SMART VILLAGES
New thinking for off-grid communities worldwide

ICRISAT
INTERNATIONAL CROPS RESEARCH
INSTITUTE FOR THE SEMI-ARID TROPICS

Energy and agriculture for smart villages in India

Workshop Report 26

PATANCHERU,
TELANGANA, INDIA

September 2016

Key words:
Energy, Agriculture, India,
ICRISAT, productive uses of energy

Smart Villages

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

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

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

ICRISAT

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, nonpolitical organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market- Oriented development (lMOD). ICRISAT is headquartered in Patancheru, Hyderabad, Telangana, India, with two regional hubs and six country offices in sub-Saharan Africa. ICRISAT is a CGIAR Research Center. About ICRISAT: www.icrisat.org; For ICRISAT's scientific information see: http://EXPLOREit.icrisat.org

CGIAR is a global research partnership for a food-secure future. Its science is carried out by 15 Research Centers in close collaboration with hundreds of partners across the globe. www.cgiar.org

Publishing

The Smart Villages Initiative is being funded by the Cambridge Malaysian Education and Development Trust (CMEDT) and the Malaysian Commonwealth Studies Centre (MCSC) and through a grant from the Templeton World Charity Foundation (TWCF). The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the Cambridge Malaysian Education and Development Trust or the Templeton World Charity Foundation.

MALAYSIAN COMMONWEALTH STUDIES CENTRE

CAMBRIDGE MALAYSIAN EDUCATION AND DEVELOPMENT TRUST

TEMPLETON World Charity Foundation, Inc.

Contents

1. Outline

This report summarises the presentations and discussion at a workshop held at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India from 21 to 23 September 2016. The workshop organised jointly by the Smart Villages Initiative and ICRISAT focused on energy for agriculture in smart villages and its potential to catalyse productive enterprises that add value to agri-business and the food chain and open new opportunities for food security, employment, education, and the engagement of women and girls in new enterprises. The report consists of a summary of the main findings, plenary presentations, group discussions, main findings, and Annexes 1, 2, and 3 of the press conference, workshop programme and list of attendees, respectively. Copies of the presentations at the workshop are available, together with this workshop report and accompanying policy brief, on the Smart Villages website: www.e4sv.org.

2. Summary

2.1 Energy access is essential for successful agribusiness

Energy is a fundamental component of the requirements for rural development, but it has not received the attention it deserves in the context of agriculture[1]. The workshop's focus on energy for agriculture in off-grid villages in India resonated with the need to create revenue streams from productive enterprises and employment opportunities, not least for young people, in thousands of villages yet to be fully electrified. Participants' first-hand knowledge and experience addressed all spheres of energy access (households, productive uses and community facilities differentiated by gender), all forms of energy access (electricity, cooking, heating, mechanical power) and all means of energy provision (grid-connected, mini-grid, and stand-alone), and the opportunities afforded by renewable sources of energy such as solar PV, wind, hydro, biomass, biofuels, and biogas, and hybrid combinations of each. A key priority identified by workshop participants was that a broad approach must be made to educate farmers groups' and policymakers in decentralised energy technologies.

2.2 Energy alone is not sufficient for development

To create a service-focused ecosystem consisting of food security, healthcare provision, education, environmental awareness, and participatory democracy, it is essential to bring together a bundle of interconnected services with providers and users acting on a single platform. ICRISAT's experience of establishing farmer producer organisations (FPOs) provides an entry point for farm interventions, encouraging interactions between farmers, research organisations, agribusinesses, and marketing experts. The integration of modern energy services into off-grid villages promises to lead to improved agricultural production, food security, and the other aspects that make a village "smart". Energy alone is not sufficient for development; it is an important catalyst, but the energy-poor and their representatives must be encouraged to participate in programmatic efforts and coordinated national policymaking if the benefits are to be realised.

2.3 Appropriate business models and policies must embrace societal needs

Important drivers for off-grid villages are public agitation for energy access, the need to produce more food and improve nutrition by increased productivity and efficiency, and adaptation to climate change. Current global investments in energy for development are still just a fraction of the IEA estimate of what is needed to meet SDG 7 by 2030[2]. An overall framework is required that is directed towards equitable energy access and distribution as outlined by the UN's Sustainable Energy for All (SEforAll) Multi-tiered Framework (MTF)[3]. Challenges exist for the identification and adoption of appropriate business models that can secure financial and institutional support and supportive policies that take into account societal needs.

2.4 Women entrepreneurs have a comparative advantage in building productive enterprises

Developing an ecosystem that connects the key stakeholders (farmers, employees, SMEs, local, state, and central governments, and industrial, social, and political organisations, and in particular local youth and women) would go a long way to improve the efficacy and efficiency of rural electrification and help to reduce the high gender inequality found in many states. Women's entrepreneurship plays a critical role because women possess valuable knowledge relevant to sustainable energy solutions and their applications, and they can draw on their comparative advantage of natural circles of family, friends,

and the community for customers in building new enterprises.

2.5 DC power and DC appliances provide a new industry

Rural energy initiatives in India are not new, but some sources of government support have been declining over the past two decades. Practical difficulties persist over load shedding and unreliable and unaffordable energy supplies, which could be addressed in part by supplementary and renewable energy sources, new and more efficient ways of energy distribution, and more efficient appliances. Progress in solar PV energy routed as DC power instead of AC power and used in efficient DC appliances could go a long way to reduce cable losses and improve the efficiency of energy distribution and use. Translating this technology into smart villages for agribusinesses has considerable merit, but much needs to be done to demonstrate the proof of principle and the economic improvements in supply chains.

