



SMART VILLAGES
New thinking for off-grid communities worldwide



INTERNATIONAL CROPS RESEARCH
INSTITUTE FOR THE SEMI-ARID TROPICS

Energy and agriculture for smart villages in India

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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.

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1. SUMMARY

The concept of the “smart village”, as developed by the Smart Villages Initiative, is that modern energy access acts as a catalyst for development—education, health, food security, productive enterprise, environment, and participatory democracy—which in turn supports further improvements in energy access. In the global context, energy access can provide a much needed driver for sustainable economic growth and development for a major, but neglected, sector of the world’s population: the 1.1 billion people who do not have access to electricity. Most of those people are based in rural areas.

The smart villages concept explores how recent developments in the use of renewable energy—solar, wind, hydro, biomass, and hybrid combinations—offer attractive and sustainable opportunities for rural communities in India. The national grid may never reach some communities in off-grid villages for economic and geographical reasons so that these villages are often without a reliable supply of energy for lighting homes, charging mobile phones, or powering agriculture and its associated businesses. Such villages depend on kerosene for cooking, which is harmful to human health, and diesel for energy generation, which contributes to greenhouse gas emissions.

Local solutions in smart villages such as home-farm- or institution-based systems could kick-start productive enterprises through agricultural diversification strategies that influence multiple value chains such as milk, rice, and vegetables. Mini-grids have been developed for power distribution,

digital tools for education and communication, information for women and girls—who are empowered to pursue entrepreneurial activities, and climate-smart initiatives to target irrigation and selective seed and animal breeding. Outcomes of these local solutions would be agri-food systems designed for production, processing and value addition, enhanced market access, and economic independence leading to improvements in the quality of life of upcoming generations.

Lack of access to energy is a severe constraint on opportunities for gainful employment not only for the agriculture sector but also for the non-farm rural economy. Even in the case of villages that are linked to the national grid electricity, supply may be erratic with frequent power outages, and only a relatively small proportion of houses may be connected, for which smart villages using renewable energy could provide a supplementary energy supply.

Examples of success are most prominent where there are motivated champions, sustainable funding, involvement of farmers’ organisations, and public-private partnerships, including corporate social responsibility investments. Challenges that arise are not insoluble, including the need to raise awareness among multiple stakeholders about the potential of the smart village concept from the grass roots to all those responsible for planning, finance and governance; the lack of appropriate policies to incentivise and encourage long term investment; and the need for appropriate regulatory systems.

2. INTRODUCTION

Focusing on energy and agriculture, this Technical Report considers demands for increased agriculture productivity and how solar, wind, hydro, and biomass can be used as renewable energy sources to kick-start new agricultural initiatives for resource-poor and the most disadvantaged farmers in off-grid villages, and integrated into smart villages. A key feature is the need to develop productive enterprises that are income-generating. Successful examples of such opportunities and some of the barriers facing such enterprises are discussed.

Initial sections of the report discuss the global context and the current situation in respect of rural development in India. Subsequently, the issues around energy and agriculture in India

are examined together with the complementary impacts of information and communication technologies. Finally, the link between the use of renewable forms of energy and food production and its impact on climate change mitigation is examined in the context of reducing greenhouse gas emissions derived from agriculture.

The report is based largely on a review of the literature augmented by key findings from a workshop held at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India on 22-23 September 2016, which will be reported separately. Both the Technical Report and the Workshop Report are published on the website, www.E4SV.org.

3. INDIA IN THE GLOBAL CONTEXT

3.1 Agriculture and development

According to the OECD-FAO Agricultural Outlook for 2016-2025, the average GDP growth rates in developing countries such as India, Philippines, Bangladesh, Tanzania, and Mozambique (6–8% per annum) are expected to exceed those of industrialised economies (about 2% per annum) over this period¹.

In many developing countries, the agriculture sector generates around 30% of GDP (India 18%) and provides work for 65% of the workforce. Some 2.5 billion people worldwide live in households that depend primarily on an agri-based economy. The South and East Asia region is the world's largest producer of agricultural products, and in the period 2013-15 produced about 40 percent of world cereals and meat and almost 60% of vegetable oils, mostly palm. Increased agricultural productivity is therefore a primary driver for food security, income generation, and development in rural areas².

Estimates suggest that agricultural productivity must increase by 70% to feed the world population, which is expected to reach 9 billion people by 2050. Population growth in developing countries is the dominant driver of global food consumption and agricultural commodities. Demand per capita is also likely to increase in these countries as income growth rate is expected to be robust, and changing patterns of food consumption will contribute to increased per capita consumption. Global demand expansions will need to be satisfied by efficiency improvements with only small increases in the production base, accompanied by a steady growth of the livestock industry and fisheries¹.

India was a signatory to the agreements reached on the Sustainable Development Goals (SDGs) as well as the Paris Agreement at the UN Climate Change Conference, which commit all countries to invest in renewable energy, energy

use efficiency and energy access. Energy access covers both electricity and clean cooking, but there is an urgent need for decision-makers to focus on promoting productive uses of energy and not just household connections^{2,3}.

3.2 Energy and agricultural enterprises

Energy is crucial to sustainable development and poverty reduction, and the lack of electricity is a major constraint to economic growth and increased welfare. Globally, 1.1 billion people live “off the grid” in rural villages without any form of modern energy access or a reliable supply of energy for lighting, cooking, charging mobile phones, or powering businesses. The national grid may never reach many of these remote villages for geographical and economic reasons. Without significant improvements in energy access this figure will increase to 1.2 billion people by 2030³. Moreover, the effects of climate change and extreme weather events could have serious effects in countries where agriculture is the main income source for rural populations. The nexus of energy and food with water, a further constraint on agricultural productivity, presents a major development challenge for 21st century agriculture⁴.

One way of looking at energy for agriculture is through three distinct types of farm power: human energy for tilling, cultivating, and harvesting for holdings of 1-2 hectares (ha) per year; animal energy for ploughing, harvesting, and transportation: 3-4 ha; and technology that uses fossil fuels, renewable energy, and hybrids (fossil fuels and renewable energy): over 8 ha. Another way to look at energy for agriculture is to note that about 40% of energy usage worldwide can be traced back to food production, processing, transport, merchandising, and consumption. Direct energy is consumed for land preparation, irrigation, harvesting, production, processing, and commercialization of products. Irrigation systems

have the potential to reduce water and energy consumption at the same time and to increase yield. Indirect energy applied through the use of machinery, pesticides, and fertilizers can be reduced by precision farming assisted by satellite technologies, drones, advanced engineering, and on-farm computer-aided technologies. Improvements in the accuracy and timing of applications, and the use of biosensors for soil fertility monitoring, can significantly reduce fertilizer usage and thus decrease energy inputs. Investment in renewable energy combined with integrated food and energy systems (IFES) is also crucial whereby food and energy can both be produced in the same holding.

Some of these technologies and procedures are currently beyond the reach of off-grid villages. But the concept of smart villages for poor smallholder farmers, who are among the most disadvantaged, and the use of off-grid energy derived from renewable sources together with ICT have the potential to change this situation and become significant contributors to a much-needed second green revolution.

3.3. Energy services in practice

The magnitude of energy demand in different smallholdings and the prospect of creating energy services for productive enterprises are reflected in

the multi-tiered matrix described by Sustainable Energy for All⁵. Requirements for very low power (Tier 1, 3–12Wh) increase progressively through low power (Tier 2, 50–200Wh), medium power (Tier 3, 200–1000Wh), high power (Tier 4, 800Wh–3400Wh), to very high power (Tier 5, min 8200Wh). Agricultural activities range across all tiers from lighting in houses to heavy duty cultivation and processing. Lack of access at any of these tiers means that opportunity costs change dramatically and influence the decision-making process. They reduce enterprise and earning potential, affect educational attainment, result in ill health from smoke inhalation indoors arising from inadequate cooking facilities, and trap poor people in poverty.

Lessons learned from recent comparative studies in Africa (Mali and Kenya), Nepal, and Peru add to our understanding of energy services and their importance for income generation, productive enterprises³, and employment^{3,6}. For smart villages, energy services aim for a reliable supply, affordability of supply (which relates to what people are prepared to pay), and adequacy of supply (since the amount of energy required will vary according to the application and time of day). Opportunities for scale-up are also important if small to medium enterprises are to become financially viable and fulfil market opportunities.

4. RURAL DEVELOPMENT IN INDIA

A large majority of the population in India continues to be based in rural areas. In 2011, almost 830 million people were classified as living in rural areas, representing almost 69% of the total population. This population is based in more than 640,000 villages across the country. Today,

India ranks second in the world in farm output, and agriculture is still the main source of income for a substantial portion of the rural population (Figure 1). The sector also provides the primary input for a number of important agro-industries including textiles, sugar, vegetable oil, etc.

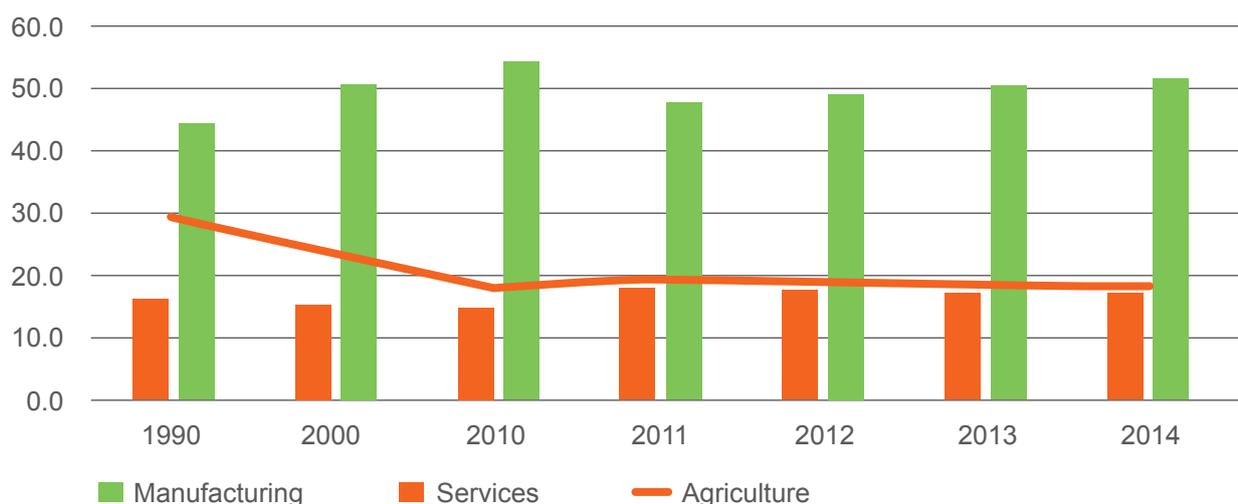


Figure 1: India's GDP composition in percentage terms 1990-2014⁷

The importance of agriculture as a source of local employment can be gauged from the fact that there are more than 138 million operational landholdings in the country. Over time, there has

been a consistent reduction in the average size of these landholdings from 1.23 ha (2005-06) to 1.15 ha (2010-11)⁸ (Table 1).

