights and duties, makes villagers likely to demand more.

Government-led initiatives to use ICT to enhance transparency, accountability, and participation include web-based referenda, consultations and debates (see box for example from Tanzania), and petitions. However, the setting up and effective use of such e-participation approaches requires an effective bureaucracy and a level of resources which may not be within the reach of the governments of some developing countries.

Tanzania Knowledge Network (United Nations 2016)

The Tanzania Knowledge Network (TAKNET) promotes knowledge and information sharing on various aspects of social and economic development of national interest to stimulate discussions by informing individuals about current development issues. Both the general public and experts take part in these discussions, which result in consensus building on policy issues of concern to Tanzanian society. Summaries of discussions covering the outcome of a particular topic are produced by moderators, which include recommendations and statements of best practices, and are shared with policymakers and the public. TAKNET is a joint initiative of the Government of the United Republic of Tanzania, United Nations and the Economic and Social Research Foundation.

The internet, social media, and mobile phones may also play an important role in enhancing transparency, accountability and participation independently of governments by strengthening the organisational links and networking capacity of civil society, both within and between countries. Such opportunities for civil society organisation add weight to the voices of citizens, and can mobilise challenges to the status quo and incumbent governments.

Enhanced service delivery and **reduced transaction costs** are made possible by putting government-related services such as welfare benefits, birth and land registrations, and tax returns online. For businesses, online portals can substantially reduce the transaction costs of business registration, regulatory processes, etc.

6.6 Recommendations on reaping the development benefits of rural energy access

This section summarises the key recommendations arising from the workshops, and the work of the Smart Villages Initiative more generally, on reaping the development benefits of rural energy access. The following subsections mirror the five preceding sections of this chapter.

6.6.1 The water-energy-food (WEF) nexus

Recommendations on financing and impact evaluation are covered in Chapter 7 on cross-cutting issues. The following recommendations are made to governments and development organisations concerned to address the challenges and opportunities of the water-energy-food nexus:

- Levels of awareness of the challenges and opportunities of the WEF nexus are low, as are the skills and capacities needed to address them. Initiatives should be put in place to increase awareness and skill levels in respect of the technologies, systems, and business models necessary to realise the opportunities inherent in the WEF nexus. The aim should be to create an effective ecosystem of players including villagers, entrepreneurs, NGOs, policymakers and the finance community.
- An integrated and market-based approach should be taken that enables farmers to sell higher value products to urban markets, linking smart villages to smart cities. Government ministries should work together and draw on the range of relevant experts who previously have not generally collaborated effectively. Mechanisms for knowledge sharing should be put in place.
- More attention should be given to research dissemination, including through the direct involvement of farmers in the research process. Support should be given to innovative applications of ICT to enhance the dissemination of information on techniques to increase agricultural productivity and the value derived from agricultural products, superseding more costly traditional agricultural extension services.

6.6.2 Productive enterprise

- Too often the various development communities focus just on their particular component of the set of development initiatives necessary to stimulate village-level productive enterprises. In order to break out of the consequent silo approach, the various development players should work together to undertake systematic analyses of market opportunities and barriers at the village level, identifying barriers and bottlenecks and necessary actions to overcome them.
- Micro-enterprise zones in villages providing local enterprises with key services (energy, connectivity, water and sanitation, business services, etc.) have been successfully piloted and should be rolled out more widely in vil-

lages to nurture new enterprises and provide a supportive environment in which they can grow. Locating the SMEs in close proximity to each other facilitates mutually beneficial interaction.

6.6.3 Education and health

- Initiatives on energy access for schools and health centres should be integrated with other related initiatives to tackle more general shortfalls in resources, staffing issues, etc., and to make the necessary investments in the energy-reliant equipment which can enhance the quality of education and healthcare in villages. This requires collaboration between ministries responsible for energy, education, and health. The focus should be on the health and educational outcomes, requiring energy access to be addressed for the village as a whole.

- Attention should be given to the long-term sustainability of energy access initiatives for schools and health centres, requiring arrangements for operation and maintenance to be in place together with the necessary long-term financing, including for equipment replacement. The design of energy systems should be based on the needs and priorities of the school or clinic, rather than be technology led.

- Arrangements should be put in place to systematically record the experiences of electrification of schools and health centres, distilling lessons about reasons for success and failure. This information should be shared within, and between, countries and the various relevant ministries and sectoral interests.

- ICT-based teaching should not be used to replace teachers, rather to augment teaching resources and modes. Good quality software and programme materials should be developed which are locally relevant and presented in local languages. Education should develop the skills necessary for villagers to get jobs.

- Facilities for telemedicine in villages should be embedded in a wider system that provides for early detection and action on outbreaks of diseases.

- Training should be provided to teachers and medical staff to make effective use of the new technologies.

6.6.4 Increasing the resilience of smart villages

Recommendations to governments, development organisations, and NGOs concerned with increasing the resilience of rural communities to natural disasters and the growing threats from climate change are as follows:

- The various players responsible for the key components of the infrastructure of villages—energy supply, communication links, health facilities, schools, etc.—should come together to take an integrated approach to establishing an appropriate level of resistance to natural disasters. Governments should map resources and vulnerabilities, sharing the information with local communities and municipalities. Systems should be in place to provide early warnings of impending shocks, and to support effective action during events and afterwards.

- The villagers themselves need to be partners in this integrated approach, and the opportunities provided by energy access and ICT should be used to develop their knowledge and skills in respect of mitigating risks. Support should be given to the sharing of knowledge and experiences between rural communities.

- Attention should be given to developing the social capital of villages along with their physical infrastructure; learning to deal with lower level but more regular shocks can help develop capacity to deal with more severe events.

6.6.5 Participation in governance processes

- Looking beyond the usual concerns to eliminate corruption in voting systems, realising the opportunities inherent in smart villages for rural communities to take a more active, informed, and influential role in governance processes requires governments to educate villagers in the workings of governance systems and how they can input to them. Governments should use the range of tools available through ICT, such as web-based referenda, consultations, and debates, to enhance transparency, accountability, and participation.
- Where possible, government services such as welfare benefits, birth and land registrations for individuals, and business registration and other regulatory processes for businesses should be made available on the internet. This is of particular value for rural communities for whom transaction costs can otherwise be very high.

Chapter 7: Cross-cutting issues

This section addresses the issues which surfaced repeatedly through the workshops and across the range of energy access technologies discussed in Chapter 5 and the various dimensions of smart villages enabled by energy access discussed in Chapter 6. These cross-cutting issues are as follows:

1. The policy framework
2. Gender issues
3. Access to finance
4. Capacity building and knowledge exchange
5. Coordination
6. Research and evaluation

The following sections summarise the key points that were made in the workshops. The chapter concludes with a summary of recommendations.

7.1 The policy framework

A stable and supportive policy framework needs to be established in order for local energy solutions to make their full contribution to sustainable energy access and the effective use of energy in enabling productive enterprises and provision of key services. The policy framework also needs to ensure that the private sector can effectively complement government and development organisation initiatives. Key elements of such frameworks identified at the workshops included:

- high-level political commitment to off-grid energy solutions
- clear, stable and supportive regulatory frameworks
- a national energy access plan
- support and incentives for project developers
- integration of energy access with other aspects of rural development.

Recognising the importance of a supportive policy framework, the World Bank and SEforALL have developed the RISE set of indicators of the quality of policy and regulations for energy access, renewable energy, and energy efficiency (Banerjee et al 2017). The RISE indicators reveal that sub-Saharan Africa has one of the least developed policy environments for energy access.

Given the competing interests for national budgets and the entrenched mindsets and incumbent interests in respect of centralised electricity generation and national grid distribution in many countries, **high-level political commitment** to rural energy access through off-grid energy solutions is a necessary driver of the required actions. Such commitments need to be backed by effective initiatives. While many governments advocate decentralised power they have not put in place the necessary policies, regulations, and initiatives to deliver it (Accenture 2015).

Concerns were expressed in several countries and regions about the lack of the necessary political commitment to decentralised power. For example, in Pakistan the focus of central government is still on large central power stations and national grid extension. Similarly, in West Africa, it was considered that the progress of local energy solutions is being hampered by weak national agencies, the absence of a level playing field, and the lack of national targets for off-grid energy schemes. At the opening regional workshop for South America, the view was expressed that, in Brazil, state and national governments need a new mind-set in respect of off-grid energy access and its role in supporting rural economic development and social inclusion.

There were calls for national champions to be appointed, charged with ensuring effective and integrated action across government departments, and securing necessary funding and budget allocations (see also PWC (2016) and UN Environment Programme 2015b).

Clear, stable and supportive regulatory frameworks should provide clarity on the roles of relevant government departments and effective mechanisms to coordinate their inputs. 'One-stop shops' for private developers, as for example in Rwanda, can substantially ease the regulatory burden for the private sector. Rural energy agencies, provided they are given the necessary 'clout' and resources, can also be effective in pushing forward rural energy access.

Policies and implementing frameworks need to be coherent and based firmly in realities, not just wishful thinking. So, for example, regulations in respect of tariffs must make it possible for the private sector to achieve acceptable returns if they are to make a substantial contribution to off-grid energy access. Similarly, requirements for tariff parity between rural and urban communities in situations where national grid electricity is heavily subsidised may imply a level of subsidy to local energy solutions that governments cannot afford (as for example in India, where the consequent level of required government subsidies for mini-grids is 90%, too high to permit scale-up).

The regulatory framework must give the clarity and stability necessary for the private sector and the financial community to invest. It should also ensure that projects are awarded on the basis of merit, not political or social contacts.

Problems of overly bureaucratic processes and approval bottlenecks were cited, for example in Nepal, in respect of public private partnerships. Procedures need to be simplified and streamlined in order to reduce the transaction costs incurred by the private sector and to achieve the necessary speeding-up of progress if the 2030 target for universal energy access is to be met. The formulation of regulations should be informed by experience on the ground, not, as suggested in the Pakistan workshop, developed in isolation from such experience. Regulations and procedures should be proportionate in respect of the scale of the local energy system and whether it is anticipated in due course to be connected to the national grid (see for example Hunt 2016).