2.6 Innovative ICT is central to smart villages

The significant advances in ICT help to underpin the success of smart villages through communication, awareness raising, education, and capacity building. Innovative software applications can establish research-extension-market linkages that were previously poorly executed or non-existent. Such applications will continue to contribute to a growing range of educational activities which include weather forecasting, soil health, irrigation systems, precision agriculture, monitoring waste water systems, and threats from extreme weather events associated with climate change. In particular, they offer the prospect of replacing inefficient and expensive extension services with up-to-date and accessible knowledge sharing and information about best practices for smallholder farmers.

2.7 Confidence has to be built around the prospect of investment return

The question of how to fund the many promising leads identified was encountered repeatedly in all discussions. Central government and states have a crucial role, not least in supporting start-ups. Some were of the opinion that available financial resources from the Indian private sector are substantial. Corporate social responsibility (CSR) funds in particular could readily support the national programme for large numbers of smart villages in numerous states. It was recommended that an organisation like ICRISAT could go for support for biomass gasifiers and act as a model for others in the development of renewable energy. Others argued that the demand-side should be given greater priority to respond to the social needs of youth employment, skill generation, and maternal health and nutrition. Banks and lending agencies have little experience of up-front investment in energy and agriculture and they need persuading that aggregated investment in smart villages are a good thing alongside integrated polices and governance.

2.8 A collective of influential stakeholders can be persuasive

Planning for decentralised energy and clean cooking technologies is rarely mainstreamed into energy planning. A key to success lies in the integrated planning of the supply chain supported by robust monitoring and appropriate governance models. Among the key actors are governments (federal ands state), NGOs and self-help groups, corporate organisations, academia, village committees, donors, and micro-financing institutions (banks and international funds). The dangers of disconnects were recognised where governments and donors are not being fully conversant with the needs of those whom they seek to serve. A collective of stakeholders has the potential to set the foundation for the supply chain whatever the enterprise.

2.9 Future smart villages must be scalable, replicable, and sustainable

Practical examples were provided by individual entrepreneurs and organisations working at the frontline, which demonstrated how smart villages are beginning to permeate the rural agricultural and educational environments. Smart villages have been set up to fulfil the electricity, cooking fuel, and water needs of tribal communities in off-grid regions of India using solar PV micro-grids, biogas-based cooking grids, and solar pumps. Trending forms of innovative ICT, sustainable irrigation, renewable energy for rural schools, and biofuel production facilitate microenterprises such as oil and grinding mills, welding machines, and pumps that promise to improve agricultural output, generate employment, and give value-addition to agriculture. The realisation and value of smart villages will be assessed by the development outcomes catalysed by energy-services such as the number of jobs created, agricultural production increased, children educated, patients served, and the participation of villagers in social democracy. The challenges will come from the economics and quality of life of smart villages, and whether they are scalable, replicable, and sustainable.

3. Introduction

The idea of creating smart villages for sustainable growth and development in rural areas means focusing on productive enterprises as well as providing access to basic infrastructure like roads, water, power, information and communication technologies, and education and healthcare facilities. Agriculture through the energy-food-water nexus has the potential to create productive enterprises provided that energy can be produced to catalyse an ecosystem that connects farmers, small and medium enterprises, markets, local state and central governments, and industrial social and political organisations[4,5]. Building productive enterprises that add value to agri-business and the food chain and engage women and girls in new enterprises was the focus of a workshop held at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Telangana, India from 21 to 23 September 2016. The workshop was organised jointly by the Smart Villages Initiative and ICRISAT.

The workshop was preceded by ICRISAT's National Farmers' Day with over 2000 farmers and representatives from seven Indian states: Tamil Nadu, Telangana, Andhra Pradesh, Maharashtra, Odisha, Karnataka, and Gujarat (Figure 1). Smart Villages Initiative team members and a number of workshop participants attended and were given tours of demonstration fields planted with varieties of crops including millets, pigeon pea and sorghum as well as seeing different watershed and other agricultural practices that could help double farmers' incomes in the next five years. The event, which was organized by ICRISAT Development Center (IDC) led by Suhas Wani (Director IDC), coincided with ICRISAT's Governing Board meeting providing an opportunity for international Board members to interact with farmers. Brian Heap and John Holmes were invited to make a presentation to the Board about the Smart Villages Initiative.

4. Welcome: David Bergvinson and Brian Heap

Welcoming participants to the workshop, David Bergvinson outlined its aim to examine the role of electricity in enabling rural communities in India to realise the full potential of the agricultural value chain. ICRISAT's focus is on inclusive market development to lift people out of poverty: this focus fits well with the Smart Villages Initiative. Energy access is a key enabler of water for irrigation to increase crop productivity, of post-harvest processing, and of internet access connecting farmers to markets. A key issue for the workshop to consider was how the different sectors can come together to support rural development.

Brian Heap spoke of the good cross-section of people attending the workshop as an interdisciplinary approach is essential to ensure that technologies bring real benefits to villagers. It was also important to continue to raise awareness about the challenges and opportunities of village level energy access.