Landholding size	Percentage of operational landholdings	Percentage of operated area
Marginal and small: below 0.5 – 2.0 ha.	85.01	44.58
Semi-medium and medium: 2.0 ha. – 10.0 ha.	14.29	44.88
Large: 10.0 ha. and above	0.7	10.59

Table 1: Operational landholdings in India 2010-11⁹

Besides the large number of people working as farmers, more than 144 million people continue to be employed as agricultural labourers and over 56% of India's labour force continues to be employed in the agriculture sector. There has been a shift in the sector's composition with increasing importance of high-value sub-sectors like livestock, horticulture, fisheries and poultry. The government has also supported mechanisation, and there has been a rising trend towards using modern inputs such as improved seeds, fertilisers, pesticides, and mechanical implements, especially tractors, in production. Increased mechanisation has been accompanied by an increasing dependence on fossil fuels for transportation and irrigation purposes.

The growth in Indian agriculture has been moderate in the past decade (nearly 3% per annum) and overall India has shifted from being a food importer to a net food exporter. As Jha et al. reflect¹⁰, "There have been some structural

shifts in terms of composition of output with increasing trends towards commercialization and diversification of agriculture. Livestock, horticulture, fisheries, and poultry sectors are growing rapidly. On the input side, there is increasing inclination towards the use of modern inputs and farm mechanization which require a significant change in the energy-use pattern in the Indian agriculture. Between 1970 and 2005, the share of animal power in agricultural operations fell from 44% to just 6% and that of manual power from 37% to 8%. Much of this has been substituted with fossil fuels and though tractors consume a lot of energy, they are emerging as a significant means of delivering power for farm operations as well as for transportation and running irrigation pumps". These trends are expected to continue affecting the development of more than 600,000 villages in India where nearly 70% of the population lives, many of whom have slender access to fossil energy and few resources to buy it.

5. ACCESS TO ENERGY IN RURAL AREAS IN INDIA: A LOOK AT THE EVIDENCE

As we have seen already, energy can act as a catalyst for broad-based rural development and can enable access to basic services like education, healthcare, clean water, and sanitation. It can also contribute to improved security, gender equality, and democratic engagement in these rural areas. Power capacity in India in 2015 was about 280,000 MW of which about 80,000 MW was generated from renewable sources (hydro—45,000; wind—25,000; solar—5,000; and solid biomass—5,000 MW). Lack of access to energy is a severe restraint for opportunities for gainful employment both in the agriculture sector as well as in the non-farm rural economy. In absolute numbers it is estimated that at least 240 million people are without access to electricity of which more than 90% are based in rural areas¹¹.

Most rural electrification programmes implemented by the government have focused on village level electrification targets as opposed to household targets (annex 1). A village is deemed to be electrified if it meets the following criteria:

- Basic infrastructure like distribution transformer and lines are provided in the inhabited locality.
- Electricity is provided to public places like schools, panchayat office, health centres, dispensaries, community centres, etc.
- The number of households electrified should be at least 10 percent of the total number of households in the village.

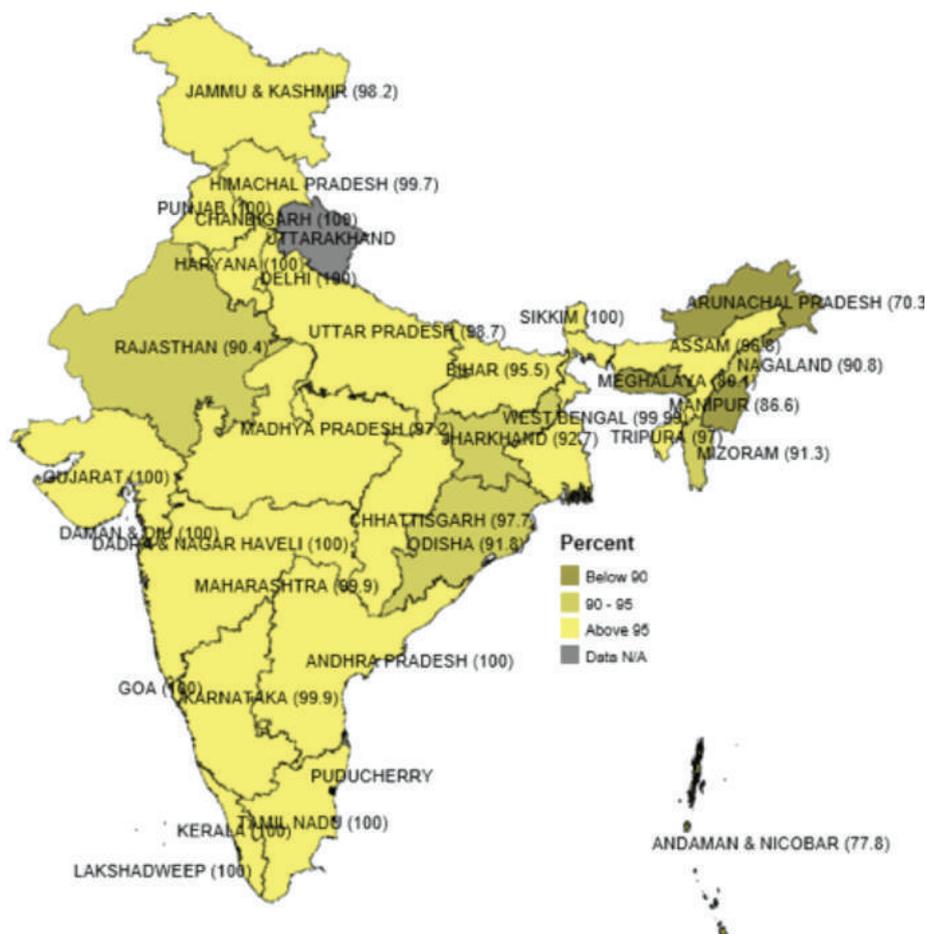


Figure 2. Status of village electrification in India (February 2015)¹²

According to the Open Government Data Platform of India, it is claimed that 96.7% of villages are electrified (Figure 2¹²). However, electricity supply remains erratic, there are frequent power outages, and often a relatively small proportion of houses are connected. Around two-thirds of those without access to electricity are located in the states of Uttar Pradesh and Bihar. As a result of these shortfalls in energy supply, rural consumers spend almost US\$2.5 billion per annum on kerosene, while almost 840 million people in India use solid biomass to meet their cooking and heating requirements in traditional cookstoves¹³. Household indoor pollution due to the continued use of such cookstoves contributes to a high

number of premature deaths and environmental degradation through the loss of biodiversity and deforestation. The demand for bioenergy in the form of solid biomass comprising firewood, dung, straw, or charcoal increased in absolute terms in the period 2000-2014; however, the overall share in the primary energy mix declined quite substantially. It is very unlikely, however, that biomass use will be displaced entirely. To reduce the impact on household air pollution and the negative impact on the environment, promoting the use and dissemination of improved cookstoves as envisaged with the government's National Biomass Cookstove Initiative launched in 2009 could provide a way forward¹³.

6. ENERGY DEMAND IN RURAL AREAS AND IMPACT ON PRODUCTIVITY

Rural development has long been an important goal for policymakers in India, and it has been widely understood that sustainable development can be achieved by promoting productive enterprises in villages. In the 1960s and '70s, policymakers in the country began to focus on rural electrification for improving productive uses in villages. Providing access to electricity for households was a secondary goal^{14,15}, and policymakers aimed to promote the use of groundwater irrigation along with other green revolution technologies to increase food supply and rural income. It was in the '80s and '90s that the emphasis shifted to household electrification in rural areas (annex 1).

In the agriculture sector, direct demand for electricity is likely to continue to be driven by irrigation. Nationally, there are around 18 million irrigation pumps operating in the country that are connected to the national grid. In villages where there is no or limited access to electricity, a further 7 million irrigation pumps are diesel based. Tractors are also used to power irrigation pumps, which require diesel fuel to run. This dependence on fossil fuels has a negative impact on the environment as well as the balance of trade. There is also a demand for energy from the non-farm rural economy, which includes all economic activities that do not fall under the purview of primary agricultural commodity production. The non-farm economy includes: mining, agro-based manufacturing, utilities, construction, commerce, transport, and the entire range of financial, personal, and government services. Within the rural non-farm economy, agro-processing activities are extremely important. Demand for energy depends on the activity

and the scale. Renewable energy sources can make an important contribution for household, cottage, smallholder farm (threshing), small-scale commercial operations (crop drying, hulling) or large-scale agro-processing activities¹⁵.

In grid-connected villages where electricity has been provided over the last decade, reliability of electricity supply remains a major problem facing the local economy. This is especially true in the case of populous states like Uttar Pradesh and Bihar where the majority of those without access to electricity reside^{14,16}. In these states (as in many others), where villages have been connected to the national grid, the reliability of supply remains poor and the minimum goal set by the government of providing six hours of electricity per day through the grid has not been met¹⁵. A World Bank report¹⁴ states that only 7% of rural consumers connected to the national grid experienced no outages. In rural Bihar, the reliability of electricity supply, especially during peak hours, is extremely poor; for example, a study looking at one distribution line showed that electricity was available for only 30% of the time during peak evening hours (6pm to 8 pm)¹⁶.

Ensuring sustainable growth in the farm and non-farm rural economy is energy-dependent, but the preferred solutions can be complex and region-specific. Among the options that need to be weighed will be to rethink whether the traditional grid extension paradigm is cost-effective, whether off-grid provision is a better option if village-level generation can complement the national grid, and whether building more large-scale power stations to power the grid is the answer.