One of the biggest uncertainties and hence deterrents for the private sector is the potential arrival of the national electricity grid. National grid extensions are generally very political processes, a tempting vote-winner for politicians. A **national energy access plan** is needed (as promoted by SEforAll), based on a systematic and objective analysis of how best to achieve energy access for rural communities. It should set out which areas are planned to get national grid access, and for cooking, access to LPG distribution networks, and on what timescale. It should properly integrate national grid and off-grid planning. Concerns were expressed in India that politicians may find it difficult to say that a village will not get a national grid connection. Similarly, in Bangladesh the point was made that as mini-grids are relatively unknown a politician who backs mini-grid development is unlikely to garner as many votes as one who champions grid extension.

The plans should provide private developers with dependable outcomes as and when the national grid arrives (African Union 2016). They should also have the political backing necessary for the private sector to be confident that they will be adhered to over time. They should set out clear responsibilities and measures of success for the relevant government bodies, including the national electricity utility. For example, in Indonesia the national electricity utility, PNC, was charged with constructing a number of high-profile mini-grids in island communities, but there was a lack of clarity on responsibilities for their long-term operation. The consequence that we observed at the Smart Villages workshop on the island of Bunaken, Sulawesi, was that a solar PV-diesel hybrid mini-grid was not operational due to a lack of spare parts and a lack of clarity as to where responsibility for its operation and maintenance lay between the utility and the local community.

With regard to **support and incentives for project developers**, entrepreneurs, particularly in East Africa, made a plea for less red tape and some breathing space in relation to tax regimes in order to get their businesses off the ground. In developing policies, regulatory frameworks and support schemes, governments and funders should consider how to support 'home-grown' enterprises which are well rooted in the communities in which they operate. Tax exemptions, for example on the import of key items of equipment, can help to kick-start the sector. Local levels of government can play an important role, providing an anchor between private developers and local institutions.

Integration of energy access with other aspects of rural development is essential if the development benefits of energy access are to be realised in practice. The potential synergies between energy access and provision of key services such as healthcare, education, clean water and sanitation are described in Chapter 6, but require integrated initiatives to make them happen. Similarly, productive enterprises will only be stimulated by energy access if the other elements of the necessary value chains and infrastructure are in place. For example, extensive mobile phone and broadband coverage, together with mobile money, play a key role in catalysing positive development outcomes.

The policy framework for energy therefore needs to be part of the broader policy framework for rural development, and the national energy access plan should be closely linked with other plans for rural development. The national energy plan itself needs to go beyond minimal levels of energy access, and provide for levels of access capable of supporting local services and productive enterprises.

7.2 Gender issues

Issues of gender equality and the empowerment of women have been important topics of discussion at many of the workshops, reflecting the concern of frontline workers to address these issues. These discussions have recognised the benefits to women arising from energy access through labour-saving devices, reduced burdens for collecting fuel wood and water, improved health and safety through clean cooking technologies and better access to healthcare, and improved educational opportunities. These issues are covered in Chapters 5b and 6 This section focuses on the need for, and benefits arising from, women's involvement in initiatives on energy access and the productive use of energy. The Smart Villages Initiative's work on gender issues has been informed by a literature review (Welland 2015a and 2015b).

Men and women experience energy differently, so energy access initiatives need to be sensitive to, and reflect, these differences: to date, most energy initiatives have not done so. For example, women are typically responsible for collecting firewood, for cooking, and for collecting water if it is not pumped to the village. They therefore benefit more from initiatives on clean cooking and provision of clean water supplies. For example, it was observed that in Senegal women work year-round (whereas men do not) on tasks undertaken through manual and inefficient labour that could be transformed by energy access. In many cases these responsibilities leave women with no time for other activities such as paid employment, engaging in the social and political life of the village, and education and training which could open up new opportunities. This impacts on their social standing in the village and their economic position and influence in the household.

Men and women tend to prioritise energy uses differently (for example, women tend to prioritise cookstoves while men prioritise light, and women are more likely to be concerned with opportunities for their children such as light to study), so both need to be involved when communities are approached regarding energy initiatives and in subsequent decisions. The case was made in several workshops that women have a better appreciation of energy needs within the home and, in Southeast Asia, that they are more receptive to opportunities for productive use.

But the critical role in energy provision and use that women undertake in households, and the valuable knowledge that arises, are often not recognised (for example, Vammen et al 2016). Inadequate attention is given to their needs and to their voices. They may be 'pushed aside' or not invited to the village meetings when village energy projects are first being discussed. Organisations leading energy access initiatives may need to make a concerted effort to work around social norms and ensure the active participation of women.

The point was made repeatedly that women make good entrepreneurs in businesses to promote and sell energy technologies, and to make productive use of energy access. Initiatives like 'Wonder Women' in Indonesia and 'Barefoot Grannies' across several countries in Africa and Asia demonstrate the practical reality of this proposition. Women are well-connected and trusted in the community, have natural links to extended families and friends, and are able to develop a good rapport with other women.

Ibu Inspirasi – Wonder Women Indonesia

Ibu Inspirasi (Wonder Women) is a Kopernik initiative working with women in Indonesia to make clean technologies for electricity, cooking, and clean drinking water available to rural communities.

Ibu Inspirasi trains local women to sell the equipment, teaches them basic bookkeeping and business skills, and supports them as energy equipment representatives. So far 800 women have benefitted from the scheme.

They become micro-social entrepreneurs: the margin between the price at which the technology is provided to them and their sale price provides them with an income. They continue to be mentored and supported as they grow their businesses. Kopernik provides backup support if there are problems with the equipment.

Women are affected most by energy poverty, and Wonder Women reinvest up to 90% of their income into their families and communities.

Discussion at the water-energy-food nexus workshop in West Africa concluded that women are more inclined to save and hence are better able to develop a good credit history. And they have proved to be diligent borrowers: for example, in Nigeria the default rate on micro finance institution loans to nearly three million women has been close to zero. Providing women with the opportunity, training and support to become entrepreneurs substantially increases the pool of talent available at the village level to progress off-grid energy access and its productive use.

Such entrepreneurial roles enhance the position of women in rural communities: as individuals increasing their income, providing them with new skills and increasing their self-esteem; in the family, increasing their financial contribution and ownership of assets leading to more say in family decision-making; and in the community, offering higher levels of participation and influence.

In order to catalyse this transformation in the lot of women in village life, and the transformational impact they can have on achieving the development benefits of energy access, training, mentoring, and ongoing support are needed. And, as pointed out at the Ghana workshop, 'women have to be empowered and see their own positive qualities, not just learn bookkeeping'. A cautionary note was that some interventions, such as the provision of basic levels of lighting to households, may just extend the working day for women while increasing leisure time for other family members.

Women's groups have also played a critical role in the success of energy projects in regions such as East Africa, Southeast Asia, and Melanesia (see box for example). In Lao PDR women's unions were influential in the success of an improved cookstoves project.

Women and entrepreneurship in renewable energy projects

Green Energy Africa Ltd was established in 2010 and started a project targeting women's groups in South Kenya in Kajiado County in September 2014, with financing from the Embassy of Sweden. Kajiado is home to the nomadic pastoralist Maasai community. Green Energy Africa works through community organisations in Kajiado and Makueni counties, and set up the 'Women and Entrepreneurship in Renewable Energy Project' (WEREP) through which it trains local women's groups and provides pico-solar lighting systems, panels, and other renewable energy equipment to rural households.

Ten women and youth groups were provided with seed capital to set up solar business enterprises. In the first phase of the project, approximately 1,000 households benefited from the solar equipment. Engaging women and young people facilitated the cultural and normative shift necessary to enable continued use of solar products.

Jackline Naiputa is a local Maasai leader heading up the Osopuko-Edonyinap women's group, which is part of the WEREP project. With little formal schooling and coming from a strongly patriarchal community, she has nevertheless grown into an influential, independent, and well-respected entrepreneur in her own right. In April 2015 she set up a shop to sell pico-solar systems; she has since scaled up to sell her goods in three villages—Magadi, Shompole and Oldonyo-Onyokie—and makes an income of approximately US$60 per week.

It is important, too, to engage young people in the villages given their distinctive needs and aspirations. An aim of development and energy access initiatives should be to provide sufficient opportunities in rural communities that young people choose to remain there. Both women and the younger generation can play transformative roles.

7.3 Access to finance

The difficulties faced by companies in accessing affordable finance were a consistent message across the countries and regions covered by the workshops. Given the need for a major ramp up in finance, as discussed in Chapter 3, if 2030 energy access targets are to be met, this is a key concern. For example, ATKearney and GOGLA (2014) estimated that US$1.5 billion was needed over two years to support PAYG customer financing, whereas to 2014 only US$70 million of equity and debt financing had been raised by the sector.

For companies developing mini-grids, financing is needed for the initial capital cost of the schemes, whereas companies distributing pico-solar lights and solar home systems need working capital. As discussed in Chapter 5, the latter companies often seek to lower householders' upfront costs through 'pay-as-you-go' or 'pay-for-service' business models. However, this model transfers the capital cost burden to the companies. Rural enterprises enabled by energy access need capital to invest in equipment and development of their markets.

Many companies are unable to demonstrate a successful track record for implementing commercially viable mini-grids or to provide data to show the reliability of pay-as-you-go / pay-for-service customer payment streams for pico-solar lights or solar home systems. This lack of a track record and data results in high perceived risk in the finance community and consequently high interest rates. This problem of perceived risk is exacerbated by the banking sector's lack of familiarity with off-grid energy. In West Africa the example was given of the US$1 billion fund for green projects set up by the African Development Bank, which off-grid energy companies have so far had little success in accessing as they cannot meet the standards set by the bank.

Financing arrangements need to be in place across the full range of the value chains, including end customers. Governments and development bodies therefore need to undertake systematic reviews to identify, and plug, any financing gaps. Recurrent gaps are in debt and equity financing for early-stage companies, and in local rather than international financing avoiding the problem of currency fluctuations. Shell Foundation estimates that US$5-US$10 million is typically needed to bring start-up companies in the off-grid energy sector to the next stage. In India, corporate social responsibility (CSR) funding arising from a government requirement for big companies to spend 2% of their profits on CSR is helping to bridge this financing gap.

Government or donor support may best take the form of some form of credit guarantee making private sector funds more available and enabling interest rates to be reduced. Governments also need to provide stable and supportive policy and regulatory environments to attract private sector capital, and to work with the private finance sector to increase their familiarity with the off-grid sector. The box summarises the lines of funding to off-grid projects provided by the Rural Energy Agency in Tanzania.