Over 2,000 farmers from across India attended the National Farmers' Day at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) headquarters, Telangana, India (photo: PS Rao, ICRISAT)

Video Message from Professor MS Swaminathan, MS Swaminathan Research Foundation, Chennai, Tamil Nadu, India

In his video message to the workshop, Professor Swaminathan reflected on a message of Mahatma Gandhi that the real India lives in its villages. The worst form of brain drain is migration of the village youth to towns. There is now an understanding of the necessity to rejuvenate villages and to make them smart in order to make possible a good quality of life and for environmental security.

Agricultural progress is essential: it is key to livelihoods in India. All forms of agriculture require energy. There is an emphasis in India on solar power given the abundant solar resources, but also biogas and other forms of renewable energy can play an important part. In a similar way to the integrated approach of the Smart Villages Initiative, the integrated child development initiative was undertaken in India many years ago that gave concurrent attention to nutrition, education, and health.

In smart villages people are happy and have work to do which requires both brawn and brain, not just manual work. Jobless growth is joyless growth. Smart villages provide a mechanism to generate joyful growth. The self-reliance of villages is essential for freedom and their energy independence is important. Professor Swaminathan ended his message with the hope that the discussions at the workshop will provide a blueprint for the development of smart villages.

David Bergvinson, Director General ICRISAT in discussion with Brian Heap, Senior Adviser, Smart Villages Initiative, and John Holmes, Smart Villages Project co-leader.

5. John Holmes: What is a *Smart Village*?

John Holmes pointed to three key numbers that provide the motivation for the Smart Villages Initiative: globally, 1.1 billion people remain without access to electricity, 3 billion people still cook on inefficient and dirty stoves, and 4.3 million people consequently die each year through inhalation of smoke and fumes. Goal 7 within the Sustainable Development Goals seeks to ensure access to affordable, reliable sustainable and modern energy for all by 2030. It is also important to recognise that energy access is a key enabler of nearly all of the Sustainable Development Goals.

Smart villages are intended as a rural analogue to smart cities recognising that nearly half of the world's population and 70% of the world's poor live in the countryside. In smart villages, energy access along with modern information and communication technologies enables the provision of key services such as education, health, clean water, and sanitation and supports increases in agricultural productivity and the creation of new productive enterprises capturing more of the agricultural value chain. Smart villages enable greater participation in governance processes and build more resilient communities better able to respond to shocks. Technological advances are shifting the balance of opportunities between cities and villages.

The Smart Villages Initiative focuses on identifying the framework conditions necessary to support the creation of sustainable local energy solutions for rural communities which catalyse development. A series of engagement activities and workshops in Africa, Asia, and Latin America have brought together the key players, enabling the development of insightful "views from the frontline" of the challenges of village energy provision for development and how those challenges can be overcome. A key aim is to identify the framework conditions to foster entrepreneurial activities in delivering and using energy services and that maximise the leverage of public sector funding. An underlying premise is that to maximise social benefit and development impact, energy access initiatives must be integrated with other development initiatives and a community level approach should be taken. And an important concern is to catalyse rapid progression through the various levels of energy access.

With regard to the water-energy-food nexus, it is estimated that by 2050 demand for energy will increase by 80%, for water by 55%, and for food by 60%. "Nexus thinking" dictated an interdisciplinary approach that brings to the fore inter-linkages between water, energy, and food systems and helps understand the potential trade-offs and synergies in utilisation of these resources. Such an approach can have a positive impact on sustainability by reducing trade-offs and by improving resource allocation and policy coherence.

John Holmes concluded his presentation with a summary of the findings of a recent workshop in Senegal that considered the water-energy-food nexus. This workshop recognised that there are complex and diverse interactions, but that typically a silo approach is taken, and there is a lack of coordination. Integrated and cross-ministry policies and initiatives are required based on a better understanding of synergies and competing interests. It is also necessary to take a participatory and bottom-up approach, building on existing practices and respecting local cultures. The workshop concluded that it was important to create a conducive environment for the private sector and to ensure access to affordable finance. Capacity building is also about including the policy community and providing advice to smallholder farmers. Particular attention should be paid to smallholder farmers in poor areas as it is harder to improve their livelihoods. It is also necessary to address gender issues as women play a key role.

Responding to a question on what had been the main surprise emerging from the workshops so far, John Holmes indicated that it had been the lack of integration between the key players involved in village-level development. For example, initiatives concerned with healthcare or education do not generally give sufficient attention to the provision of the necessary energy services and how they are maintained over time. An integrated approach is essential.

Indian initiatives to introduce liquefied petroleum gas (LPG) for cooking were raised. John Holmes considered that LPG may well have a role to play in establishing cleaner cooking approaches. For example, there are similar initiatives in other countries such as Indonesia, but it is a fossil fuel, and other more sustainable approaches such as biogas and clean cookstoves should also play a role.

6. Kiran Sharma: Smart villages and agribusiness

Kiran Sharma explained that there were three main elements in ICRISAT's initiatives on "Inclusive Market-Oriented Development": harnessing markets in ways that included the poor, reinvesting gains in innovations that move smallholders along the development pathway, managing risks that are stumbling blocks for the poor, and building resilience.

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

Kiran Sharma, Principal Scientist, Plant Biotechnology, ICRISAT.

In addressing the relationship between smart villages and agribusiness, Kiran Sharma considered that there are a number of key questions that need to be addressed:

- How to create energy access and sustainability within villages?
- How to improve livelihood and quality of life in the rural sector?
- How to enhance farm productivity and returns from the field by reducing farm input costs?
- How to address the carbon footprint at farm level?
- How to promote social ventures to challenge grassroots issues?
- Can community-driven interventions lead to smart villages and rural development?