7. ANCHOR LOADS AND THE PRIVATE SECTOR

The emphasis on ensuring productive use of energy in rural areas is extremely important, and developing smart villages in India will require deploying off-grid and mini-grid systems that generate electricity utilising a number of different renewable energy technologies. Providing access to electricity is not enough to ensure sustainable rural development and energy access has to be linked to increasing opportunities for productive use of energy¹⁷. This realisation has led to the emergence of business models, especially in decentralised mini-grid projects, that seek to improve financial sustainability by linking with anchor loads in rural areas. Anchor loads are usually commercial consumers in an area around which the system can be developed and demand predicted. This means that anchor loads are the primary consumer and additional capacity can then be used to meet local consumer demand and provide electricity to the poorest members of society. Examples of such anchor loads in rural areas include mobile phone towers, ATMs, petrol pumps, and other local businesses.

Using anchor loads as a stable source of revenue is increasingly being seen as a best practise by many mini-grid operators in rural areas, some of which apply in an agricultural context¹⁸. Anchor clients are likely to sign long-term power purchase agreements at competitive rates and can help mini-grid enterprises achieve stable revenues. Stable revenues from an anchor load can help stimulate demand for electricity from other local businesses such as agribusinesses. An anchor load-based model could therefore provide a boost to local development, help reduce electricity costs, and improve financial sustainability by providing a stable source of revenue for mini-grid operators.

The Climate Group¹⁹ highlights around 40 mini-grid enterprises operating in India which are using a variety of technologies and have installed capacities to serve up to 1,000 to 2,000 households. Solar seems to be the preferred technology followed by biomass and hydro based generation. Only a few enterprises use wind or solar-wind hybrid technologies. Solar mini-grids typically

Box 1: Solar mini-grids and innovative business models in India²⁰

OMC Power is pioneering an anchor load-based business model in rural areas of northern India. The mini-grid provides electricity to a local anchor load that requires access to reliable power throughout the day. OMC then uses the remaining energy to provide electricity to households and businesses in the surrounding areas. Besides solar, the company is also using other renewable technologies like wind and biogas. For rural consumers, OMC supplies electricity either through wired connection to the mini-grid, or through pre-charged products like solar lanterns, etc. on a daily basis. This business model is referred to as the anchors-businesses-community (ABC) model. OMC has also pioneered the development of a “business in a box” solution through which village-level entrepreneurs are emerging as partners in the electrification process. In other mini-grid based innovations, there are moves to introduce high efficiency electric irrigation pumps coupled to a transformer which is linked to a solar PV plant. The idea is that each transformer could be connected to a PV plant ranging from 25 kWp to 500 kWp in a community, public and private ownership. The PV plant will feed power to the cluster of pumps. In case surplus power is available, the PV plant will feed back power to the grid. Irrigation pumps could act as reliable anchor loads in the case of off-grid mini-grids.

have a capacity of less than 10 kW and have generally been subsidised under government rural electrification projects.

The availability of sufficiently high quantities of biomass in rural areas of India means that, apart from solar powered mini-grids, biomass-based power plants could be used to provide electricity to local communities through mini-grids. Husk Power Systems (HPS) and Decentralised Energy Systems India (DESI) Power are two companies that have been working on developing these systems. Both began their operations by installing plants that utilise rice husks as the basic fuel and have now diversified their fuel sources to other biomass sources including wheat husks, elephant grass, mustard stems, corn cobs, etc. HPS began operations in 2007 and since then has provided electricity to almost 200,000 people in 300 villages through 80 biomass-based gasification power plants in the state of Bihar. The company has also developed a business model where power generation has been integrated with rice milling to ensure availability of rice husk. This model

also allows the rice mill to serve as the anchor load and ensures better load utilisation, which reduces the average cost of electricity supply. A typical plant of HPS supplies electricity to almost 300–400 households in a cluster of between 2–4 villages in a radius of 1.5 km^{21,22}.

In Bihar, DESI Power, a private power company, has been installing biomass gasifier-powered micro-grids in rural communities (Box 2). Its business model is based on attaining stable revenues by establishing contracts with anchor loads in areas where they operate. DESI Power has established and operated 15 mini-grid projects¹⁹. These mini-grids supply electricity to anchor loads, usually a mobile phone tower and micro-agro based enterprises, and to households. DESI is a not-for profit company that works with the local communities to develop partnerships for service delivery in rural areas. The company integrated the core goals of providing electricity for rural areas using renewable sources and achieving rural development by promoting rural enterprises²² and established its first biomass gasification system

Box 2: A holistic model for rural development, DESI Power in Baharbai Village²²

In 2001, DESI Power established a biomass-based power plant in Baharbari Village in the district of Araria in Bihar. The company helped establish a cooperative in the village that currently has 19 members and owns water pumps and paddy mills. DESI Power also worked with the Indian Institute of Science, Bangalore to help train 3–4 local people who could operate the gasifier plant. The project has played an important role in empowering local women as DESI Power employs them to operate their grids. In 2007 and 2008, the company also expanded its presence in two other villages in the district. To manage feedstock, DESI Power has also created a feedstock calendar, which is shared with the community. An evaluation of the project shows that almost 70% of the total revenues of operations are reinvested in the villages in the form of salaries and payment for feedstock. Productivity of agriculture has also increased because of availability of low cost irrigation. Villagers used to sell paddy at low price, however, now they sell hulled rice as there is an electric-powered rice huller in the village. Commercial activity has also witnessed an increase in the village and almost 25 shops have also been established in the area, ranging from an agricultural input supplier to shops that provide daily groceries and computer parts. The DESI Power model in Baharbai evolved from providing electricity initially for productive uses before moving to household-level electrification.

for electricity supply to rural areas in 1996 in Madhya Pradesh.

Despite the success of many of these models, successful scale-up of anchor load-based mini-grid models require appropriate policies and associated regulations to spur rural development²³. Policies and regulations governing mini-grids have to vary to be compatible with the operating model in different parts of the country. Examples of different operating models include:

- Mini-grids with local generation in areas where the national grid is absent and the private mini-grid operator installs the distribution network
- Mini-grids where the national grid is already present and mini-grid operators have their own generation facilities but use the electricity distribution infrastructure that has already been put in place by the government.

The availability and eligibility of mini-grid operators for national government-supported or state-level subsidies²⁴ in both these operating models is likely to vary.

The anchor load based model is still in its nascent stages of development, and one challenge that is facing mini-grid enterprises is ensuring reliability of supply to the anchor, especially mobile phone towers during peak hours of consumption. On the other hand, effective demand management during off-peak hours is also extremely important to improve load utilisation. Access to finance is another major challenge facing mini-grid enterprises, especially those that aim to take a cluster approach and serve multiple off-grid villages. While the Indian government has provided substantial funding to states in the past for grid extension, subsidised capital targeted at private companies that have demonstrated proof of concept can help them expand their presence in rural areas. Using anchor loads to develop a long-term revenue stream can also help these firms access private capital and contribute to their expansion helping them achieve scale.

8. CAN RENEWABLE ENERGY HELP TO KICK-START PRODUCTIVE ENTERPRISES IN SMART VILLAGES?

Renewable sources of energy in India are substantial as we have seen in Section 4. They can be used to promote the development of productive agribusinesses that lead to income generation, but it is important to examine how they can be integrated into systems of food supply and demand and into bioenergy production in ways that are efficient and sustainable.

8.1. From services to income-generation.

The traditional grid extension model in India has limitations of reliability for the multitude of smallholders and landless labourers based in rural

areas. There is a need to better understand the market opportunities that smart villages bring for people currently living off-grid in order to predict future trends. What do people truly value? What local enterprises and powered equipment will be of the most utility to a community? Can smart villages enable progress along the pathway of the energy escalator so that services as shown in Table 2 evolve into income-generating productive enterprises by adding value to agricultural products especially through value addition (Annex 1 and Table 3).

Technology	Generation capacity (kW)	Energy sources	Services available	Estimated economic cost
Pico-power systems	0.001 – 0.01	Hydro, wind, solar	Lighting, radio communication reception, two-way mobile communication	US\$10-100
Stand-alone home systems	0.01 – 1	Hydro, wind, solar	Same as above plus additional lighting and communication, television, fans, limited motive and heat power	US\$75 – 1,000
Mini-grids	1 – 1000	Hydro, wind, solar, biomass, diesel, hybrid combinations	Same as above plus enhanced motive and heat power, and ability to power community-based services	Medium-large capital cost, low marginal cost to end-user
Regional grid connection	1000 – 1000000	Gas, hydro, wind, solar PV, biomass	Assuming high quality of connection, same as above up to a full range of electric power appliances, commercial and industrial applications	Medium-large capital cost, low marginal cost to end-user

Table 2: Smart villages and the energy escalator²⁵

Globally, renewable electricity generation is gradually increasing, and in 2015, it showed an increase of around 23% of the overall generation. The fraction of land needed to displace global fossil fuel use with renewable like solar and wind energy is not great and would be equivalent to around 1.5% of the land area currently used for agriculture. Furthermore, large scale solar systems could be typically located in deserts or arid lands, while wind energy systems generally permit the continuance of agricultural systems beneath them or may be located off-shore. Nonetheless, in order for renewable energy and electricity to capture more value from agriculture significant transformations and adaptations will be required to achieve a sustainable system^{26,27,28,29,30,31}. Table 3 highlights some of the options available for different value chain operations²⁴. The International Energy Agency (IEA) emphasises that a mixture of grid extensions and off-grid solutions like mini-grids and stand-alone systems will need to be deployed if we are to meet universal electricity access targets described in the Sustainable Development Goals.

For productive enterprises in smart villages, distributed generation and transmission systems are especially important where they are economically more viable than costly grid extensions. In locations in India where renewable energy resources can be expanded, farmers, fishermen, and food processing businesses have opportunities to kick-start productive enterprises using energy sources such as biomass, solar and wind power, and hydropower, as well as adopting the use of batteries to facilitate energy storage. These sources can help develop agro-businesses

through improved solar energy-based irrigation systems, reduced harvest losses, post-harvesting processing, and best agricultural practices. Where heating and cooling systems can be provided, farmers have the opportunity to gain added-value from agricultural products through food preparation, processing, extraction, refining, and preserving³² (Annex 2).