Lines of funding available from Tanzania Rural Energy Agency

- Matching grants support pre-investment activities such as feasibility studies, socioeconomic studies and market analysis; environmental and social impact assessments; preparation of bankable business plans; financial intermediation and closures; training and capacity building; and market development.
- Performance grants support the buy-down of project capital costs to lower the unit cost of energy service provided. For example, US$500 is provided per grid extension connection and US$5 per watt-peak solar PV installed.
- Long-term financing provides a credit line to shortlisted banks for loans up to 15 years with a grace period of five years (three projects have been supported).
- Access to carbon finance, in which the Rural Energy Agency acts as the coordinating and management entity in partnership with the World Bank.

Start-up companies selling pico-solar lights and solar home systems on a pay-as-you-go basis face a catch-22 as they grow and consequently seek debt financing: banks are unwilling to lend unless they can be convinced of the reliability of customer repayments (also Alstone et al 2015). At the Cambridge business models workshop in January 2016 it was proposed that concessional donor funds should finance credit risk on the basis that customer repayment records are collated and made public, thereby building the evidence base of the credit worthiness of this sector.

Transaction costs are too high for companies seeking financing to implement projects and to expand, distracting them from their 'day jobs' of establishing and meeting the needs of customers and growing their businesses. This applies to access to carbon funds (where just getting accredited can cost $10,000) as well as to private sector capital. Mechanisms are needed to reduce these transaction costs, for example, by bundling small projects. Smallholder farmers and SMEs may usefully form cooperatives to achieve greater scale in financing, and to reduce both their and the banks' transaction costs. In Tanzania, the Rural Energy Agency acts as a coordinating body to enable access to carbon finance in partnership with the World Bank.

The high transaction costs associated with supporting village-level initiatives also pose a significant challenge for banks, investors and development organisations. The example was given in the Nepal workshop of villages which may be a two-to-three day walk from the nearest road: for a bank employee to make a visit to evaluate a project proposal which may be seeking a loan in the tens of thousands of UD dollars this represents a substantial overhead on the loan. Similarly, for major development funders such as the European Union, funding many relatively small village-level projects rather than a few large, central generation projects represents a big increase in transaction costs and overheads which they are often not resourced to deal with. Project bundling and effective intermediary organisations may offer ways to deal with these issues.

Calls were made for better communication and coordination between national and multilateral financial institutions, which sometimes seem to compete rather than to support each other. PWC (2016) points to the fragmented nature of the funding landscape. An off-grid development and innovation fund may appropriately be set up by governments and donors in partnerships with banks, which can provide a high-profile and single focus for financing to off-grid enterprises (for example, the Rural Energy Fund in Tanzania: Mnzava 2015). The 'New Deal on Energy for Africa' (African Development Bank 2016) represents a continent-wide initiative to address the issue of fragmentation of funding.

7.4 Capacity building and knowledge exchange

A consistent message in all the workshops has been that a lack of skills (technical and business) and institutional capacity continue to be major impediments to progressing energy access and ensuring the sustainability of energy schemes. For example, in Latin America, a lack of training in the maintenance and use of energy technologies was identified as a major contributor to project failure. A shortfall in the availability of people with the necessary technical and business skills was identified in Africa and Asia as a constraint on the expansion of entrepreneurial businesses selling solar home systems and pico-solar lights.

Systematic analyses of all the stages in value chains are needed to identify shortfalls in skills and capacity. Reflecting the conclusion documented elsewhere in this report that the development benefits of energy access will only flow if an integrated approach is taken with other elements of rural development, such analyses and consequent capacity building initiatives need to address all aspects of rural development. Training programmes should be put in place to fill the gaps; they may need to be ongoing activities with periodic 'refresher' training rather than one-off events.

Governments and development organisations should take the lead, as local businesses generally do not have the resources needed to build the required levels of capacity, particularly given the high rates of turnover of staff that many of them experience. Government ministries responsible for education and training, business development, and innovation, together with ministries concerned with agriculture, health, and education, should collaborate with energy ministries in identifying and satisfying the need for training programmes.

In respect of **installation, operation, and maintenance of energy systems**, training is needed at all levels, from local technicians to engineers, product designers, and university researchers. There were calls for the creation of technical training and vocational institutions run by governments in partnership with entrepreneurs. In Cambodia, carbon credits received by an improved cookstoves programme were directed to support training and capacity building rather than to subsidise producers.

The Cedesol training programme in Bolivia

In the municipality of Yamparaez, Chuquisaca in Bolivia Cedesol, a Bolivian organisation established in 2003 implemented a modular training programme on the use of wood stoves in connection with the delivery of 720 stoves to more than 20 beneficiary communities. Visits were made to the communities to demonstrate the operation of the stoves in order to draw the audience's interest. Those interested filled out a form and then an agreement was signed with the beneficiaries where they committed to participate in an educational programme on the maintenance of the stoves. The programme was one year long and was divided into bi-monthly modules. Most of those who received training were women, with the objective that they would later repeat the process in their villages. As well as learning to maintain, repair, and recycle the stoves, they were taught environmental concepts, and principles of hygiene and health, nutrition and food safety. Tuition included how to replicate the technology with thermal stoves, and how to use insulating materials for better cooking.

Villagers have proved to be adept at acquiring and using the skills necessary to support the installation and operation of local energy systems, which creates valuable employment opportunities. In East Africa, the point was made that building local capacity also helps to shift the mindset of villagers from being continuing recipients of aid to becoming self-reliant and 'doing it for themselves'. A 'brain drain' problem is sometimes encountered in which people leave the villages for employment in the cities once they have been trained. This has been countered in some initiatives by focusing training on people who have strong ties to the village such as the 'train the grannies' focus of Barefoot Power. In contrast, there were calls at workshops in India and West Africa for major government-led training programmes focusing on rural youth.

As a footnote, it is of concern that projects on energy access continue to overlook the fundamental need to have sufficiently skilled local people in place to support the operation and maintenance of energy systems. For example, the state-owned Indonesian power utility PLN (Perusahaan Listrik Negara) launched a high-profile initiative to install solar PV mini-grids on a number of islands, seemingly with insufficient regard for establishing on-site arrangements for maintenance and operation. Consequently, the mini-grids experienced severe operational problems (including that visited in connection with the smart villages workshop on island energy held in Bunaken, Indonesia). Belatedly, PLN has introduced a capacity building initiative to train local operators, and all plants now have to submit regular operational reports.

Alongside technical training, it is important to **provide training and support to local entrepreneurs** in how to run a successful business. Knowledge and skills need to be developed in areas such as bookkeeping, marketing and how to identify and access potential markets, accessing finance, managing their value chains, etc. Where local entrepreneurs are key players in delivering energy services, and to support the establishment and growth of businesses making productive use of energy, it is useful for governments and development agencies to invest in business incubation and advisory support services. For example, in Rwanda the government has set up a 'one-stop shop' to provide advice to entrepreneurs initiating energy projects. In India, ICRISAT has established 22 business agriculture incubators in universities and agricultural institutes that have trained 3700 entrepreneurs and created over 200,000 jobs. The boxes give examples from Nepal and Tanzania.

Support in Nepal for the productive use of energy services

The Nepal Government's Alternative Energy Promotion Centre (AEPC) offers technical support, a central renewable energy fund, and advice on productive uses of energy in order to contribute to an increase in income generation and employment potential for micro, small and medium-sized enterprises (MSMEs) in rural areas, especially for men and women in disadvantaged groups. The 'Productive Energy Use Component' of AEPC has established 2800 new MSMEs and upgraded 1300 existing ones.

Support is offered through business development and financial assistance. Technical assistance is given to identifying what is available in terms of markets and capacity in the area through business opportunity assessment, followed by facilitation of business plan development and business registration. Networking with business development service providers and provision of entrepreneurship training courses for people with ideas is useful for identifying those who feel able to progress to the next step and are keen to develop their ideas after an initial feasibility investigation. Training is offered on business orientation, enterprise creation, business management, and skill development. Market linkages are facilitated. There is regular follow-up and monitoring for those moving to the next level.

Business incubation: Kakute support to Mobisol

Incubators work with start-ups that are in nascent stages of development and provide them with institutional support and guidance to emerge as fully operational businesses. An example of such incubation from Tanzania is the support given by Kakute (an organisation established in 1995 to support technology transfer for SMEs for sustainable development: www.kakute.org) to Mobisol, now a leading supplier of solar home systems in East Africa using a pay-as-you-go business model (http://www.plugintheworld.com/mobisol/). The local knowledge that Kakute had access to through years of working in the renewable energy eco-system was invaluable for Mobisol's growth in the local market. Starting with a prototype, through a number of different development phases, the product was adapted to local conditions before being launched commercially. This incubation model can be replicated in other East African countries as well.

Advice may also usefully be given on opportunities for services and products that have been successful elsewhere. Training of local artisans should look beyond their current activities to broader opportunities and give them the business skills needed to scale up. Industry associations (for example TAREA, the Tanzania Renewable Energy Association) can play a useful role in supporting the sharing of knowledge and the establishment of networks.

One of the reasons regularly cited for the reluctance of banks to lend to off-grid energy initiatives is their lack of familiarity with the sector and their consequent inability to realistically evaluate the risks. Initiatives are needed from governments, bilateral, and multilateral development organisations to **increase the capacity of the finance sector** to evaluate project proposals, particularly in the countries undertaking off-grid energy projects. Similarly, national governments often lack the skills and knowledge required to establish supportive policy and regulatory frameworks; here too international development organisations should support governmental capacity development, including through sharing of experiences between countries.

In all regions, there is an ongoing need for initiatives to **increase villagers' awareness** of the available off-grid technologies, and of their benefits (for example, financial and time savings, and health benefits) and how to use them. Also, villagers need to be made aware of the arising opportunities for productive enterprises and increasing the productivity of their existing activities. It is appropriate to harness the media and to target keystone actors in communities, such as teachers and village leaders, whose views will be trusted by community members.

Marketing approaches and techniques (which may have a somewhat negative connotation for some NGOs) may be used to identify what people value and prioritise, and to explore opportunities and benefits that they may not initially be aware of (Hirmer and Guthrie 2016). Face to face interaction and word of mouth knowledge sharing can be effective mechanisms, particularly where villagers do not have access to media such as TV and radio (Wheeldon 2017). Awareness-raising initiatives may appropriately be funded by governments and donors as they create a 'public good' which individual companies cannot afford to fund given that other companies would share the commercial advantage (Diecker et al 2016).