ICRISAT is supporting the establishment of farmer producer organisations (FPOs) as the entry point for farm interventions. 15 FPOs have been established in the states of Telangana, Tamil Nadu, and Andhra Pradesh, mobilising 750 farmers. The FPOs are used as a mechanism to connect ICRISAT research and scientists to farmers. ICRISAT connects agribusiness start-ups, services, and products to FPO members and supports the FPO management team with business development and marketing assistance.

A key focus for ICRISAT is how to strengthen the agricultural value chain based on an integrated value chain development strategy and considering the extension of the value chain backwards to suppliers, and forwards to end-market requirements. Energy access issues need to be addressed at every stage of the value chain in order to increase farm revenue, improve field productivity and soil quality, improve nutritional security, and enhance quality of life. Critical aspects to be considered include appropriately defining the problem to reflect the multiple actors, systems, and interactions at play, and to aggregate demand since it is a dispersed market with diverse needs.

There are currently a number of opportunities in India for agribusiness in smart villages, for example through the wide range of clean technologies that are available through the National Solar Mission, the International Solar Alliance launched by India and France, India's Corporate Social Responsibility Act 2013, the thrust to promote FPOs, and increasing government support for start-ups.

Kiran Sharma concluded his presentation by reflecting on the close parallels between ICRISAT's work to develop agriculture in Indian villages and the concerns of the Smart Villages Initiative linking up energy access along the agricultural value chain.

7. Shailaja Fennell: Women entrepreneurs in smart villages

Shailaja Fennell argued that there is a huge potential economic gain if we focus on gender: not only can this be an abstract fact, but this can also be true from an operational perspective. Rural electrification can serve to improve quality of life, saving labour and time, and improving health, security, and incomes. Reliance on biomass for cooking created risks and hardships that fall inordinately on women. In the states of Bihar and Uttar Pradesh 87% and 71%, respectively, of households have no electricity connection. There is also high gender inequality in both these states.

Figure 1. Percentage of households with no electricity connection

Dis-empowered

Percentage of households with no electricity connection

	Rural*	Urban**
Bitah	87	33
Uttar Pradesh	71	19
Assam	66	16
Jharkhand	63	12
Odisha	52	17
Meghalaya	46	5
Manipur	45	18
Madhya Pradesh	43	7

* As on May 2016 **As per Census 2011

Source: http://www.ddugly.in/ and Census 2011

Whilst there may not be direct causal links between these two issues, they are inter-related.

Enabling energy access could provide opportunities for women's entrepreneurship. Women play a critical role in energy provision and consumption within households and communities, and therefore possess valuable knowledge relevant to sustainable energy solutions. Women are in a strong position due to their ability to draw on natural circles of family, friends, and the community for customers. This has been shown as an effective way of distributing solar technology to rural households. In Dharnai, Bihar (a solar-powered village) women participated in community engagement and had the chance to discuss a wide range of issues with each other—the "roof top solutions" were not solitary ones.

Women entrepreneurs have not yet been scaled up in number, yet women appear to conduct energy entrepreneurship better than men as a result of their social networks. There is a distinct track record of women functioning as effective entrepreneurs, with many visibly successful organisations and networks such as: Grameen Shakti, Self Employed Women's Association (SEWA), Technology Informatics Design Endeavour (TIDE), All India Women's Conference (AIWC), and Solar Electric Light Company (SELCO). As Yannick Glenarec, UN Assistant Secretary General noted in 2016, whilst speaking on India's energy policy: "Women have a comparative advantage in this sector of work. The price of renewables has come down significantly, and if rural women have access to easy credit via microfinance, then they can work in the grassroots to drive a change in energy consumption behaviour on the ground".

Shailaja Fennell, University of Cambridge

Barefoot College, started in the 1990s, aims to teach grandmothers from all over the world how to build solar panels at a six months workshop. Following the workshop the "grannies" go back to their villages, and the villages in India get solar cells sponsored by the Indian government that the grannies repair as solar engineers. The idea is that Barefoot College presents technology that disrupts existing practices by empowering grandmothers (who have never left their village previously) to travel to a different location for training to become a solar engineer. Training is based around actual experience, observing illustrative colours and wires, rather than formal reading and writing.

Another example of innovation in gender empowerment is the work of Ajaita Shah who began working in Indian villages by launching her own company, Frontier Markets, to bring safe and affordable clean energy to the north-western region of Rajasthan (Rajasthan still has a long way to go in terms of gender inequality). Shah, who was brought up in the U.S., is now in Forbes magazine's Top 30 Social Entrepreneurs and has raised more than US$550,000 in funding, including a grant from the National Geographic Society's Great Energy Challenge. Frontier Markets trains women to sell clean energy solutions like solar lighting and cookstoves; these trained women are known as Saral Jeevan Sakhis. As one such saleswoman noted: "I like being a Saral Jeevan Sakhi because I get to save my village from kerosene fires and fear of darkness. I am learning about solar and its benefits, I am making money, and now, I am respected by my family members" (Meena Kumari, Chomu Block, Saral Jeevan Sakhi).