In rural areas of sub-Saharan African countries (Mali and Kenya), Nepal, and Peru³, studies of micro- and small-scale rural enterprises (MSEs) such as shops, grain mills, and small bakeries also show how energy services can add value to agricultural products. They can be cooked and heated, as in the case of withering tea leaves and roasting coffee, or they can be stored and transported after chilling and freezing, preserved by air and sun drying, and manufactured or converted into higher-quality added-value products such as flour, expelled nut oil and fibre extraction. Energy services also enable the powering of ICTs for communication, entertainment (television, radio, and hi-fi), and support kiosks that provide charging and ICT-related services. Women in MSEs gain from energy services that support food processing, which is heat intensive, and indoor work, which is light intensive. In addition, women tasked with energy-sourcing such as wood fuel for cooking and heating gained from better fuels which had an immediate effect on their health, productivity and income-generation.

Diesel and electric pumps have been promoted since the 1960s as part of India's aggressive

Value chain, enterprise	Type of energy	Energy demand	Application	Costs
MILK				
Harvesting	Motors on vacuum and milk pumps	Moderate	Farm	Labour and plant
Cooling	Pre-cooling of milk; heat exchanger for hot water.	Moderate	Farm	Labour and plant
	Spraying cold water on churn	Nil	Farm	Labour
Processing	Pasteurisation; motors and fans	Moderate	Factory	Labour and plant
Drying	Dryers	High for drying milk powder	Factory	High
RICE				
Production	Manual	Nil	Small-scale farm	Labour
	Tractor	Moderate	Farm	Biodiesel
	Irrigation	Low-moderate	Small-scale farm	Biodiesel
			Nil	Small-scale farm
Processing	Dryers	Moderate	Farm	Moderate
	Parboiling	Moderate	Farm	Low
	Milling	Moderate; surplus power sold to grid	Mill	Moderate
VEGETABLES				
Production	Irrigation	Low-moderate	Farm	Biodiesel
	Greenhouses - hydroponic	Low	Farm	Labour
	Greenhouses - heated	Low	Farm	Labour
Processing	Hydrothermal	Low	Farm	Labour
	By-products reuse	Low	Farm	Low
	Cooling/refrigeration/freezing	Moderate	Farm	Moderate
	Heat for drying	Moderate	Farm	Moderate

Table 3: Exemplars of income-generating production and processing activities for smart villages³⁰

Categories	Commodities/Technologies	Energy Sources
Low tech (<5 kWh/day)	Field packing of leafy, stem, or fruit vegetables, root, tuber and bulb crops, fruits and berries	Electric grid; solar power with battery back-up
Basic tech (5 to 25kWh/day)	Packinghouse operations and pre-cooling for tropical and subtropical fruits and vegetables; evaporative cool storage (temperature range 15°C to 20°C)	Solar water heater, electric grid; generator(diesel or gas); hybrid PV/ generator systems with battery back-up
Intermediate tech (25 to 100 kWh/day)	Cooling and cold storage for temperate fruits and vegetables (temperature range 0°C to 7°C)	Electric grid; generator (diesel or gas)
Modern tech (> 100 kWh/day)	Automated packinghouse operations, pre-cooling and cold storage for any kind of fruits and vegetables (temperature range down to 0°C)	Electric grid; generator

Table 4. Energy requirements for packing and preservation of fruits and vegetables³³

agricultural development programme to increase crop yields (the “green revolution”), and several states have experimented with alternative irrigation methods. The aim was to reform the subsidy structure that farmers have relied on for decades and ease the adjustment costs. In addition, there has been a successful uptake of stand-alone energy technologies such as treadle-pumps and two-wheel tractors. Nonetheless, the utilisation of renewable energy technologies and equipment targeted at smallholder farming and small-scale processing (Tables 3 and 4) has often been challenging largely because of the difficulty of achieving commercial success on a significantly large scale³⁴. For higher-energy categories, research and development are in progress to address how mini-grid distribution and advanced renewable energy technologies can lead to sustainable productive enterprises.

8.2. Integrated food and renewable energy systems (IFES). Energy, food, and water have frequently been investigated in isolation but they are no longer viewed as separate pillars of development, rather as a nexus. Integrated food-energy systems (IFES)^{35,36} can produce food and renewable energy in villages on the same parcel

of land where they will use multiple cropping or agro-forestry systems, linked with livestock and fish production. IFES can contribute to on-farm synergies by using by-products such as crop residues, animal wastes and food waste to generate bioenergy. Hence, the installation of simple anaerobic digesters for biogas production in smallholder crop-livestock systems is found throughout the world.

IFES envisage the division of labour and financial arrangements between farmers and energy operators. Smallholder farmers take responsibility for what they do best, which is farming, and energy producers provide a return. For example, a farm in China buys pigs from the district pig farm, gets its yearly dividends from sales of pigs, and sells the manure to the energy producers for biogas production. In Bangladesh, women receive a loan from an organic tea farm to purchase a cow and a calf; the women repay the loan from the sale of milk and dung back to the organic tea farm. In another scheme, households receive loans from the organic tea farm to pay for setting up a biogas system. They repay the loan by selling cattle dung and/or the slurry to the tea farm. Once the biogas installation has been completely paid for,

the households have the option to continue selling the slurry and dung to the tea farm³⁷.

This integration of food crops, livestock, fish, and bioenergy can lead to agro-industrial technologies such as gasification or anaerobic digestion, which allow maximum utilization of crops, livestock and their by-products and make use of freely available biomass. Yet despite all these benefits, the uptake of biogas technology has been relatively slow because of the cost barrier for the initial investment and the often poor institutional support in terms of information, capacity-building and technical support. These are significant constraints that need to be overcome³² as in China where “the government supports local biogas service stations that sell and implement biogas digesters and end-use appliances and offer technical support and maintenance services, for which they charge small fees. The government makes sure that shop-owners are regularly trained and updated, and it evaluates their quality of work”³⁸.

IFES based on agro-ecological farming practices can contribute to climate-smart agriculture and food security, and lend themselves to scale up, a key objective of smart villages, as neighbouring farms and villages with access to renewable energy can invest in mini-grids to support rural development. However, specific case studies are scarce and the idea of integrating different farming practices has not gained wide appeal: the more crops and procedures that have to be managed, the greater the losses of economies of scale, and for which farmers require a greater range of management skills³⁸.

Looking ahead, the agricultural engineering company, New Holland, in its concept of the “Energy Independent Farm” sees renewable electricity being generated on-site to produce hydrogen fuel for tractors and trucks³⁹. Similarly, the “Integrated Energy Farm” is conceived as a central business and living area surrounded by land producing food, biomass, and other renewable energy sources⁴⁰.

8.3. Bioenergy Biomass is the world’s fourth largest energy resource for heat, burning and cooking. Bioethanol and biodiesel currently provide about 3% of the world’s transportation fuels which, in some projections, could increase to about 30% by 2050. Biogas, a mixture of methane and carbon dioxide, is produced by anaerobic digestion of organic waste as the feedstock including manure, landfill organics, or dried and ensiled grass⁴⁰. Concerns exist about the impact of bioenergy on greenhouse gas emissions⁴¹, which are discussed in Section 12.

The use of biomass for energy can range from woody cellulosic biomass (grasses, trees, wastes) for combustion to produce heat and electricity; sugar rich crops (sugar cane, sugar beet) for fermentation to produce ethanol; oil seeds (rape seed, soy, sunflower, palm oil) for pressing and biodiesel production; sorghum and cassava for ethanol production; to jatropha, peanuts and palm oil for biodiesel. Biomass also originates from the food supply chain such as animal wastes, crop and forest residues, by-products of food processing; and wastes from retailers, households, and restaurants. It can be used on-site to provide direct energy inputs; processed into energy carriers for sale elsewhere; sold for community heating or anaerobic digestion at combined heat and power plants; and sold in greater volumes to supply larger commercial liquid biofuel production plants.

India’s renewable energy sector, amongst the world’s most active in renewable energy utilization, is rich in biomass with a potential of about 17,000 MW from surplus agro-residues and a further 5,000 MW if the sugar mills switched over to modern techniques of co-generation⁴². Two-thirds of households use biomass and charcoal for cooking purposes, and Figure 3 illustrates the energy flows through a low-input small-scale farming enterprise.

There are several concerns about the use of biomass for biofuels, particularly at scale. They include the un-regulated production of biofuels

that threatens food security and damage to the environment; full life cycle analyses are needed to inform the work of policymakers. These concerns extend to land being used for non-food use crops with farmland being taken out of food production. They lead to indirect land use change (iLUC) whereby land outside a feedstock's production area is needed to replace the supply of the original commodity, and to rebound effects where the replacement of fossil fuels reduces demand, induces a lower price leading to higher

fuel consumption, and increases greenhouse gas emissions. There is also concern that by linking carbon to bioenergy production, the carbon will not be returned to the soil contributing to soil nutrient depletion^{43,44}. Therefore, for smart villages, the benefits of productive enterprises using second generation biofuels from agricultural residues and by-products or from purposely-grown energy plantations, need to flow to the village rather than a distant corporation.