'Seeing is believing'— there is a strong demonstration effect—and successful pilots and examples of smart villages should be promoted to snowball success through replication and imitation. For example, in Pakistan it was observed that when villagers see something working they will be inspired to put it into practice. In Latin America, shops selling pico-solar lights and solar home systems were considered to have a useful role in allowing people to see the products and become familiar with them. In the entrepreneurial competitions run by the Smart Villages Initiative in East Africa, a significant proportion of aspiring entrepreneurs from the region noted business opportunities in the demonstration of off-grid energy products and proposed social enterprises based on marketing off-grid energy technologies to villagers.

As mentioned previously, an issue that often arises is that villagers consider local electricity solutions to be second-best or 'not proper electricity'. An open dialogue is needed with rural communities to address this issue, exploring the realities of the various options for electricity supply (for example, a supply from the national grid which is often unreliable versus a lower tier, but potentially more reliable, level of electricity access from a solar home system or mini-grid), the likely timescales on which national grid electricity might become available, and the opportunity costs in the meantime.

The **value of sharing information** between different stakeholder communities and between countries and regions was repeatedly stressed. This information needs to cover failures (and the reasons why) as well as successes and good practices. Otherwise, governments, development organisations, and NGOs are prone to cover up failures and repeat mistakes. Information sharing should include the experiences of developed as well as developing countries. There is much value in the kinds of engagement events run by the Smart Villages Initiative, and there were calls for information portals to encourage collaborative learning between communities. Not least, in order to avoid the repetition of costly mistakes which has too often been a characteristic of the off-grid energy landscape, academia can undertake a useful independent review function.

The OLADE networking experts' knowledge platform

The Latin American Energy Organisation has created a social networking platform for the energy sector in Latin America and the Caribbean. It is a platform that brings together policymakers, academics, businesses, multilateral agencies and consultants. It focuses on Latin America, and on themes such as best practices in the energy sector for rural electrification. It provides for numerous outreach activities, including news, webinars, reports, and discussion forums. It also seeks to inform energy policy and to ensure that affordable energy for rural areas and climate change remains a policy priority.

7.5 Coordination

Sustainable Development Goal 17 to 'Strengthen the means of implementation and revitalise the global partnership for sustainable development', includes a target (17.16) to enhance global and multi-stakeholder partnerships to support the achievement of the Sustainable Development Goals. In this context, an important point made in many of the workshops was that there is a lack of coordination and effective partnership working at all levels:

- In countries where several donor organisations and development agencies are active (for example, in East and West Africa and in Pakistan) there is little coordination and low levels of awareness of each other's activities. Indeed, in some cases there is apparent competition between those organisations.
- Collaboration between development organisations and national governments is often limited.
- Cross-Ministry cooperation is often ineffective and there can be a confusion and fragmentation of responsibilities (for example, in the Philippines 33 government offices and agencies have responsibilities in respect of initiatives on water and sanitation).
- There is a lack of coordination between national and multilateral finance organisations, and between the finance community and governments.
- There is generally a tendency to 'silo' approaches and sectoral working within organisations such as the World Bank.

This leads to duplication, gaps, and missed opportunities for synergies. It is unhelpful to the intended beneficiaries on the frontline when organisations are distracted from their core activities to deliver energy for development by endless and time-consuming rounds of grant calls and application processes, often providing relatively small sums of money for a lot of effort. The integrated approach necessary to maximise the development benefits from energy access requires a much higher level of coordination and collaboration across all the key players concerned with rural development.

There is a need to move away from a silo approach to policymaking and to establish new ways of working across key ministries such as agriculture, energy, and water: suggestions were made for one-stop shops, and, in India, a 'war room' to coordinate activities. The United Nations Environment Programme (2015) argues for the appointment of a champion within government who can work across government departments. A concern was expressed that there is a dearth of human capital in the public sector able to understand and address cross-sectoral challenges. In the Philippines workshop, a donor-

NGO 'dating' agency was proposed to enhance collaborative opportunities between those two groups of organisations.

7.6 Research and Evaluation

Workshops in East and West Africa, Southeast Asia, and Latin America all pointed to the value of collaboration between university researchers and frontline organisations delivering energy access on the ground, but expressed concern about the infrequency of such collaborations and low levels of relevant R&D more generally in developing countries to date. Such applied and collaborative research can better ensure that technological developments meet customer needs. For example, practical experience of using improved cookstoves should feed organically into further improvements in design. With regard to the capacity building element of Sustainable Development Goal 17 (17.9), more could usefully be done to build the capacity of universities in developing countries to work effectively with entrepreneurs on real-life technical challenges.

The point was made in the first Forward Look workshop that adequate rather than comprehensive solutions should generally be the focus for R&D ('appropriate technology' in the terminology of Practical Action (2012)). Frugal (jugaad) innovation (Radjou et al 2012) is an appropriate approach, improvising effective solutions with limited resources and under harsh constraints, and designing around local behaviours and economics. Researchers from developed and developing countries, from major corporations and village-based entrepreneurs, need to come together to search for such radical and appropriate solutions. International research programmes and research networks that bring together developed and developing world researchers are valuable—for example, the African Network for Solar Energy (www.ansole.org), a collaboration of researchers from African and non-African countries.

Jugaad innovation

Western innovation processes are typically resource intensive, time-consuming, and focus on solutions for the wealthier portion of the world's population. In contrast, 'Jugaad' innovators overcome harsh constraints in emerging markets by improvising effective solutions with limited resources, and are inclusive of the four billion people who live at the base of the world economic pyramid, earning less than $9/day.

As an example, in an affluent society, a high-end refrigerator can cost US$3000. You can talk to it, and the focus is on the technology. In contrast, in India a clay refrigerator has been developed that costs around US$30 and can keep fruit and vegetables fresh for five days. Mansukh Bhai, who comes from a village in Gujarat and has only a high school education, designed the refrigerator. He then up-scaled his enterprise by training local women to make them.

Frugal innovation occurs when a lack of resources provides the stimulus for innovation of products and services. A good example of this is the Stanford course on 'Design for extreme affordability' (http://extreme.stanford.edu/), which has produced technologies at one hundredth of the cost of normal products.

The point was made in East Africa that there is a wealth of village-level innovations and that governments should put in place mechanisms to nurture such innovators: in Tanzania the government's Commission for Science and Technology (COSTECH) undertakes this role working across government departments. In the Forward Look workshop on breakthrough technologies to use energy in off-grid villages, it was suggested that young people in villages need to be exposed to technologies such as 3-D printing: they will come up with innovative ideas as to how best to use the technology to meet local needs. Innovation competitions along the lines of those run by the Smart Villages Initiative can provide a useful impetus to local innovators.

The contribution of village communities to innovations and successful projects is sometimes not recognised, credit being taken by the NGO or development organisation that initiated the project. This is a source of frustration to villagers, as expressed in the workshop in East Africa which brought together community leaders.

A concern was expressed in several workshops that R&D should be guided by a better understanding of what communities value in respect of development, and of their distinctive opportunities and challenges. An interdisciplinary approach is needed involving social scientists and anthropologists alongside engineers and technology developers. Systematic approaches such as the 'service value test' are being developed to enable the aspirations and priorities of villagers to be determined. Decisions on research directions should be informed by a thorough analysis of the social and economic context, along with the scientific state-of-the-art and prospects, and avoid the 'myths' (for example in respect of materials choices for batteries) which can result in 'bandwagons' in which many researchers follow lines of investigation which are ultimately unproductive.

'Proving factories' as used in the automotive industry were suggested in the second Forward Look workshop scale-up of new technologies. Such proving factories typically employ 15 to 20 people: they take ideas and test out how they might be scaled by examining issues like sourcing components, required accuracy, and design for market.

With regard to **evaluation**, there is a lack of evidence on the development impacts of energy access, which makes it difficult for development organisations to justify investment. Organisations delivering energy access initiatives are increasingly being asked by donors for evidence of development impacts from proposed projects which they have difficulty in providing. Such measures as are in place are often not well linked to the realities on the ground, and metrics such as power or energy supplied often do not adequately reflect the benefits that are derived from energy provision. Practical Action (2016) proposes that measures should assess the energy services delivered and impacts on development objectives such as number of jobs created, agricultural productivity increased, children educated, etc.

Better methodologies and measures need to be developed to evaluate the development outcomes resulting from energy access. Such methodologies need to analyse the complex interactions between the availability of energy services and other components of rural development. They need to be routinely embedded in all initiatives. Records of failed projects, and the reasons why they failed, are valuable and need to be shared (but are often not made public as they may be uncomfortable for sponsors).

The large datasets on the use of solar home systems now being collected through remote monitoring systems provide an opportunity for the better evaluation of consumer behaviours and consumption patterns.

7.7 Recommendations on cross-cutting issues

Recommendations for each of the six issues addressed in Chapter 7 are summarised below in corresponding sub-sections.

7.7.1 The policy framework

Governments should put in place a supportive policy framework which includes the following components:

- High-level political commitment to off-grid energy access for development backed by effective initiatives.
- Clear, stable, and supportive regulatory frameworks which provide clarity on the roles of relevant government departments and effective mechanisms to coordinate their inputs, which are coherent, firmly based in realities, and built on simplified and streamlined procedures to reduce the transaction costs incurred by the private sector.
- A national energy access plan setting out which areas are planned to get access to the national electricity grid and to LPG distribution networks, on what timescale.
- Tax exemptions and a minimum of red tape to enable entrepreneurs to get their businesses off the ground.
- Integration of energy access with other aspects of rural development.

7.7.2 Gender issues

- Men and women experience and prioritise energy differently; rural development initiatives to provide and use energy should therefore involve, and give equal weight to, the voices of both sexes at every stage.
- The good track record of women as village-level entrepreneurs indicates that they should be given the training, mentoring, and encouragement necessary to realise the transformational business opportunities that arise from energy access.

7.7.3 Access to finance

- Governments and development bodies should undertake systematic reviews of sustainable energy supply and use value chains in order to identify, and plug, any financing gaps. Particular concerns are debt and equity financing for early-stage companies, and the availability of funding in local currencies.
- In order to reduce interest rates on loans and to make private sector funds more available, an effective approach can be for governments and development bodies to provide some form of credit guarantee. Governments should also provide stable and supportive policy and regulatory environments to attract private sector capital, and work with private finance organisations to increase their familiarity with the off-grid energy sector.
- For companies selling pico-solar lights and solar home systems, concessional donor funds should finance credit risk on the basis that customer repayment records are collated and (appropriately anonymised) made public, thereby building the evidence base of the creditworthiness of the pay-as-you-go sector.
- All stakeholders should work together to reduce the transaction costs for companies seeking financing to implement projects and to expand, and for banks, investment bodies, and development organisations which finance projects to supply and use off-grid energy. Potential mechanisms include bundling of projects for financing, and the formation of cooperatives at the village level.