However, Shailaja Fennell noted that a key concern is sustaining this entrepreneurship after the donor leaves. Energy access provides opportunities for women entrepreneurs to make an income and enhance their social status by creating and disseminating sustainable energy solutions. Barriers to the sustainability of, and engagement in, energy entrepeneurship include a lack of training and education and social norms that view modern energy technology businesses as "men's work". Energy access needs to be about changing women's perceptions of the way they work and their role. Women's leadership and participation need to be enhanced in the energy sector with the development of training programmes specifically targeted at women—these can counteract some of the barriers to participation. Publications such as *Boiling Point* (Energia) provide women with focused training manuals within this area.

Whilst it is great to begin with grandmothers, as with Barefoot College (age has a mark of respect in India), the next generation also need to be empowered, particularly due to the lack of safety often experienced by young girls. In Ranchi (where Shailaja Fennell had previously held a workshop), young women know about mobile phones but not about renewable energy. Empowering girls is important for a number of reasons. Firstly, girls are left behind without educational opportunities due to the lack of reliable light. Secondly, a number of quantitative and qualitative studies have shown that clean energy access is linked with better chances for girls to complete primary education and for women to earn better wages. Thirdly, energy access can contribute to a reduction in gender-based violence, and an ability to power mobile phones means better connectivity and better business opportunities.

Shailaja Fennell concluded by considering "energy, entrepreneurship, and disruptive technology". She noted the importance of advancing the opportunities for girls-health, education and their learning aspirations. Their lives and opportunities can be improved by using disruptive technologies such as renewable energy and mobile phones. Initiatives in this field can change young girls' perceptions of themselves

and empower them in the making of smart villages.

In the discussion that followed the benefits of solar cookers to help with the burden of cooking were noted. Whilst solar cookers are valid at present, they may not be a long-term solution, and baseline studies are needed to understand what the women in those communities really want. It was also noted that in the work of Gram Oorja (see Anshuman Lath below), from their years of experience, the involvement of women in energy committees is a necessity for the successful working of projects.

8. Debajit Palit: Renewable energy and mini-grids for agriculture

Debajit Palit described how The Energy and Resources Institute (TERI) is currently conducting a project on women to discover how women do or do not benefit from energy (with Energia). TERI is also implementing a "Lighting a Billion Lives" programme targeting base of the economic pyramid (BoP) households, providing solar lanterns and pico-solutions to help the transition from harmful kerosene fuels to cleaner low carbon alternatives. The programme uses an entrepreneurial model of energy service delivery, creating a viable and socially relevant value chain for service delivery. By the end of December 2015, 0.8 million households had been illuminated and more than 57,792 improved cook stoves disseminated.

A range of clean energy technologies that are customisable, cost effective, accessible, and affordable include solar charging stations, solar micro-grids, solar home systems and solar multi utility. Key features for success are: development of relevant techno-socio business models; enhanced energy efficiency; institutional capacity building and value chain development; strong feedback mechanism; standardisation of technology specifications; customised technology solutions with a range of options; and flexible financial models. Impacts include improved education, new livelihood opportunities, cleaner indoor air and better health, women's empowerment, enterprise development and skill development, and inclusive energy provisioning.

Research conducted as part of the Off-Grid Access System for South Asia (OASYS) concerned an analysis of appropriate business models (see http://www.teriin.org/eventdocs/files/OASYS-Project-Presentation_22April2015.pdf). One of the key design challenges was ensuring that systems were not just technologically smart but also institutionally smart. There was a need to consider the impact of site conditions (how remote is the village), socio-economics (how much are people in the village earning), and the perspectives of potential stakeholders (as in the private sector). The failure of previous projects was largely due to the assignment of roles to the village energy committee that they were not adept to handle; capacity building and appropriate role assignment need to be a priority.

Four different management and technical models were tried out at various locations in three states. In the remote islands of Sunderbands, West Bengal, a community-managed model with district administration (in collaboration with the Mlinda foundation) supported the implementation of solar AC pico-grids to cover around 500 households, 200 shops and four villages. Joint liability groups were organised in each cluster of 6-10 households (pico-grids). Shops in the marketplace were catered for by a separate micro-grid with larger capacity. The after-sales service was provided by Mlinda foundation. Loans came from NABARD (facilitated by the Mlinda foundation), with the overall project cost being met partly through OASYS South Asia.

A private developer-managed solar DC grid business model in Uttar Padesh showed that where villagers were unable to pay on a monthly basis, innovative financing was arranged by weekly payments supplemented with grant funding; revenue was re-invested to cover additional households. This was an example of a project design that was formulated in line with the financing available in a particular location. Cost effectiveness and innovative financing were the key to success.

A community-managed AC/DC micro grid business model (with an NGO) in Odisha saw the need to create one institution (with both men and women) from five villages, where everyone had equal rights to share their thoughts and take