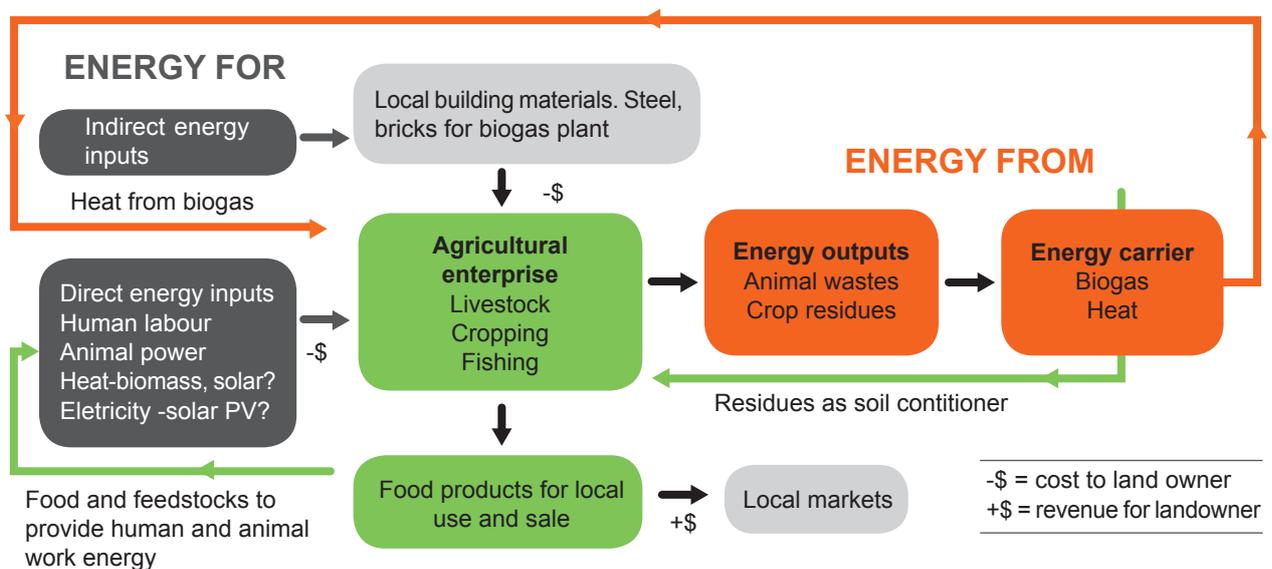


Figure 3. Example of a small-scale, low-input, family-managed, farming enterprise showing energy flows through the system. Outputs are primarily fresh food for local consumption, although they may also be delivered to local processing companies. Along with human and animal power, some direct energy inputs can be obtained from other sources, such as solar thermal and solar PV systems and biogas produced using a simple anaerobic digester²⁹.

8.4. Jugaad Introducing renewable energy into off-grid villages is only the first step towards converting the energy into productive use, whether electricity or heat. A familiar concept in India is that of *jugaad*: a low-cost solution based on the principle that use is the key factor determining the worth of a technological creation, discovery, or invention. Many examples of *jugaad* exist as in user-led innovations in the mechanical field where reduced research and development costs result in a frugal solution. An example in the agricultural

context is the “missed call” strategy by which a farmer rings once and hang-ups thereby signalling to a device (such as a SIM-fitted irrigation pump) the need to communicate. The device responds by sending an SMS to the farmer’s mobile phone stating whether the power supply is working or not. If it is not working, then a second “missed call” will turn on the power supply. This low-tech device has the potential to greatly improve the life of farmers by saving time, irrigation water, and money^{45,46}.

9. SUCCESSES IN, AND BARRIERS TO, THE DEVELOPMENT OF PRODUCTIVE ENTERPRISES

There is a long history of promoting small-scale industries (SSI) in India. Developing and protecting small-scale industries has formed an important part of the industrialisation policy followed by successive governments. Policymakers believed that these industries could play a pivotal role in helping absorb surplus labour, especially in rural areas and those areas classified as “backward”. The Industrial Policy Resolution (1948) highlighted the role of the small-scale sector in promoting better utilisation of indigenous human and physical resources. Promoting SSIs could also help achieve local self-sufficiency in the production of certain consumer goods. During the period after independence, cottage and village industries formed the bulk of the small-scale sector. Despite changes in certain policies, public sector support remains vital for rural development as more than 14 million non-rural people were employed in enterprises classified as “village” and “khadi” enterprises by the government in 2014-15 (Annex 1).

The success of productive enterprises in smart villages will be influenced not only by the development of mini-grids (see Box 1) but also by the green energy culture that introduces distributed solar systems for lighting such as solar lanterns, home lighting and street lighting equipment, and solar water heating and steam systems. But while energy access has the potential to stimulate productive enterprises in rural communities, tariff structures for local energy production and importing policies for goods and components will need to be designed such that local manufacturing using energy is not unfairly discouraged. Success, therefore, will depend not just on technology but on removing barriers to uptake by the adoption of rigorous business plans, bank support, a climate conducive to investment, and policies for regulatory incentives that waive some of the tax and testing charges (Annexes 3 and 4).

For small-scale farmers increasing productivity by energy-smart technologies is a key step (Annex 3). Successes referred to previously include solar irrigation⁴⁷ and the adoption of climate-smart crop varieties for improved crop and livestock quality. The caveat is that the solar equipment must be subject to a rigorous process of servicing and maintenance, the lack of which is a common source of setback in the use of renewable energy technologies. Solar drying, threshing, sorting, grading, and minimal packing are initiatives that do not require high investment and provide increased price returns and youth employment. ICT successes include access to information about best practices, weather forecasts, market prices, environmental benefits, and connection to buyers as well as access to sources of credit which will reduce travel time, costs, losses, and fraud. ICT also help with local language training and the provision of advice about sustainable self-financing business models⁴⁸ (Annex 4).

Lessons from studies in sub-Saharan Africa (Kenya and Togo) and Bangladesh³ confirm the value of rural electrification decentralised options. Stand-alone or mini-grid systems were found to be cost competitive: they provided more reliable power, and they could be deployed much more swiftly, whereas traditional grid electrification was unreliable, time-consuming, and required greater upfront capital expenditure. Energy for agricultural production including irrigation and non-domestic loads such as water pumps and rock crushers were among the top three priorities in half of the communities studied. However, these studies discovered that national plans were often out of touch with end-user needs and aspirations (not least in gender issues) relating to pumps, cooking and cooling of crop produce, and lighting. This disturbing disconnect between policymakers, decision takers and smallholder farmers prompted Practical Action to recommend that an energy literacy programme is fundamental for ministries

if they are to be equipped with knowledge of the new technologies and business opportunities available for productive enterprises and clean cooking with its impact on health and incomes at the local level³.

Other barriers to success include the practicable scale of some post-harvest processes such as canning, juice preparation, and paste production,

and the physical access to markets limited by transport infrastructure and distance of travel. The heavy reliance on water resources cannot be overlooked as it will always be a major limiting factor depending on the technology applied (Table 5). India has just 4% of the world's freshwater resources, but 17% of the world's population and agriculture is responsible for 90% of water withdrawals nationally.

Irrigation Method	Irrigated Area	Water Requirements	Energy Requirements	Capital Cost	Operating Cost
Manual	<0.5 ha	Low to High	Low (manual only)	Low	Low to Medium
Surface / Gravity fed	Unlimited	High	Low (manual only)	Medium	Low
Sprinkler	Unlimited	Medium	High	High	High
Drip / Micro-irrigation	Unlimited	Low	Medium	High	Medium

Table 5: Energy requirements for various irrigation method³³

Other challenges to the development of productive enterprises in smart villages relate to co-operatives and agricultural businesses, which demand improved efficiencies and communication in rural supply chains. Agri-businesses that focus on the quality and sustainability of agricultural produce require mobile field auditing, testing, and receipting to overcome opportunities for loss, fraud, and theft. Gaining access to finance

and auditing is essential as only one quarter of women of working age have a bank account, which leaves many reliant on the informal lending sector and subject to very high interest rates. Scalable and replicable enterprise models improve productivity and are favoured by administrations as they reduce the costs of running agricultural extension services.

10. INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IN AGRICULTURE

Information and communication technologies have emerged as important contributors to economic growth and development because they provide sources of information on markets and agricultural best practices. In smart villages, ICT can act as a mode of remote communication between researchers, extension agents and farmers⁴⁹. These tools can help to deal with some of the weaknesses of traditional agricultural services and redirect the attention of extension service providers towards the needs of small resource-poor farmers and help them achieve better productivity. ICT, like mobile phones, can reduce the information asymmetries faced by small and marginal farmers and help to engage them in high-value agricultural chains (Box 3).

One company that is leveraging ICT to reach underserved smallholders in rural areas is Digital Green (www.digitalgreen.org). The company has coupled easily available video recording equipment with small-sized projectors to disseminate agricultural best practices. Digital Green has reached 68,000 farmers and produced

more than 2000 videos. Trained community members record videos of the experiences of other farmers and extension staff. The recorded content is uploaded on micro SD cards and distributed to villages participating in the programme⁵⁰. The availability of distributed energy solutions like solar PV lanterns and solar home systems (SHS) that have built-in mobile charging facilities can help facilitate access to information for farmers. It provides the chance for farmers at the bottom of the pyramid to use mobile phone technology to improve their livelihoods and improve their resilience (Box 3).

Access to weather forecasting information is becoming extremely important for agriculture-based economies like India's, especially at a time when the traditional weather patterns are changing due to the impact of climate change. Not only is there an impact on weather patterns, increasing temperatures can also have a negative impact on yields and soil quality and can affect the growing seasons. It is likely that the negative effects of climate change will have a larger impact

Box 3: The impact of mobile phones on farmer behaviour⁴⁹

Results of a large-scale farmer survey in Bihar showed that 20% of those surveyed used their cell phones for accessing economic and agricultural information on a wide range of issues such as agriculture, employment, trading, and credit. The same survey also showed that using mobile phones, farmers in the state were able to achieve better yields and a higher price from the market. In Punjab, mobile telephony has helped farmers gain better information about technological innovations such as high-yielding varieties. They have also been able to gain better information about potential pest attacks and the pesticides required to counter these attacks. In a more institutionalised approach, the Centre for Agriculture and Bioscience International (CABI) with support from the Coffee Board of India, the International Coffee Organisation and Common Fund for Commodities, rolled out a mobile extension service aimed at an estimated 150,000 coffee farmers in the south of India. The service includes a section on frequently asked questions (FAQs), a private discussion thread between farmers and experts, and market as well as weather information over voice feeds.

on small and marginal farmers based in rural areas who do not have access to energy. These farmers are already severely disadvantaged as they cannot access knowledge and potential mitigating strategies to adapt their production systems to the changing environment. The lack of access to energy means that they also have limited access to technologies and cannot access credit facilities.

Moves to develop services that provide predictive weather analytic services to clients have been employed in some parts of India to help small and marginal smallholders deal with the challenges of climate change (Box 4). One such project is the e-Arik (e-Agriculture), which was initiated in 2007 in areas inhabited by the *Ari* people of

northeast India. More than half the households in the area did not have access to electricity. The e-Arik project aimed to implement and popularise climate smart agriculture practises, which implied lowering inputs and using organic technologies as a means of increasing productivity and improving food security. A Village Knowledge Centre was established at the Yagrung Village with a computer, internet connection, and other modern communication tools. While farmers could directly access a dedicated internet portal to access information, most preferred working through intermediaries who acted as facilitators to access ICT-based information and helped them engage remotely with agricultural experts⁵¹.