- Action should be taken to address the fragmented nature of the funding landscape; one option is to set up an off-grid development and innovation fund which can provide a high profile and single focus for financing to off-grid enterprises.

7.7.4 Capacity building and knowledge exchange

- Working with local businesses, governments and development bodies should take the lead on evaluating all stages of value chains to identify shortfalls in skills and capacity. Training programmes should then be put in place to fill the gaps. Government ministries responsible for education, business innovation and development, agriculture, and health should collaborate with energy ministries in identifying and satisfying the need for training programmes.

- Technical training and vocational institutions should be set up and run by governments in partnership with entrepreneurs.

- Governments and development bodies should invest in business incubation and advisory support services, and set up training programmes for village-level entrepreneurs in how to run a successful business.

- International development organisations should support governmental capacity development, including through sharing of experiences between countries. Initiatives are also needed to increase the capacity of the finance sector to evaluate village-level projects to supply and productively use energy.

- Governments, development bodies, and NGOs should continue to undertake initiatives to increase villagers' awareness of the available off-grid technologies and the consequent opportunities for productive enterprises, and to increase the productivity of their existing activities. 'Seeing is believing' and successful pilots and examples of smart villages should be promoted to snowball success through replication and imitation.

7.7.5 Coordination

- International development organisations should achieve a much higher level of coordination in order to avoid duplication, gaps and missed opportunities for synergies, and to provide a more seamless experience for the frontline beneficiaries of development initiatives and funding in order to reduce their transaction costs.

- It is essential to move away from a silo approach to policy-making and to put in place new ways of working across key governmental ministries. Senior champions should be appointed within government with the authority to establish the required integrated approaches.

7.7.6 Research and Evaluation

- With regard to the capacity building element of SDG 17 (target 17.9), governments and development bodies should put in place initiatives to enable closer collaboration between universities and frontline organisations delivering energy services and making productive use of them. Such research activities need to be informed by the priorities, opportunities, and challenges as seen by the villagers themselves, and should focus on frugal innovation and appropriate technology which provide appropriate and affordable solutions to local problems.

- Initiatives should be put in place to expose young people in villages to the new technologies becoming available: they are most likely to come up with innovative ideas as to how they might best be used to improve the lot of rural communities.

- Better methodologies and measures should be developed to evaluate the development outcomes resulting from energy access. They should be routinely embedded in all initiatives.

Chapter 8: Making smart villages happen

The previous chapters have examined the various ingredients of smart villages. In this chapter consideration is given to how those ingredients can be brought together to make smart villages happen.

Technological and business model developments mean that sustainable energy services and unprecedented levels of connectivity through mobile phones and broadband internet can now be brought to rural communities at costs that are becoming ever more affordable. That said, the overall levels of investment required are still large, and rates of investment several times higher than have been achieved so far will be required in order to deliver smart villages on the 2030 timescale compatible with achieving the Sustainable Development Goals.

Once good levels of energy services and connectivity are available in villages, a raft of new opportunities arises. Education and healthcare at the village level can be revolutionised through the availability of lights, refrigeration, diagnostic tools, telemedicine, distance learning, and access to the world's knowledge base through the internet. Clean cooking, water and sanitation, alongside improved healthcare, can dramatically reduce the burden of ill health at the village level. Enhanced education means that skills can be brought up to levels previously only achievable in cities. These are important factors in establishing a workforce capable of making the most of the new opportunities for productive enterprise discussed in the following paragraphs.

Agriculture will remain the bedrock of employment and incomes for most villagers. Energy access, connectivity and modern farming techniques offer the prospect of substantially enhanced incomes from agriculture (by a factor of two or three, or more) through increased yields (by irrigation, improved seeds, higher value and more appropriately chosen crops, precision farming techniques, long-range weather forecasts, etc.), reduction in post-harvest losses (by drying, refrigeration, etc.), production of higher-value products through post-harvest processing, and achieving higher prices in markets through connectivity, cooperatives, and having more control over the timing of sales.

Higher levels of economic activity in and around agriculture, and the activities needed to maintain and support the new service infrastructure in villages (energy, ICT, health, education, clean water and sanitation) bring new opportunities for local service industries (for example welding, carpentry, business support) which are most appropriately located in the villages. Other opportunities may arise from the distinctive location of the villages, enabled by the connectivity which provides the links to markets, for example tourism and craft products (unique, bespoke, etc.). New technologies for distributed manufacturing, 3-D printing, etc., will open up the potential for competitive manufacturing at scales possible in larger villages and clusters of villages.

These new opportunities for village-level enterprises and income generation reflect the shifting of the balance of opportunities between rural and urban communities made possible by new technologies and business models. Once smartphone ownership and internet connectivity reach levels comparable to those in cities, those economies of scale and agglomeration effects (that have driven urbanisation) arising from information flows can be reproduced in villages. So distance becomes largely irrelevant in respect, for example, of business services such as accountancy, consultancy, legal, licensing, etc. Internet-based recruitment can match people with the requisite skills to jobs wherever they may be located. And mobile/internet-based banking can ensure that financial services can be made available to businesses whether they are located in a village or a city.

Given the diseconomies of scale inherent in over-urbanisation, the opportunities to substantially increase incomes and employment in villages as discussed above, and the availability in villages of key services (education, healthcare, clean water and sanitation) and entertainment (radio, TV, internet, etc.), villagers may well make different decisions about where to live. The good levels of connectivity inherent in smart villages should also enable villagers to make better-informed decisions about their prospects in the cities. Such decisions may alter over the course of people's lifetimes, resulting in a more fluid interchange of populations between villages and cities.

It is important to recognise and build on the interdependence of cities and villages. For a sustainable transition of the entire economy there needs to be a linkage of networks, both human and technical, between rural and urban areas to sustain growth and to promote the convergence of living standards for all citizens.

By bringing opportunities into the villages that hitherto were only available in cities, the technical and social advances characteristic of smart villages challenge traditional economic models of development which make a sharp distinction between the roles of 'urban' and 'rural' (van Gevelt and Zhang 2017). These distinctions become sufficiently blurred that the utility of these models to inform development strategies is increasingly limited, suggesting that development no longer be subject to an urban bias.

A key question is **where should the money come from** to make the initial investments in village-level services and productive enterprises, and to sustain the services over time. Figure 8 illustrates the challenge. Initially, the major part of that investment will need to come from external sources in the form of subsidies, grants, preferential loans, etc. But over time, as productive enterprises ramp up and incomes consequently rise, more of the required investment can be generated from within the village itself.

At some point in time ($t_{breakeven}$ in the figure) the village may become self-sustaining in respect of continuing investment in the upkeep and further development of infrastructure, services, and productive enterprise (including through raising private sector capital)[24]. Given the global challenges of finding the large sums of money required to achieve the Sustainable Development Goals, the aim must be to make $t_{breakeven}$ as early as possible, and the shaded area X (the cumulative external investment required) as small as possible.

24 Though some societies may decide that some level of continuing economic transfer from urban to rural is desirable and affordable

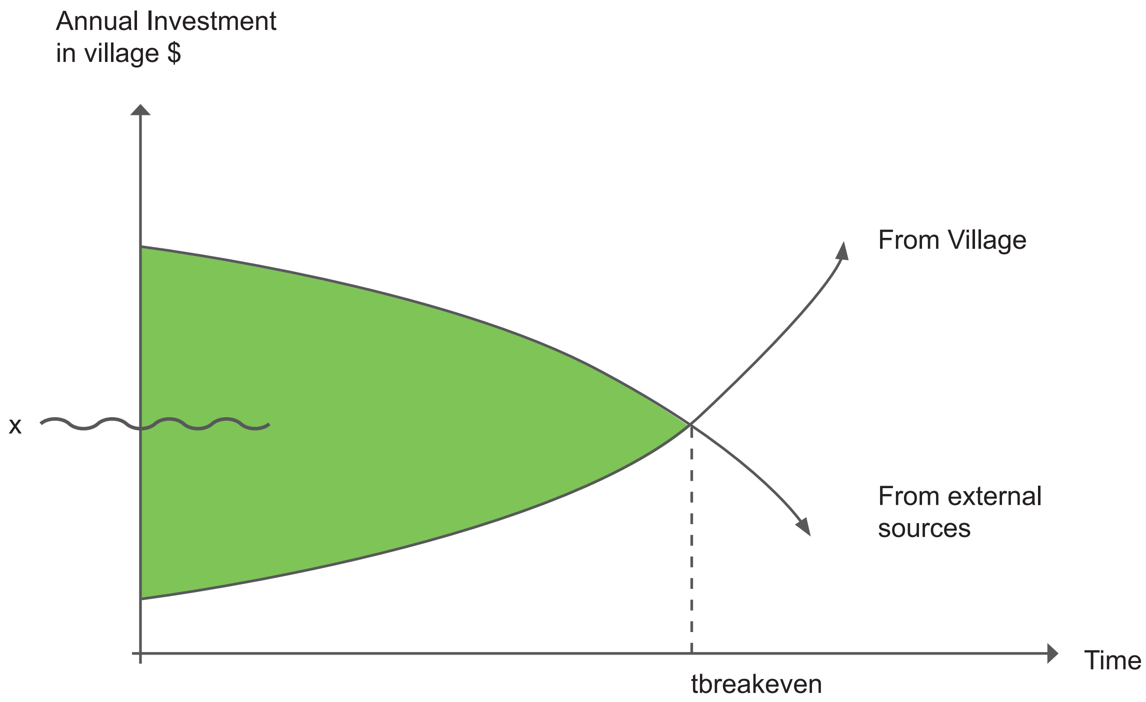


Figure 8: **Balance of investment in villages over time**

The bottom curve, the investment generated from within the village, needs to run steeply upwards, pointing firmly to an emphasis on productive enterprises and increasing incomes. Over time, payment for services such as healthcare, education, clean water and sanitation may come directly from the villagers, or via taxation as the village becomes more prosperous and increasingly part of the formal economy. As farming generates greater revenues, and as productive enterprises generate profits, capital for investment to grow further can be self-generated and obtained through an increasing ability to attract equity investment and for the financial sector to make loans.