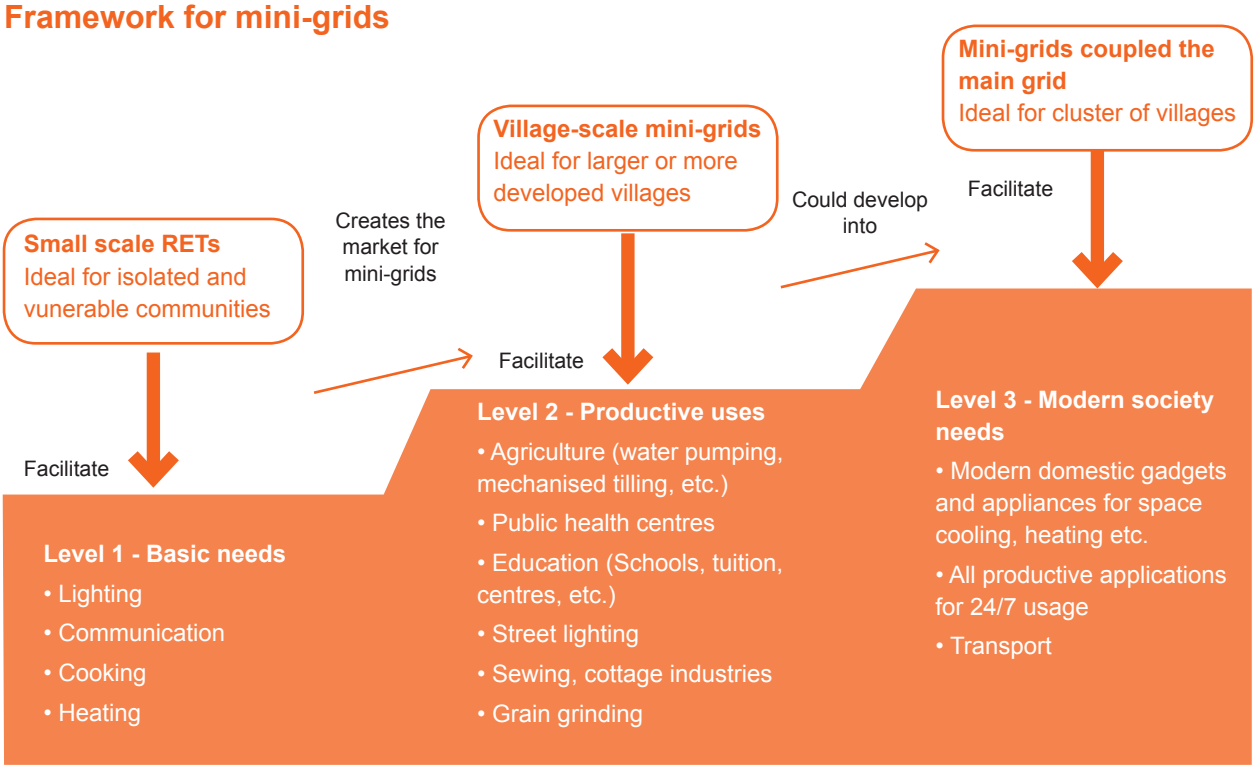
a collective decision, which enabled entrepreneurship and cut out the middle men. In addition to lighting, applications such as grinding and packaging machines, a sal leaf plate-making machine, and a water pump supported the project financially. Smart grid-fed/interactive inverters with battery management and timer-based operations for energy management were included in anticipation of future grid-interconnection.

Numerous co-benefits were noted in these projects including sewing machines in the community centres provided by the partner NGO, civil construction, employment opportunities for the community, a new focus for development by the local panchayat, improvement in the condition of roads and better accessibility, and people coming from nearby towns and cities to buy the organic vegetables that enhanced farmers' income.

Technical challenges emerged in the Odisha project because of damage to the inverter and other equipment due to a lighting strike, spoilage of LED bulbs over the first two months of operations due to short circuits caused by rains, and occasional problems with inverters. On the operational side, there were problems in some households with tampering with connections and installation of additional electrical sockets to operate appliances. Some households resisted paying the connection fee due to a teething problem with the inverter and LED bulbs. Despite these challenges, OASYS South Asia went on to win the International Green Gown Award.

Debajit Palit outlined an overall framework for mini-grids comprising three levels of access: 1) small-scale renewable energy technologies for isolated and vulnerable communities providing for basic needs such as lighting and cooking, which can create a market for mini-grids; 2) village-scale mini- grids for larger or more developed villages which can cater for productive uses in agriculture, education, sewing, and cottage industries as well as street lighting; 3) mini-grids coupled with the main grid for a cluster of villages providing modern societal needs such as modern domestic gadgets and appliances for space heating, cooling and productive applications for 24/7 usage.

Framework for mini-grids



In summary, experience shows that there is a need for multiple approaches in the use of mini-grids because one size did not fit all requirements. The needs include innovative financing and targeted subsidies to help support the BoP population, long-term capacity building of local operators and communities beyond just training, a responsive after-sales service infrastructure, understanding aspirational demands, and creating linkages between different agents and stakeholders.

In the subsequent discussion, the relevance to farming was noted. In the case of solar pumping, knowledge of the kind of crops you want to use the system for should be identified before forming a solution, for example vegetable crops or certain cash crops need less water. Connecting the solar pump to the micro-grid can be designed to function at times when grinding is not taking place, making more efficient use of the equipment and energy supply. Issues were raised about tariff rates, battery replacement costs, and the sustainability of projects over the long term. It was argued that the electrification company gathering the tariff should take responsibility for the replacement of the battery and that the tariff should cover such eventualities.

Hari Sharan, Chairman, DESI Power, a pioneering company which has developed a micro-grid pay-as-you-go model for renewable electricity produced from biomass and distributed through privately developed micro-grids.

9. Joanna Kane-Potaka: Smart Food

Joanna Kane-Potaka noted that energy only adds real value in villages if food is integrated into the smart villages concept with an emphasis on achieving nutritional security and not just food security. Quality rather than quantity of food is important. Sustainable nutrition is a United Nations (UN) priority as it counters malnutrition but is influenced by environmental degradation, water scarcity, and migration of labour force, amongst other issues.