Box 4: Combining mobile and tablet technology for real-time information sharing⁵²

The International Crops Research Institute for the Semi-Arid Tropics launched a customised low-cost mobile phone and a tablet called “GreenPHABLET powered by the GreenSIM”. It allows for real-time information sharing between farmers and researchers and helps them improve crop productivity. For researchers, it presents the chance to collect accurate and real-time field data. The GreenPhablet also allows for information to be delivered precisely to smallholders as per their individual requirement. It also helps them with information regarding inputs prices and helps them achieve better returns in the market. Similarly, Reuters Mobile Light (RML), a mobile information service firm, has helped farmers in rural India access agricultural advice, local weather forecasts, and market price updates. RML has a network of 300 agricultural experts as well as content developers who are responsible for providing real time and personalised information to farmers. Information on prices from 1,300 markets is available to farmers, covering 450 crop varieties.

11. CAN ENERGY ACCESS AND ICT EMPOWER WOMEN AND GIRLS IN SMART VILLAGES?

Agriculture is increasingly knowledge intensive, and energy access gives women the opportunity to tap into new opportunities provided there are good prospects for training and support. For ICT, adequate facilities for charging and maintaining equipment are essential. Of the 1.3 billion poorest people in the world, 70% are women, and gender equality and empowering women and girls have been identified as the aim of Goal 5 and several of the other 16 goals of the Sustainable Development Goals

Two key concepts for gender equality—women’s empowerment and women’s bargaining

power—concern the ability of women to make real choices, access resources, and influence household decision-making. Gender inequality is not something that can be solved purely by energy access, but women farmers who have the opportunity to earn and control their income spend more on their children’s nutrition, education, and health. They are also more likely to ensure that food for their families is reliably available, accessible, and nutritionally balanced. It is therefore critical that women are viewed as primary food providers in local rural enterprises (Box 5) because this will improve their well-being and that of their families^{53,54,56}.

Box 5 Rural enterprise for women in India⁵⁶

In India, Sakhi Unique Rural Enterprise (SURE) enables social change and economic empowerment by developing and strengthening competencies of women at the grassroots level as leaders and entrepreneurs. It is a training and development organisation working across 13 districts in four states in India. It promotes the use of clean energy products and solutions by building the entrepreneurial capacity of a women’s network for people who are part of the poorest socioeconomic group. Rural women entrepreneurs are encouraged to undertake micro-businesses, and are provided with training, technical support and access to technology, finance, and markets. Women are able to have more effective interactions with potential customers due to their place in the community as “one of their own”. The initiative tries to improve access to clean energy solutions such as smokeless cookstoves, biomass pellets, biogas, solar lamps, and other socially relevant solutions that are provided at affordable prices through an effective network.

Women’s experience of poverty—and energy poverty, specifically—can differ greatly from men’s due to their different roles. At a national level, more than 60% of all employed women work in agriculture while in rural areas the percentage is as high as 84%^{56,57}. Their take-home earnings are about two-thirds of men’s wages for the same work, and many additional women contribute unpaid labour. Up to 75 percent of women engaged in agriculture are illiterate, posing further barriers to improving their status. They face extreme disadvantages in terms of pay, land rights, and

representation in local farmers’ organisations. Their lack of empowerment often results in lower educational attainment for their children and poor family health.

The average for women’s share of total time-use in agriculture is about 32%, but it varies widely according to the crop, the phase of the production cycle, age, ethnic group, and a number of other factors. Women’s total time use in West Bengal and Rajasthan ranges from less than 10% to more than 40%, respectively. Younger women contrib-

ute a higher share of the total time provided in agriculture by their age group than older women did in theirs^{57,58}.

Access to energy influences the lives of women and girls in various ways including:^{56,58}

- *Time and labour-saving technologies.* Clean cook-stoves, water pumps, and grinding machines help to save women's time and labour, freeing them up for other productive activities (education, paid work and/or entrepreneurship), and for leisure time and community participation.
- *Entrepreneurship.* Women can increase their own income, improve their self-worth and confidence, and gain greater bargaining power through resource ownership (Box 5).
- *Improved health.* Cleaner air due to clean cookstoves can improve their health as can reduced risk of accidents, better nutrition and food safety from refrigeration, and health knowledge from access to the internet.
- *Educational information.* Access to light means increased time for studying and ability to participate in adult evening classes.
- *Mobility.* Improved lighting makes it safer for women to move around at night.
- *Gender awareness.* Women become more aware through the media (TV, radio, videos etc.) of gender equality issues.

The disparity in mobile phone ownership between men and women in low- and middle-income countries means that there are still significant challenges in ensuring women are not left behind in an increasingly internet-enabled world⁵⁰. GSMA⁵⁹, Vodafone^{60,61}, and the Centre for Research on Innovation and Science Policy at Hyderabad⁶² have all addressed the significant effect of ICT adoption in the empowerment of Indian rural women.

As well as empowering women, ICT complement radio and television dissemination of information on agriculture, health, rural employment, environment, and e-governance. New services such as ICRISAT's GreenPHABLET⁶³ (Box 5) provide farm education and market intelligence, and complementary routes to conventional modes of learning. Women who are engaged in small-scale agriculture are also keen to have educational information on other aspects such as child health, women's health, nutrition, prevention and cure of common ailments, and employment opportunities. New programme formats such as phone-in-programmes are beginning to make mobile phones more interactive.

The Smart Villages Initiative recognises the fundamental importance of gender concern and sensitivity in rural energy projects, not only for policy makers and project organisers but also for technology developers, academics, and young entrepreneurs starting at the root of energy development initiatives. The prospect of utilising the transformative power of renewable energy sources to bring about change for women living in off-grid villages is a central theme.

12. PUBLIC AND PRIVATE INITIATIVES

The Government of India's focus on the "100 Smart Cities Mission" has been enlarged to include making villages smart and growth centres of the nation (Shyama Prasad Mukherji Rurban Mission, *SPMRM*). The Government is preparing for 2,500 smart villages using 14 parameters: skill development training linked to economic activities, agro-processing, storage and warehousing, digital literacy, sanitation, provision of piped water supply, solid and liquid waste management, village streets and drains, streetlights, fully equipped mobile health units, upgrading school infrastructure, village road connectivity, electronic delivery of citizen centric services, public transport, and LPG gas connections⁶⁴. It remains to be seen if the target date of 2019 can be achieved as early progress has been slow in some states.

An important financial development that came into force in April 2014 was the decision of the Government of India that any company having a net worth of rupees 500 crore (1 crore rupees =US\$160,000) or more, a turnover of rupees 1,0000 crore or more, or a net profit of rupees 5 crore or more has to spend at least 2% of the last three years' average net profits on corporate social responsibility (CSR) initiatives, a concept well

known in India. This means that organisations are concerned not only with maximising shareholder value but also include steps to improve the quality of life of rural communities and people. As part of CSR, a business can set up renewable energy technologies like solar PV and biogas to serve energy needs⁵⁹ and this has significance for smart villages by potentially linking with small-scale farming communities.

For example, ITC (formerly the Imperial Tobacco Company), one of India's leading corporate organisations in the agricultural sector and the largest exporter of agricultural products, is a private enterprise with specified CSR objectives: "enhancing environmental and natural capital; supporting rural development; promoting education; providing preventive healthcare, providing sanitation and drinking water; creating livelihoods for people, especially those from disadvantaged sections of society, in rural and urban India". Clearly, ITC, along with several other influential corporate companies in India, is very well placed to pioneer the smart villages concept as part of their CSR activities as well as participating in public-private partnerships^{60,61}, and it will be important to monitor progress in this sector.

13. SMART VILLAGES AND THE MITIGATION OF CLIMATE CHANGE?

Globally, about 20 percent of greenhouse gases (GHGs) come from the food sector (including input manufacturing, production, processing, transportation, marketing, and consumption) and the transition to an energy-smart and climate-smart agricultural sector will be a huge undertaking. The Smart Villages Initiative¹⁹ is consistent with this transition and with its policy recommendations^{62,63}, which focus on improving energy efficiency at all stages of the food supply chain, and substituting fossil fuels with renewable energy systems.

India is the fastest growing major economy in the world and the fourth largest GHG emitter accounting for 5.8 percent of global emissions⁶². GHG emissions increased by 67.1% between 1990 and 2012 and are projected to grow a further 85% by 2030 under a business-as-usual scenario. In 2011 coal accounted for 43.5% of the total energy supply, followed by biofuels and waste (24.7%), petroleum (22.1%), natural gas (6.7%), hydropower (1.5%) and nuclear (1.2%). By 2022, India aims to provide electricity to the 25 percent of the population (more than 300 million) who

do not currently have it⁶². GHG emissions in 2007 from energy, industry, agriculture, and waste sectors were 58, 22, 17 and 3 percentage points of the net CO₂ equivalent emissions, respectively⁶³ (Figure 4). To mitigate the impact of GHGs the Government of India has implemented two major renewable energy policies: the Strategic Plan for New and Renewable Energy and the National Solar Mission. The latter sets capacity targets for 2017 at 27.3 GW for wind, 4 GW solar, 5 GW biomass and 5 GW other renewables. For 2022, these targets increase to 20 GW solar, 7.3 GW biomass and 6.6 GW other renewables.

Climate change gives higher atmospheric CO₂ levels, which can increase the yields for some crops (wheat and soybeans) but not others (maize). If temperature exceeds a crop's optimal level, or if sufficient water and nutrients are not available, yield increases may be reduced. More extreme temperatures and precipitations are to be expected reducing crop growth or causing serious damage, as in the case of drought. This means that the food sector could be seriously impaired by rising levels of GHGs.