The top curve, the investment in the village from external sources, needs to run steeply downwards. To some extent, its slope will mirror that of the bottom curve: if the capacity to generate investment from within the village increases more quickly then the requirement for external investment in the form of subsidies, grants, etc., will reduce more rapidly. Villagers should always have a stake in the infrastructure, facilities, and services supported by external investment; their financial stakes may be increased as incomes rise. Achieving a steep downward curve also requires that external investments are carefully targeted, guided by their ability to stimulate incomes and the investment capability of the village. Ongoing and systematic evaluation of value chains is required in order to identify bottlenecks and measures to overcome them.

In the case of electrical services, a first step of a pico-solar light can be quickly (often in a matter of months) paid for by savings in candles, kerosene and batteries. The step up to a solar home system is primarily motivated by improving domestic living conditions and is capable in many rural families of being paid for (typically over a period of one to three years) by diversion of a modest proportion of household incomes from other expenditures. As the costs of solar home systems continue to reduce, the proportion of households able to afford them will rise. Companies selling solar home systems are increasingly making available 'energy ladders' in which customers can upgrade to a more powerful system when they have paid off their existing system, and are extending their ranges of products to include domestic appliances.

The significantly more expensive step of a mini-grid (and potentially in time a national grid connection) is primarily motivated by the consequent ability to power productive enterprise, which should therefore be the main source of its financing. An integrated approach is needed in which initiatives on electricity access go hand in hand with complementary initiatives to stimulate productive enterprises. Such integration needs to extend to the electricity needs of village facilities such as schools, health centres, street lighting, community centres, clean water and sanitation, etc.: their payments for electrical services can usefully augment income streams from productive enterprises and households, helping to 'balance the books' of mini-grid schemes. Whatever combination of public and private ownership and operation is chosen, a key aim should be to achieve the financial viability of the scheme, independent of subsidy, as quickly as possible to minimise the call on external investment (and hence to contribute towards steepening the downward slope of the upper curve) and to ensure that investments can be made in increasing the capacity of the system as demand increases.

In respect of the **sources of external investment**, the major part will need to come from the private sector: funding available from national governments in developing countries and the international development bodies may be anticipated to fall far short of what is required, even allowing for targets on overseas development assistance (0.7% of donor's national income) being met. Previous chapters have discussed the conditions necessary to attract private sector investment in rural development and to leverage public sector investment.

A stable and supportive policy and regulatory framework is required that creates an environment in which village-level enterprises can prosper. Support needs to be given to the banking sector, in particular, to enhance relevant knowledge and skills, and its willingness to lend at affordable rates through risk mitigation measures. Track records of the credit-worthiness of village-level borrowers (households, smallholders, cooperatives, SMEs, etc.) need to be built, and where appropriate shared, to provide confidence to the banking sector to lend.

A further consideration is **where to focus investment** over time. For example, should it be spread thinly across all rural communities, focused on the poorest households, or concentrated at least initially on the villages with the best prospects of rapidly increasing enterprise and incomes? In any case, limited resources mean that investments need to be carefully targeted, investment decisions being informed by analysis and effective engagement with local communities. Those communities should be in the 'driving seat' in respect of the development path taken by their villages, and care must be taken not to impose development paradigms that are incompatible with local desires and cultures.

It is important also to recognise that there is not a simple binary choice between villages and cities; in reality, there is a distribution of population across all levels of habitation which we may expect to change over time. Productive enterprise (or at least some types of productive enterprise) may most appropriately be located in rural towns or larger villages, or in clusters of villages. Such rural concentrations of productive enterprise may achieve the requisite critical mass and avoid some of the diseconomies associated with the imperfect realities of many cities in developing countries. Some level of intra-rural migration may be anticipated as a result.

It has been argued earlier in this report that achievement of many of the Sustainable Development Goals will require smart villages to become the norm, not the exception, for rural communities. With just 13 years to go to 2030, **speed in the wide-scale development of smart villages is therefore of the essence.**

History suggests that rural electrification and development can be achieved rapidly if a well-focused and integrated approach is taken. For example, in South Korea over a ten-year period from 1970 levels of rural electrification went from low to high levels, and household incomes increased by a factor of nearly 10 (van Gevelt 2014). In this case, government initiatives on rural electrification were accompanied by initiatives to increase agricultural productivity and rural value added, and to develop rural industry. In Thailand over a 30-year period from 1972 rural electrification increased from 10% to 99%, a key factor in the success being a strong emphasis to promote the productive use of electricity. China has achieved 100% electrification for 1.3 billion people through a multi-stage rural electrification programme over 50 years which has taken a bottom-up approach, emphasising the productive uses of electricity along with a pricing system for electricity which provided for almost full cost recovery (Barnes 2007).

Care must be taken in interpreting these historical examples as the global economic circumstances now may not be so conducive to rapid rural economic progress as it was then (Collier 2008). On the other hand, developing countries are not so encumbered by outmoded infrastructures as developed countries and have opportunities to leapfrog to technologies and infrastructures capable of taking full advantage of 21st century opportunities.

Notwithstanding these considerations on the extent to which lessons can be drawn from these historical examples, van Gevelt and Yhang (2017) identify the following four principles for rural electrification and development:

1. Sustained government commitment to rural electrification, circumventing typical political cycles, and based on dedicated institutions able to work effectively across government with a high degree of autonomy.

2. Effective planning based on a project selection methodology which systematically prioritises particular areas, often initially communities that require the least investment in infrastructure for maximum economic and social return.

3. Sustainable financing of rural electrification programmes in which tariffs are set to at least cover operating costs.

4. Effective engagement of rural communities and a focus on the productive use of electricity.

At the village level, the development agenda and associated actions need to be driven by the villagers, mentored and supported by development bodies, NGOs, etc. Mechanisms are needed whereby actors concerned with energy access, village services, agriculture, and productive enterprise can work together to ensure a holistic approach to village development which can turn potential synergies between sectors into realities. Such mechanisms should provide for systematic evaluation of the distinctive challenges and opportunities inherent in each village setting. Standard but flexible processes and analytical frameworks are required, rather than blueprints.

Lessons on how to achieve a positive and steep spiral of development need to be learned and shared rapidly. Such knowledge may be encoded and disseminated via the internet, but just as importantly also by interactions between people, enabled by effective networking within and across regions.

Recognising the paucity of information on the development impacts of rural energy access discussed earlier in the report, pilot smart villages may usefully play a role in supporting initiatives to learn how to navigate the complex, situation specific, and dynamic landscape of rural development. In setting up such pilot projects, care must be taken to establish baselines and appropriate controls, and to undertake monitoring and evaluation in such a way as to be able to distinguish locally specific and generalisable causes and effects.

Chapter 9: Conclusions

The extensive programme of engagement with the frontline players in energy access for rural development across six regions undertaken by the Smart Villages Initiative over the three-year period 2014-17 has amassed a rich source of up-to-date information on the barriers to, and opportunities for, rural energy access to substantially enhance the living conditions of villagers. This report has drawn together key findings and recommendations, and provides links to the underpinning reports and presentations accessible on the e4sv.org website.

Throughout the engagement activities, strong support has been expressed for the smart villages concept, not least for its ambitious vision for rural development, and its concern to take an holistic, village-level approach in which energy access initiatives are closely integrated with initiatives on connectivity, productive enterprises, agricultural productivity, and key services such as healthcare, education, clean water and sanitation. Only through such integration can the full development benefits of energy access and synergies with other sectors be realised.

It is interesting to note that over the course of the Smart Villages Initiative others around the world have independently coined the 'smart villages' term to label a more holistic approach to rural development which realises the breakthrough potential of modern technologies. For example, 'smart villages' is the term that has been attached to government-led initiatives in Malaysia and India, and is being used for initiatives led by the Institute of Electrical and Electronic Engineers (IEEE), and by the Haas School of Business at the University of California[25]. Indicative of the global reach of the smart villages concept, the European Commission launched an EU action called 'Smart Villages' in April 2017 intended to revitalise rural communities in Europe.[26] The rationale for the initiative was expressed as follows: 'With modern technologies and new concepts, we want to reinvigorate rural areas, reverse the trend of depopulation and protect people against rural poverty'.

All players—villagers, entrepreneurs, NGOs, civil society organisations, policy makers and regulators, development organisations, financiers, researchers, etc.—have important roles to play, but need to achieve much better levels of coordination and collaboration going forward. The focus and drive for the development of rural communities should rest with the villagers themselves: external bodies should ensure that effective engagement with villagers underpins all their interventions.

Clear, supportive, coherent, and stable policy and regulatory frameworks which bring together

25 For the Government initiative in India: http://www.businessinsider.in/Smart-Villages-Lending-A-Rural-Flavour-To-Modis-Growth-Agenda/articleshow/45271399.cms. And in Malaysia: http://www.bbc.co.uk/news/av/business-19722288/malaysias-smart-villages. For the IEEE initiative: https://www.ieee-foundation.org/smart-village. For the University of California initiative: https://www.linkedin.com/pulse/prototyping-scalable-smart-village-leveraging-open-solomon-darwin

26 See link: http://www.euractiv.com/section/agriculture-food/news/commission-the-future-relies-on-boosting-smart-villages/

the interests of the relevant ministries should be put in place in each country. They need strong political backing, the necessary resources and actions to deliver them, and to be based on careful analysis of the realities, not just wishful thinking. If SDG targets are to be met by 2030, a stronger sense of urgency is needed in actions across the board.

Substantially enhanced rates of financing are needed, not just for energy access but for all key components of village development. Access to private sector funding at affordable interest rates is essential, and requires innovative approaches to risk mitigation and to building the confidence of the private sector to invest in order to maximise the leverage of government and donor funding. Ways need to be found, for example through project bundling, to reduce the transaction costs of the developers and their financiers for the large numbers of village-level projects to supply and productively use off-grid energy that are required. Where subsidies are used, they should be well targeted and time limited.

Governments and government bodies should continue to invest in increasing awareness of the opportunities arising from modern technologies to supply and use energy, in building skill levels across all relevant value chains, in providing support and advice to entrepreneurs and small businesses, in setting and policing quality standards, and in university research which responds to the needs of, and is well linked to, frontline delivery.

Looking to the next phase of the Smart Villages Initiative, a key focus for future work should be to develop a better understanding of how, in practice, the various factors in village development can be brought together in an effective way. As one important route to furnish such understanding, the development path of a number of pilot smart villages may appropriately be baselined and systematically monitored and evaluated over a number of years.