Smart Food is a movement (started by ICRISAT) that can only be achieved with significant investment into more diversified foods. There is currently a major focus on three crops—rice, wheat, and maize—which attract the biggest amount of research, development, policy support, and investment. To bring in smart foods, the focus needs to change by taking learnings from the big three crops to establish how smart foods from less familiar crops (e.g., millet, quinoa) can receive greater attention from different communities, health workers, and agri-business.

An ICRISAT video detailed the benefits of smart foods, in particular of millets, which tackle some of the biggest micro-nutrient and food deficiencies. They can be high in micro-nutrients and provide the full daily allowance of iron and zinc. Millets are also high in antioxidants and are gluten free. Different varieties of millet also present different nutritional value as kodo millet is high in fibre while pearl millet is high in protein. They require 30% less water than maize, they grow faster (maturing in half the time of wheat), put less stress on the environment, and grow on minimal pesticides/fertilizer. In times of drought they are often the last crop standing making them potentially critical for addressing the challenges of climate change. Whilst the breeding of millets has received a lot less investment, they have the potential to increase yields by up to three-fold and produce biomass for alternative use (for example, fodder, biofuels, and brewing).

In the subsequent discussion, concerns were raised that there may be too much of a top-down approach in this initiative. However, it was countered that the project is also working bottom-up and engaging directly with villagers. It was noted that the top-down approach is important as global and national patterns do influence the market. Another concern was affordability, with demand and marketing driving the change, how will this affect affordability? It was argued that a core part of ICRISAT's Smart Food approach is how smallholders benefit, and that there is a need to develop the whole value chain for millets and sorghum whilst working directly with the farmers.

If smart food is being introduced to smart villages it should be marketed to the middle class to make sure it is processed and purchased in the cities initially. A lack of desire to change cropping practices in rural areas was seen as something that could be influenced by changes in urban trends. Some of the difficulties encountered were illustrated by one case in Mali where schools wanted to use millets for school meals, particularly as they were available in abundance in the area. However, parents and children wanted rice as this had become trendy in the urban areas. Another case in Kenya was noted where they used to grow millet and sorghum, but in strife maize was given as food aid. People grew accustomed to maize and so farmers continued to grow it even though it would only be successful one in four years.

10. Ashok Jhunjhunwala and Prabhjot Kaur: Green homes for smart Indian villages

Ashok Jhunjhunwala spoke about green homes for smart Indian villages and highlighted the current energy situation in India where 50 million homes are not on the grid. In addition to this, there are 100 million homes that have load-shedding 2 to 12 hours a day. Whilst supply has been rising, 50% of Indian homes cannot afford the power available—even if it is at a subsidised rate. Thus, there have to be alternatives to provide power to the poorer households.

One suitable alternative is roof-top solar, however, current systems experience large losses. Roof-top solar produces DC power—when this is converted from DC to AC, approximately 15% of power produced is lost (for pico-systems). If we add a battery, the battery only stores DC thus another conversion has to take place using an AC-DC converter resulting in a further loss of 15%. Every time there is a conversion from DC to AC during discharging there is another loss of 15%, resulting in total losses of over 45%.

Ashok Jhunjhunwala from IIT Madras

To minimise these losses, the solution is an entire system run on DC power. For example, a small solar panel of 0.75 m^2 can provide 125 W, powering TV, lights, cell phone charging, and a refrigerator, for example. This is only possible when operating on DC power as losses are reduced from 45% for AC power to 7% for DC, something that would have not been possible several years ago. Home loads have slowly begun moving towards DC appliances and the power consumption of such devices is much lower. Changing the system as well as all appliances to DC can reduce power consumption by 50%. Such systems can also be connected to the grid, the only AC-DC conversion necessary being at the entrance of the grid to the home. Furthermore, using 48 V DC for safety considerations there are lower cable losses compared to the conventional system of 12 V/240 V. The idea is to design something that minimises losses and power consumption as this in turn reduces costs.

As part of this, Ashok Jhunjhunwala and his team at IIT Madras have designed a device called "Solar-DC Inverterless", which can be monitored using Bluetooth. In their effort to maximise power utilisation and minimise losses throughout the system, they have partnered with different organisations to work on a) maximising the number of cycles that a battery can sustain, and b) designing low watt appliances including LED bulbs (5 W instead of 30 W), brush-less DC motor fan, cell phone charger sockets, LED tube lighting, and remote control for fan and LED tube lighting. Furthermore, they have been working on reducing the power consumption of larger appliances such as a DC cooler (80 W DC power consumption compared to 180 W AC cooler), 19/24" colour TV (30 W DC power consumption), and a DC mixer (consuming 75 W DC instead of 150 W AC). This highlights that using DC appliances can significantly reduce power consumption. Another key benefit of DC systems is the cost: DC appliances can cost a quarter that of AC appliances. Using a converter from AC to DC at the grid entrance, the whole system can be connected to the grid. DC systems have proven to be much more cost effective.

To put all this into practice, the IIT Madras team have electrified 4000 off-grid homes in the difficult terrains of Jodhpur and Jaisalmer districts of Rajasthan, and they are planning to electrify a further 7500 homes in the hills of Assam. To ensure sustainable operation they have been training the local people to install the equipment. Ashok Jhunjhunwala highlighted that it is also important not only to connect but also to monitor. To do this, they introduced Bluetooth monitoring as the most appropriate technology as most Indian homes have a cell phone. This allows them to record power availability, the load, the battery status etc., and to quickly rectify any problems as each component in the system can be monitored. Home power costs with off-grid solar-DC are approximately 25% less than the cost of on-grid AC homes with no power cuts.