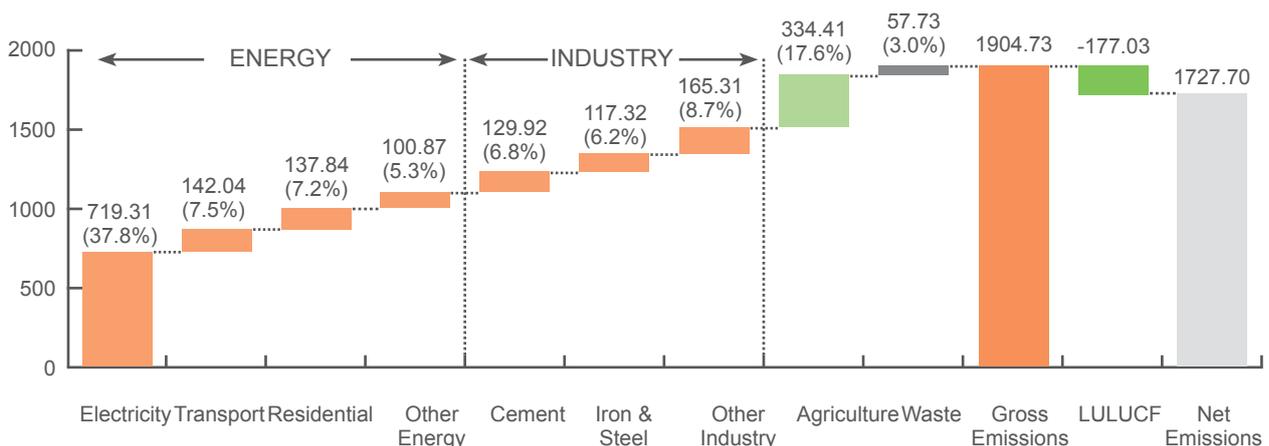


Figure 4: Net greenhouse gas emissions from India (with land use, land change, and forestry, LULUCF) in 2007 in million tons of CO₂ equivalent (eq.)⁶³

Agriculture as an energy-dependent enterprise can help to mitigate the problem by transitioning to renewable energy and sequestering carbon in forests and soil. The issue is how to do this without threatening viable food production. An IFES approach, as noted previously, is one possibility despite the high start-up costs and specialized support required for installation and servicing⁶⁴. In addition, there are climate-smart initiatives seeking efficiency gains from the use of more fuel efficient engines, the use of compost and precision fertilizers, irrigation monitoring, and targeted water delivery, and the conservation and production of suitable seed varieties and animal breeds.

Millions of small-scale domestic digesters are used by subsistence farmers to produce biogas for home use³⁸. In the industrial context the impact of using biomass on the emission of GHGs is a subject of continuing debate^{35,65}. A study carried

out by The Royal Netherlands Academy of Arts and Sciences (KNAW) reached the verdict that “the combustion of wood in power stations and fuelling cars with bioethanol and biodiesel make virtually no contribution to reducing CO₂ emissions. These technologies are therefore unsuitable for facilitating the transition to sustainable energy generation”⁶⁵. It is notable that alternative mitigating initiatives are being developed in India^{66,67,68} (Annex 5), and while they are directed primarily at dense urban communities, their impact could influence the development of smart villages in the rural setting. TERI and IFFCO Kisan Sanchar Limited (IKSL) have signed a Memorandum of Understanding with the objective to “empower farmers and people living in rural India with pertinent and high quality information and services through affordable communication network in a sustainable manner”⁶⁷.

14. POLICIES, MEASURING RESULTS, AND UNINTENDED CONSEQUENCES

For policymakers, the rising number of marginal and small landholdings in India along with the large number of people that continue to be employed in agriculture is a major development challenge. National estimates show that poverty among smallholders is much higher than for other farmers. The high levels of poverty highlight the need to implement measures to increase productivity and income levels of marginal landholders and landless agricultural labourers. It also raises the importance of promoting non-farm activities within rural areas.

Policies to enable the creation of smart villages need to be developed in a way that strengthens job security, public health, education, food security, democratic engagement, and climate change mitigation. Policies should cover regulations for health and safety, codes of practice and tax impositions; fiscal measures and incentives for capital grants; operating grants, soft loans, tax credits, and private sector investment; guidance for technology transfer and capacity building; and specialist training, promotion and education. Leading examples from early adopters that can have a great effect include government demonstrations and information about the procurement of technologies. Policies need to set realistic targets for different sectors⁶⁹ bearing in mind the importance of understanding the political economy of access to electricity to better plan which communities are more likely to benefit

as a result of investments⁷⁰.

Measuring the outcome of policies is crucial, but there is a danger of thinking that megawatts installed and connections achieved are the key metrics that assess the suitability of measures taken to promote development objectives. Such metrics may be disproportionately influenced by mega-projects or unreliable measures of connection numbers so that both indicators are flawed in terms of the quality or quantity of energy supply to the poor. The holistic approach proposed by Practical Action is one that takes into account how improved services increase the number of jobs, agricultural productivity, women's time saved for other purposes, children educated, and medical patients treated³. SEforAll's multi-tiered framework⁵ tells an important part of the story, but policymakers, decision takers, and donors need to know about the outcomes of investments in the lives of the rural poor. Concerning jobs, the displacement of one form of energy supply with another such as renewables can produce new forms of employment created by the replacement energy source, and increases in overall levels of economic activity enabled by more effective/cheaper energy sources will increase employment opportunities and the reduction of drudgery and opportunity costs. After all, the use of renewable decentralised systems also creates more energy per GWh than grid extension (Figure 5)²

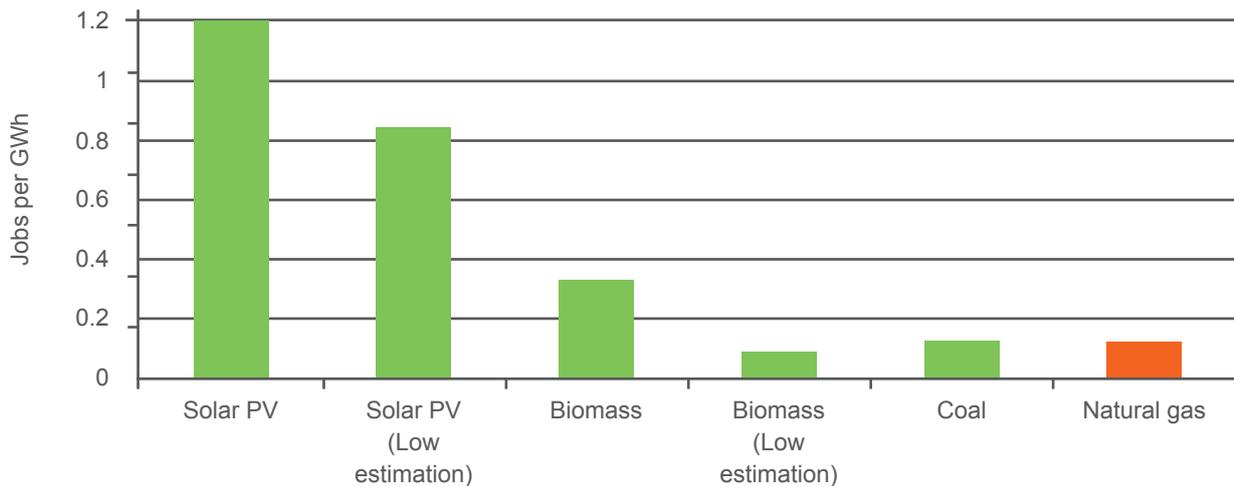


Figure 5. Estimated jobs created per GWh²

As Deepak Nayyar⁶ argues “employment expansion is at least as important as growth in productivity. In a sense, both represent the utilisation of labour as a resource. Why, then, does thinking about efficiency focus on one and neglect the other?In the sphere of economics, the meaning of efficiency must extend beyond output per worker or growth in productivity to encompass employment expansion and labour use. In the realm of politics, employment and livelihoods, supported by off-grid energy provision, must become an integral part of the discourse and the process, as a primary objective rather than a residual outcome”.

In summary, the establishment of smart villages will require the policymaker to create the framework conditions necessary for entrepreneurs to meet the off-grid energy challenge, to catalyse rapid progression through the various levels of energy access, and to ensure that public funding achieves maximum leverage of private sector investment. It is also essential to integrate energy access with initiatives on productive enterprises in agriculture and food supply, taking a community-level approach that maximises social benefit and development impact.

15. CONCLUDING COMMENTS

The idea of creating smart villages means focusing on sustainable growth and development of villages through productive enterprises as well as providing access to basic infrastructure like road, water, power, education and healthcare facilities. Communication and information technologies will play a major role in design, delivery, and monitoring of the services. Above all, the key to success will lie in integrated planning that is well supported by robust monitoring and execution of the activities using appropriate governance models. In terms of energy and agriculture the opportunities in smart villages are:

- To create a smart villages ecosystem that brings a bundle of interconnected services, providers, and users on to a single platform
- To utilise the ecosystem to connect farmers, employees, SMEs, local, state, and central governments, and industrial, social, and political organisations, and, in particular, local youth and women
- To produce more food through increased productivity and efficiency by improving access to modern energy services
- To provide sufficient, secure and “climate-smart” food supplies and to reduce losses along the food supply chain
- To adopt appropriate policies, institutional, and financial measurements
- To build productive enterprises in the village that add-value to agri-business and the food chain and empower women to create new enterprises and alert girls to future opportunities after schooling
- To develop new policies and institutions along the food chain to encourage off-grid villages to become smart
- To select renewable energy systems to reduce GHG emissions by getting away from carbon-based fossil fuels

16. ANNEXES

Annex 1. Small-scale industries in India

Developing and protecting small-scale industries (SSIs) has formed an important part of the industrialisation policy followed by successive governments. Policymakers believed that these industries could play a pivotal role in helping absorb surplus labour, especially in rural and areas classified as “backward”. Promoting SSIs could also help achieve local self-sufficiency in the production of certain consumer goods. During this period, cottage and village industries formed the bulk of the small-scale sector⁷¹.

Successive governments used multiple policy instruments to incentivise the development of SSIs. One of the novel features of the SSI promotion policy followed by India was that of reservation. As per this policy initiated in 1967, the manufacturing of certain products could be undertaken only by SSIs. While initially only 47 products were earmarked for production by SSIs, the number increased to more than 1,000 by 1996⁷². Promoting village-level industries formed an important part of the reservation policy. To do so, the government created the All India Khadi and Village Industries Board in 1956, which was restructured in 2006 and is now called the Khadi and Village Industries Commission⁷³.

Various industrial policy statements have also aimed at developing and implementing policies that promote rural industrialisation. For example, the Industrial Policy Statement of 1977 stressed the importance of promoting small and medium industries in rural areas and small towns as a means of achieving rural development. The policy also made it mandatory for public sector organisations to procure certain products entirely from the SSI sector.