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Smart Villages East African Community Leaders' Dialogue Workshop Report: http://e4sv.org/publication/east-african-masterclass-workshop-report/

Smart Villages Energy and Agriculture for Smart Villages in India Workshop Report (ICRISAT): http://e4sv.org/publication/energy-agriculture-smart-villages-india/

Smart Villages Energy and water nexus for off-grid communities in the Philippines and Southeast Asia Workshop Report: http://e4sv.org/publication/energy-and-water-nexus-southeast-asia/

Smart Villages Energy for Off-Grid Islands: Bunaken Workshop Report: http://e4sv.org/publication/energy-off-grid-islands-bunaken-workshop-report/

Smart Villages Forward Look Workshop: Potential breakthroughs in the use of energy in off-grid villages: http://e4sv.org/publication/smart-villages-forward-look-workshop-potential-breakthroughs-use-energy-off-grid-villages/

Smart Villages Frontier Energy Storage Technologies and Global Energy Challenges Workshop Report: http://e4sv.org/publication/frontier-energy-storage-technologies-global-energy-challenges/

Smart Villages in East Africa: Arusha Workshop Report: http://e4sv.org/publication/report-of-1st-regional-smart-villages-workshop/

Smart Villages in South America: Lima Workshop Report: http://e4sv.org/publication/smart-villages-south-america-lima-workshop-report/

Smart Villages in Southeast Asia: Kuching Workshop Report: http://e4sv.org/publication/kuching-workshop-report/

Smart Villages in Nepal: Kathmandu Workshop Report: http://e4sv.org/publication/smart-villages-in-nepal-kathmandu-workshop-report/

Smart Villages in West Africa Regional Workshop Report: http://e4sv.org/publication/smart-villages-west-africa-accra-regional-workshop-report/

Smart Villages off-grid energy for rural development in Southeast and South Asia Workshop Report: http://e4sv.org/publication/workshop-report-thailand

Smart Villages in Pakistan: Islamabad Workshop Report: http://e4sv.org/publication/smart-villages-pakistan-islamabad-workshop-report/

Smart Villages Ecuador Workshop Report: http://e4sv.org/publication/workshop-report-ecuador/

Smart Villages Senegal Workshop Report: http://e4sv.org/publication/workshop-report-senegal-media/

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Annex 1: Listing of Smart Villages Initiative Engagement Events

Workshops and Capacity Building Events

Date	Location	Focus	Reports
January 2014	Cambridge UK	First Forward Look workshop to discuss emerging technologies for the sustainable production and use of energy in developing countries	Workshop Report No. 1: New technologies for off-grid villages: a look ahead
June 2014	Arusha, Tanzania	Opening regional workshop for the East Africa engagement programme	Workshop Report No. 2: Smart villages in East Africa: Arusha workshop report Policy Brief No. 1: Findings from the Arusha Smart Villages workshop
November 2014	Kigali, Rwanda	Regional media dialogue workshop: East Africa	Workshop Report No. 3: East Africa Media Dialogue: Kigali Workshop Report
January 2015	Kuching, Malaysia	Opening regional workshop for the Southeast Asia engagement	Workshop Report No. 4: Smart villages in Southeast Asia: Kuching workshop report Policy Brief No. 6: Findings from the Kuching Smart Villages Workshop
April 2015	Kathmandu, Nepal	Workshop on Nepal's experience of off-grid rural energy systems	Workshop Report No. 5: Smart villages in Nepal: Kathmandu workshop report Policy Brief No. 3: Findings from the Nepal Smart Villages Workshop
June 2015	Seoul, South Korea	Regional media dialogue workshop: Southeast Asia	Workshop Report No. 6: Southeast Asia Media Dialogue: Seoul Workshop Report
August 2015	Terrat, Tanzania	Dialogue event with East Africa village leaders	Workshop Report No. 7: East Africa community leaders' dialogue workshop report
August 2015	Dhaka, Bangladesh	Workshop to learn from Bangladesh's experience of solar home systems and solar/ solar-hybrid mini-grids	Workshop Report No. 8: Smart Villages in Bangladesh: Dhaka workshop report Policy Brief No. 8: Findings from the Dhaka Smart Villages workshop

September 2015	Kigali, Rwanda	Wrap-up regional workshop for the East Africa engagement programme	Workshop Report No. 9: High-level workshop on off-grid village energy in East Africa Policy Brief No. 7: Lessons learned from the Smart Villages engagement programme in East Africa
October 2015	Islamabad, Pakistan	Workshop on Pakistan's experience of developing enabling frameworks for the dissemination of mini-grids	Workshop Report No. 10: Smart Villages in Pakistan: Islamabad workshop report Policy Brief No. 9: Enabling frameworks for deploying micro-grids: lessons from Pakistan
November 2015	Bunaken, Indonesia	Workshop on sustainable energy provision to small island communities	Workshop Report No. 11: Energy for Off-Grid Islands: Bunaken workshop report Policy Brief No. 10: Findings from the Indonesian Smart Villages workshop on energy for islands
November 2015	Colombo, Sri Lanka	Regional media dialogue workshop: South Asia	Workshop Report No. 12: South Asia media dialogue: Colombo workshop report
December 2015	Yangon, Myanmar	Regional workshop on the sustainable dissemination of improved cookstoves in Southeast Asia	Workshop Report No. 13: Sustainable dissemination of improved cookstoves: lessons from Southeast Asia Policy Brief No. 12: Sustainable dissemination of improved cookstoves: lessons from Southeast Asia
December 2015	Cambridge, UK	Second Forward Look workshop on breakthrough technologies for the use of energy in off-grid villages	Workshop Report No. 14: Smart Villages Forward Look Workshop: potential breakthroughs in the use of energy in off-grid villages
January 2016	Cambridge, UK	Workshop on business and financial models for off-grid electricity	Workshop Report No. 15: Smart Villages workshop: business models for off-grid electricity
January 2016	Lima, Peru	Opening regional workshop for South America engagement programme	Workshop Report No. 16: Smart Villages in South America: Lima workshop report Policy Brief No. 11: Off-grid energy in remote communities: lessons from South America

April 2016	La Paz, Bolivia	Workshop on access to, and use of, renewable energy sources for rural communities in Bolivia	Workshop Report No. 17: Sustainable energy sources for off-grid rural communities in Bolivia: opportunities, challenges and perspectives Policy Brief No. 14: Findings from the workshop on sustainable energy sources for off-grid communities in Bolivia
May 2016	Singapore	Workshop on Smart Villages and resilience to natural disasters	Workshop Report No. 18: Smart Villages and resilience to natural disasters Policy Brief No. 13: Smart Villages and resilience to natural disasters
May 2016	Edinburgh, UK	Third Forward Look workshop on energy storage technologies for off-grid electricity	Workshop Report No. 19: Frontier energy storage technologies and global energy challenges Policy Brief No. 15: Findings from the Edinburgh Forward Look workshop on Frontier energy storage technologies and global energy challenges
May 2016	Accra, Ghana	Opening regional workshop for West Africa engagement programme	Workshop Report No. 20: Smart Villages in West Africa: Accra regional workshop report Policy Brief No. 16: Findings from the Smart Villages West Africa regional workshop
June 2016	Burgos, the Philippines	Workshop on energy access and its relationship with water, sanitation, and hygiene in off-grid communities in Southeast Asia	Workshop Report No. 21: The energy and water nexus for off-grid communities in the Philippines and Southeast Asia Policy Brief No. 17: The energy and water nexus for off-grid communities in the Philippines and Southeast Asia

July 2016	Bangalore, India	Fourth Forward Look workshop on developments in mini-grid technologies in India	Workshop Report No. 22: Mini-grid energy generation, storage and transmission technology in India for the next 10 years Policy Brief No. 18: Findings from the Bangalore Forward Look workshop on mini-grid technologies for India
July 2016	Asuncion, Paraguay	Regional media dialogue workshop: South America	Workshop Report No. 23: Media Workshop
August 2016	Saly, Senegal	Regional media dialogue workshop: West Africa	Workshop Report No. 24: Media Workshop
August 2016	Saly, Senegal	Regional workshop on the water-energy-food nexus in West Africa	Workshop Report No. 25: Smart Villages workshop on the water, energy, and food nexus: lessons from West Africa Policy Brief No. 19: The water-energy-food nexus in West Africa
September 2016	Patancheru, India	Workshop on energy for agriculture in Smart Villages in India	Workshop Report No. 26: Energy and agriculture for Smart Villages in India Policy Brief No. 20: Findings from the workshop on energy and agriculture for smart villages in India.
April 2016	Odisha and Ranchi, India	Workshop on India state level brainstorms	Workshop Report No. 27
November 2016	Punta Cana, Dominican Republic	Opening regional workshop for engagement programme in Central America, the Caribbean, and Mexico	Workshop Report No. 28: Sustainable energy sources for rural development and climatic resilience of off-grid communities in Central America, the Caribbean, and Mexico. Workshop Report No. 29: Media Workshop Policy Brief No. 21
January 2017	Port-au-Prince, Haiti	Workshop on energy solutions for the sustainable construction of rural Haiti and the strengthening of resilience	Workshop Report No. 30 Policy Brief No. 22
January 2017	Quito, Ecuador	Workshop on sustainable energy sources for risk management and the resilience of communities in Latin America and the Caribbean	Workshop Report No. 31 Policy Brief No. 23

February 2017	Lome, Togo	Workshop: From the bottom up: the role and place of community-led approaches in national energy planning in West Africa	Workshop Report No. 32 Policy Brief No. 24
March 2017	Bangkok, Thailand	Closing regional workshop for South and Southeast Asia	Workshop Report No. 33 Policy Brief No. 25
March 2017	Abidjan, Cote d'Ivoire	Closing regional workshop for West Africa	Workshop Report No. 34 Policy Brief No. 26
April 2017	Matagalpa, Nicaragua	Workshop on the link between access to energy, financial mechanisms, and energy policies of Nicaragua	Workshop Report No. 35 Policy Brief No. 27
May 2017	Panama City, Panama	Closing regional workshop for Latin America	Workshop Report No. 36 Policy Brief No. 28
June 2017	Brussels, Belgium	EU Workshop on Smart Rural Development: the SDGs and the New European Consensus on Development	Workshop Report No. 37 Policy Brief No. 29

Webinars

9 March 2016	Off the beaten path: Rural energy and remoteness
20 April 2016	Failure and off-grid energy access: Why failure matters to development
18 May 2016	Energy entrepreneurs: Business models for off-grid energy and social impact
30 June 2016	The big chill: Off-grid cooling for water, refrigeration, spaces and more
18 July 2016	Addressing energy governance: Questions of scale and scope
11 August 2016	Women and energy entrepreneurship: Business models for off-grid energy and social impact
13 October 2016	Scaling up gender: Women in off-the-grid energy business models and supply chains
22 November 2016	Going off the grid: Disaster, resilience, and off-grid energy
19 December 2016	Growing smart villages: Agriculture and energy for development
16 February 2017	Healthy villages are smart villages: Health, energy, and development
16 March 2017	Refugees and energy: Meeting the needs of refugees and displaced people
30 May 2017	A breath of fresh air: What's next for clean cookstoves?