Wide-ranging economic reforms announced in 1991 were accompanied by policy measures aimed at reforming growth of SSIs. The policy reforms aimed to de-regulate and simplify the rules and procedures to establish and maintain small manufacturing units. A special package was announced by the government in 1993 which sought to deal with the credit constraints faced by the SSI sector⁷⁴. As per this policy, commercial banks were to accord preferential treatment to village and tiny industries. Another scheme aimed at infrastructure development was also launched in a similar time period. As part of the scheme the government aimed at developing 50 centres in “backward” and rural areas. The aim of the Integrated Infrastructure Development programme was to promote the location of small and medium enterprise in rural areas. By 2001, 57 such centres had been established.

Despite these policy measures and incentives, the SSI sector has witnessed mixed growth. As part of the reform process from 1997 to 2015, the government has completely reversed the reservation policy and the last group of 20 products marked for exclusive manufacturing by the SSI sector were de-reserved in 2015. Changes have also taken place on the institutional front and in 2007 the Ministries of Small Scale Industry and Agro and Rural Industry were merged to form the Ministry of Micro, Small, and Medium Enterprises (MSME)⁷⁵.

The primary responsibility of promoting MSMEs is with individual state governments. The Government of India supports their efforts through a number of different initiatives. In case of rural industries, the aim of the public sector is to promote sustainable non-farm rural employment opportunities for those based in rural areas⁷⁵.

Annex 2. Adding value to agricultural products (selected from the Indian Council of Agricultural Research)³²

The Indian Council of Agricultural Research (ICAR)-Central Institute of Post-Harvest Engineering and Technology (CIPHET) was established to undertake research in the area of post-harvest engineering and technology appropriate to agricultural production catchments and agro-industries. ICAR-CIPHET has state-of-art research laboratories, which are described as being used “to address problems related to post-harvest losses, processing, storage, and value addition of food commodities”. It has pilot plants that are used for “training and incubation services to the stake holders for primary processing of food grains, mini modern rice mill, agro-processing centre, pulse and small millet processing plants; for extrusion processing, oil extraction and refining, cotton ginning mill, dairy analogues processing plant (soymilk, peanut milk), animal feed plant, for citrus fruits cleaning, grading and waxing, tomato cleaning, grading, coating and processing, aonla processing and product development, chilli processing and environment control chambers”.

To achieve sustainable food security and provide safe foods for all by 2050, ICAR-CIPHET has to play a major role and integrate itself synergistically to promote post-harvest management at national level by collaborations with other institutes.

Its goals for 2050 are “to reduce post-harvest losses to bare minimum level (< 2% losses) and to develop value added products from agricultural commodities; mechanise processes for manufacture of the indigenous technology knowledge based Indian traditional and ethnic food products; develop and provide health foods in the form of functional and nutraceutical foods for various target groups; apply the concepts of Secondary Agriculture for processing of by-products, agro-industrial wastes and residues into high value products; establish a national facility for testing and certification of processing equipment and machinery; focus research on green (eco-friendly) technologies in order minimize the electricity/ water consumption; develop and strengthen research in frontier areas; capacity building; and efficient IP management for commercialization of technologies and efficient transfer of technologies”.

Annex 3. Selected examples of technologies for productive enterprises and smart villages^{28,29,40,47, 48,60}

- *Irrigation services* using solar pumps instead of diesel and electricity pumps. The Government of India plans to replace 30 million agricultural pumps in 3 years with solar powered pumps across the country. Tatapower's solar water pump system consists of a matching solar array of modules; irrigation pumps such as submersible, surface, or deep well can be coupled with drip irrigation systems to enhance returns; added-value for off-grid villages from irrigation in smallholder gardens and rice fields; and support for vegetable production, the raising of livestock, and the operations of dairy facilities.
- *Solar systems*; pumps improve the availability of water for domestic use in off-grid villages and reduce the drudgery of travelling long distances to get potable water faced by many people in rural areas, especially women; thermal systems use sunlight to heat water for domestic use with significant cost benefits.
- *Wind farms* physically arranged on the landscape to minimize land use conflicts. Wind turbine equipment occupies about 5% of the land and the remaining 95% can continue to be used for farming.
- *Renewable energy* produced from the food chain on-farm or in processing plants; used either on-site as a substitute for purchased direct energy inputs or sold for use off-site to earn additional revenue for the owner of the farm or processing plant.
- *Reliable electricity* boosts local entrepreneurs who can develop viable businesses centred on agro-processing; local agro-processing has positive impact on food security as the cost of food coming in from other areas is higher than local produce.
- *Reduced post-harvest food losses* in rural areas with cooling facilities; almost 18% of fruits and vegetables in India are wasted due to inadequate availability of post-harvest cold chain facilities; reductions in waste across the food supply chain saves energy and GHGs as the demand for energy, land and water is reduced.
- *ICT-based businesses* develop networking with farming communities; has enabled a highly cost effective procurement system; provision of Internet kiosks in villages give access to the weather, crop conditions, best practices in farming, and ruling international prices.
- *Positive impact on educational* outcomes in rural areas; students can study for longer hours which improve learning outcomes.
- *Healthcare advances* in Rajasthan shows how improved energy access has been effective in rural areas.

Annex 4. Successes and challenges in the development of smart villages in India^{29,48, 56,60}

- *Success for co-operatives.* Transparency and accountability can lead to market expansion through mobile receipting and attractive pricing offers at co-operatives. More than 20% of all rice and wheat produced is bought by co-operatives. The National Co-operative Farming Advisory Board was formed to promote co-operative farming in the country. Strong progress on information services recognised but slower uptake in the development of mobile money and mobile marketplaces.
- *Challenges from land ownership and small-scale farming.* Total land used for agriculture is substantial (44%) but highly fragmented. 62% of farmers hold less than one hectare, competition from non-agricultural purposes, such as special economic zones, housing, tribal areas, and development projects. The number of marginal farmers with landholdings below one hectare has increased to 92 million landholdings. This form of small-scale farming is less productive, there are fewer opportunities for economies of scale, and levels of mechanisation are low.
- *Water access.* A growing problem as only a third of the population has easy access to clean, safe water supplies; energy that can be used to gain access to water reserves adds value to villages. A huge increase in irrigated land occurred in the past decade, and 47% of farm land is still reliant on monsoon rains, leaving farmers vulnerable to unpredictable or changing weather patterns.
- *Market linkage.* Market linkages are greatly influenced by the large number of middlemen who play an important role in aggregating produce from small suppliers, but they take a large share of the value. Lack of infrastructure, including poor roads and unreliable logistics services, lead to high losses of produce after harvest and affect product quality.
- *Access to finance and auditing.* One-third of India's rural population and only a quarter of women of working age have a bank account; lack of access to credit leaves many reliant on the informal lending sector and subject to very high interest rates. Potential exists to provide for mobile payments and loans estimated to be worth about US\$300 million per annum by 2020. In addition, 178,000 tonnes of CO₂ a year could be saved due to farmers not needing to travel by bus to collect loans and payments.
- *Agribusinesses and consumer goods companies.* Companies are increasingly focused on the quality and sustainability of agricultural produce, leading to a rise in mobile field auditing and testing; buyers need to ensure compliance with certification standards.
- *Markets.* Supply chains for daily commodities can be inefficient and complicated, with many opportunities for loss, fraud and theft leading to farmers supplying less of their produce via the co-operative. India is the world's largest producer of dairy products by volume. Half of dairy farmers sell their produce to large buyers and co-operatives, but about 60 million low-volume dairy farmers are currently outside this organised sector. Mobile receipting will be important.
- *Public-private partnerships.* Partnerships between the public, private, and NGO sectors can play a key role in delivering successful services for agriculture. Private sector partners bring market access, cutting-edge business practices, and innovative insights. Mobile receipting, mobile payments, and financial services, and a tracking and loading module for tracing transportation are attractive options. Scope for improving the efficiency of

co-operatives and their supply chains would enable more small farmers to benefit from co-operative membership.

- *Farmers' organisations.* More than 1.25 million farmers have benefitted from Vodafone's Farmers' Club and the service has helped in-

crease productivity and achieve efficiency savings. More than 700 million SMS alerts have been sent to members since it was launched in 2009; 35,000 adverts have been placed on the mobile marketplace; and the app for smartphone users has been downloaded 10,000 times.

Annex 5. Climate change initiatives in India⁷²

- The United States and India are cooperating to deploy 175 gigawatts of renewable energy by 2022; the U.S. has announced 5.4 GW of new commitments from its renewable companies that are seizing the opportunity to invest in India; three Indian states will develop rooftop solar to improve utilities' capacity scaled up through the "Greening the Grid" initiative.
- Two commitments aim to nearly double current installed solar energy: firstly, 8minuten-energy Renewables, is planning a 4 GW solar photovoltaic project, and secondly, SunLink Corporation is partnering with domestic Indian companies with a deployment target of 1.4GW over the next five years helping to stimulate domestic Indian manufacturing and construction jobs.
- The support of mini-grids for off-grid communities is encouraging, but the relevance of these initiatives to energy and agriculture for smart villages is less clear. Two hubs will mobilize up to US\$1.4 billion in climate finance for Indian solar projects with U.S. philanthropic and government investment; the U.S.-India Clean Energy Finance (USICEF) initiative will deploy up to US\$20 million for solar power projects; the U.S.-India Catalytic Solar Finance Program (CSFP) will deploy up to US\$40 million in high-impact catalytic capital with a particular focus on the off-grid and solar rooftop markets that benefit poor communities.
- The Export-Import Bank of the United States (EXIM Bank) with the Indian Renewable Energy Development Agency (IREDA) will identify opportunities for financing made-in-America renewable energy and energy efficiency exports in support of India's ambitious clean energy goals.
- Promoting Energy Access through Clean Energy (PEACE), the PACEsetter Fund, and the Energy Access Investment Readiness Initiative, a public/private partnership launched in 2015 to mobilize US\$41 million for off-grid enterprises, the U.S.-India Joint Clean Energy Research and Development Center (PACE-R), a US\$100 million program funded by the United States and Indian governments and private sector, and the renewed PACE-R extending funding for solar energy, building energy efficiency, and advanced biofuels for five years are all part of a raft of initiatives.
- The Government of India also has the ambitious goal of training 50,000 solar professionals, and the United States has its own target to train 75,000 solar workers. The two countries will collaborate to establish the Solar Energy Training Network.

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