Annex 2: Energy access in smart villages and the Sustainable Development Goals

For each of the Sustainable Development Goals 1 to 16, this Annex illustrates the interconnectivity of Goal 7 on energy access and the other SDGs. It sets out the ways in which rural energy access and the forms of development envisaged in the smart villages concept are necessary enablers of achieving the targets within the other goals. For Goal 7 it summarises the ways in which achievement of other goals are necessary enablers of Goal 7. An analysis by the World Bank's Energy Sector Management Assistance Program indicates that 125 of 169 SDG targets are linked to energy (SEforALL 2016).

Goal 1: End poverty in all its forms everywhere

- Through enabling increases in productivity, the creation of new productive enterprises, and capturing more of the agricultural value chain, energy access can make a major contribution to reducing rural poverty.
- Clean cooking saves households time and money, and is necessary to lead a healthy and productive life.
- In respect of target 1.4 on access to basic services, energy access supports the provision of better levels of healthcare and education, and of clean water and sanitation in villages.
- In respect of target 1.5, energy access and the development of smart villages increases resilience to natural disasters and economic shocks.

Goal 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture

- Energy access supports increases in agricultural productivity by powering irrigation, and through enabling ICT results in enhanced connectivity, access to farming advice and weather forecasts, and knowledge of/access to improved crop varieties, etc.
- Cooking is a key step of the nutrition chain (80% of foods need to be cooked): efficient cookstoves reduce the burden on families of sourcing fuel to cook.
- In respect of target 2.3, energy access enables more of the agricultural value chain to be captured at the village level so increasing incomes, for example through refrigeration and drying to reduce post-harvest losses, processing to produce higher value products, and through ICT better knowledge of markets to achieve higher prices.
- In respect of target 2.4, 'smart' rural development is founded on sustainable approaches and maintaining supporting ecosystems.

Goal 3: Ensure healthy lives and promote well-being for all at all ages

- Substantial improvements in rural healthcare require energy services to light clinics, to power refrigeration to preserve vaccines and medicines, to sterilise equipment, and to provide a working environment that will retain medical staff.
- Through enabling ICT, energy access supports telemedicine, bringing specialised expertise to bear at the village level.
- Through clean cooking technologies and powering clean water and sanitation, energy services can reduce the burden of disease and ill-health in villages.
- By enabling effective and well-connected healthcare in villages, energy access can con-

tribute to the early detection and control of epidemics such as Ebola and flu.

Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

- Lighting in schools and homes provides a substantially enhanced learning environment.
- Energy access with ICT provides villagers of all ages access to the world's knowledge base and the opportunity for distance learning.
- The smart villages concept provides for training in the installation and maintenance of energy services and the equipment that uses that energy to drive productive enterprises.
- Clean and efficient cookstoves reduce the call on children to be kept out of school to collect firewood, and facilitate the provision of a mid-day meal in schools.

Goal 5: Achieve gender equality and empower all women and girls

- Clean and efficient cookstoves, or a shift to gaseous fuels, reduce the burdens of firewood collection and health impacts of smoke inhalation which often fall disproportionately on women. Together with other labour-saving devices such as mechanisation of crop processing, this can free up women to take a more active role in the social, economic, and governance activities of the village.
- Lighting in the home and village streets, and toilets in homes, provide a safer environment for women.
- Access to ICT and the media exposes women to other norms of empowerment which can motivate and catalyse their own fight for equality.
- The smart villages concept provides for the proactive development of women as entrepreneurs in the provision and productive use of energy services, which leads to their economic empowerment and consequently more general empowerment in the home and village life.
- In respect of target 5.5, better and equal access to education, enabled by energy access, provides women with the skills necessary to participate and to lead in political, economic, and public life.

Goal 6: Ensure availability and sustainable management of water and sanitation for all

- Electricity is needed to power pumps, for water purification and effluent clean-up
- In respect of target 6.4, energy access and ICT can enable precision irrigation as a component of modern agricultural systems, reducing water use.

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all

- Lifting people out of poverty (Goal 1) corresponds to increased incomes and consequently being able to afford higher levels of energy access.
- Sustainable agricultural, sanitation, and effluent treatment systems (Goals 2 and 6) can provide biogas for cooking and power generation.
- Sustainable agriculture (Goal 2) and water management (Goal 6) are necessary to ensure the long-term sustainability of micro-hydro schemes.
- Good levels of rural education and skills development (Goal 4) including of women (Goal 5) provide the skills base necessary to

support the installation and operation of energy services and the use of energy in productive enterprises.

Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

- Energy access (with ICT) is a key enabler of growth in the rural economy (which is a major component in the overall economies of Least Developed Countries) through improving agricultural productivity and value addition, and through enabling the creation of productive enterprises, including innovations such as distributed manufacturing.

- Local electricity generation, and manufacture and distribution of clean cookstoves, generate jobs for rural communities.

- In respect of target 8.2, energy access with ICT is necessary for technology upgrading and supports opportunities for diversification.

- In respect of target 8.9, energy access with ICT enables the necessary connections with tourists and, with other elements of improved infrastructure in smart villages, the facilities needed to attract them.

Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation

- Energy services are a core component of rural infrastructure, necessary to support economic development and well-being. In respect of target 9.1, given that rural electricity access rates are much lower than urban, it is essential to focus on rural energy access in order to achieve equitable access for all.

- More generally, the smart villages concept provides for the establishment of sustainable and resilient rural infrastructure and (with regard to target 9.3) access to financial services for rural communities.

- In respect of target 9.2, the establishment of small-scale industries in villages enabled by energy access is a key element of the smart villages concept. Such rural industries play a key role in building the economies of Least Developed Countries.

- In respect of target 9.4, the focus on renewable energy sources and efficient energy use technologies in smart villages is necessary to achieve upgraded infrastructure which is sustainable.

Goal 10: Reduce inequality within and among countries

- As rural energy access rates are substantially lower than those of cities, a focus on sustainable rural energy access is essential to reduce inequality of opportunity between rural and urban communities.

- In respect of target 10.1, given that rural poverty rates are higher than those in cities, the focus on rural development envisaged in the smart villages concept is necessary to achieve higher rates of income growth of the bottom 40% of the population.

- In respect of target 10.2, the enhanced connectivity through energy access and ICT envisaged in smart villages is a necessary enabler of the social, economic and political inclusion of rural communities.

- In respect of target 10.7, the enhanced opportunities to lead healthy and prosperous lives in rural villages, central to the smart villages concept, will mitigate urban migration out of desperation, and provide for a more balanced choice between rural and urban living.

Goal 11: Make cities and human settlements inclusive, safe, resilient, and sustainable

- The interdependence of cities and villages implies that the sustainable development of rural communities as envisaged in the smart villages concept is essential to the sustainable development of cities.

- Energy access is a key enabler for villages to provide the goods and services needed by cities, not least processed agricultural products.

- The sustainable management of the countryside envisaged in the smart villages concept is a prerequisite to the provision of the ecosystem services essential to sustainable cities, including the sustainable management of water catchments to provide clean water and (in respect of target 11.5) to mitigate flooding risks.

- The reduction in urban migration, particularly of the poorest, consequent on the establishment of smart villages will ease the pressure on housing and services, currently the source of many of the most deleterious consequences of rapid urbanisation.

Goal 12: Ensure sustainable consumption and production patterns

- In respect of target 12.2, the deployment of clean and efficient cooking technologies in villages will reduce the pressure on forests and enable more sustainable use of biomass. More generally, the sustainable agricultural practices and environmental stewardship embodied in the smart villages concept will enable the sustainable management of natural resources.

- In respect of target 12.3, village level energy access will enable refrigeration and post-harvest processing which will substantially reduce post-harvest losses.

- In respect of target 12.8, the rural connectivity consequent upon energy access and ICT will enable villagers to have the relevant information and awareness for sustainable development and lifestyles.

Goal 13: Take urgent action to combat climate change and its impacts

- Given the central tenet of the SDGs of 'leave no one behind', and that over 1 billion (mainly rural) people do not have energy access, it is essential to provide rural communities with sustainable (i.e. 'climate friendly') energy services at levels which can support their social and economic development.

- Clean and efficient cooking technologies reduce emissions of CO_2 and black carbon (globally, 25% of black carbon emissions come from burning solid fuels for household energy needs).

- In respect of target 13.1, sustainable agricultural practices and management of local ecosystems in smart villages will help build resilience and adaptive capacity to climate-related hazards and natural disasters.

- In respect of target 13.3, enhanced connectivity and educational levels in smart villages will increase knowledge and awareness of climate adaptation/mitigation issues, and enable early warning systems for natural disasters.

Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

- Smart coastal villages, many of which are on islands, will manage local marine resources and ecosystems sustainably. Energy access will enable refrigeration of catches, reducing losses and hence the pressure to over-fish.

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss

- The environmental stewardship, sustainable agricultural practices, and sustainable management of local ecosystems services embodied in the smart villages concept will contribute to the sustainable use of terrestrial ecosystems.
- In respect of target 15.2, the deployment of clean and efficient improved cookstoves will reduce the pressure on forests.
- In respect of target 15.7 the improved village-level livelihood opportunities incumbent on smart development will reduce incentives for poaching of wildlife.

Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels

- The enhanced connectivity of rural communities consequent on energy access and ICT will enable better access of villagers to information (target 16.10), provide the mechanisms for, and the pressure to deliver, more accountable and transparent institutions (target 16.6), and enable villagers to be more informed and influential participants in governance processes (target 16.7).

Goal 17: Strengthen the means of implementation and revitalise the global partnership for sustainable development

SMART VILLAGES

New thinking for off-grid communities worldwide

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