Next steps include developing DC solar water pumps with which agricultural water can be pumped throughout the day so that water can be stored in a sump and used when needed, and looking at the main requirements to change the motors of agricultural machinery so the power consumption and subsequently machinery costs are reduced.

Ashok Jhunjhunwala and Prabhjot Kaur concluded that:

- Roof-top solar-DC can change rural homes as power can be available 24/7 at affordable rates even during load-shedding, as lower to middle income homes cannot afford power today even at subsidised rates. Furthermore, these systems draw less power from the grid and so reduce the financial losses for DISCOM (Distributed Company India)—the financial turnaround and revival package for electricity distribution companies of India initiated by the government to improve power distribution.Properly designed roof-top solar and solar-micro-grid could power agricultural pumps and supplement power for rural industries.India's rural scenario can change as India aims to get 50% of power produced using solar by 2030.

11. Suhas Wani: Role of ICT in agricultural productivity

Commenting on the previous presentation by Ashok Jhunjhunwala, Suhas Wani said that to own a DC system there needs to be prosperity in villages to afford all of these appliances. Furthermore, there is a need to make these technologies available to farmers through improved supply chains. The aim of Suhas Wani and his team at ICRISAT is to reduce rural poverty primarily through addressing malnutrition and food security whilst protecting the environment. But there are a number of challenges that India is currently facing which include water security (drought and flood), land degradation (because of increased population pressures), weak delivery systems, and climate change (min/max temperature). Whilst there have been improvements in some areas, others have lagged behind.

At present, most scientists work at discovery, pilot, and proof-of-concept stages, and then they stop —this has been coined the "Death Valley of Impact". There have been no means to make these new discoveries available to the large number of small-scale farmers because of insufficient and dispersed knowledge, weak delivery systems, and a lack of scaled-up approaches. More work has to be done on the potential of rain-fed agriculture, delivery systems, and knowledge sharing (what scientists know and what farmers don't know). Addressing these three key areas, there is huge scope to breach the yield gap between what is experienced and what could be achieved.

Suhas Wani's team has taken new technologies to the villages through participatory research and development, a scheme with much relevance to the establishment of smart villages. Initial findings were brought back to research centres, and only after further improvements did they continue along the road map towards improvements in the value chain leading to better livelihoods. This journey can be applied to scaling-up technologies leading to sustained growth when applied in the field. The aim is to develop skills, increase production efficiency, add value through consortiums and partnerships, and increase profits for farmers. Soil Health mapping is a good example because the lack of knowledge among farmers has resulted in a large yield gap. Through participatory research and development ICRISAT identified that there were widespread deficiencies that farmers do not know about. By transferring this new knowledge to the farmer, yields were increased by 20% showing the benefit of knowledge transfer.

In line with this approach ICRISAT has distributed, in the local language, cards, and boards that outline soil nutrition and rainfall information. This information is also available on an online platform so that it can be accessed by other organisations. "Seeing is believing", and ICRISAT in partnership with Digital Green (see below) has provided farmers with short videos for local discussion groups. Demonstrators were provided with software called Krishi Gyan Sagar, an innovative tablet-mediated system in the local language, which helped to establish research-extension-market linkages for improving productivity and profitability of farmers. It also helped smallholder farmers to make informed planting

Suhas Wani, Director, ICRISAT Development Center

decisions by monitoring rainfall, strengthened farmer field schools, acted as a tablet-based extension system, and built awareness of local issues for policymakers. ICRISAT also addressed the need to recycle waste water using plants, mechanical filters, and domestic waste water.

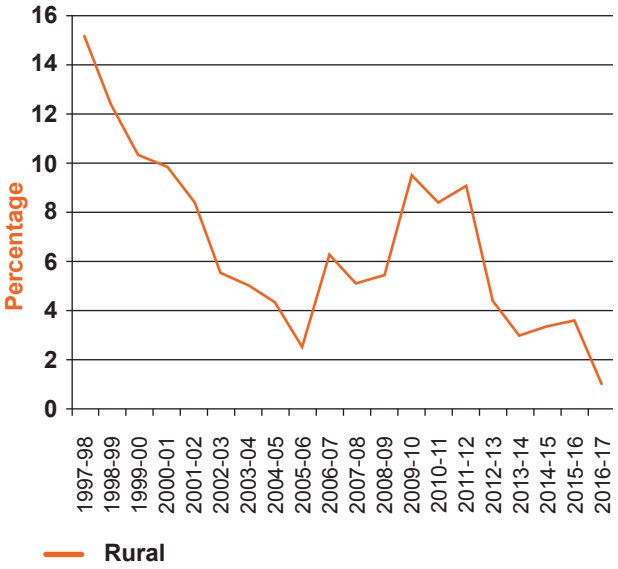
Suhas Wani highlighted the value of solar-drip irrigation systems and thermal solar drying for 1,000 farmers working with vegetables, fruit, and small fish. Through government subsidies these technologies could be made available to farmers, but unless the findings were reflected in appropriate policies, the impact is limited.

12. Ashok Mangotra: Energy and agriculture for smart villages in India

Ashok Mangotra began his presentation by summarising the primary energy demand in India in 2013: coal (44%) led, followed by biomass (24%) and oil (23%). Comparative values in 2000 were 33%, 34%, and 25%, respectively. Bioenergy is mostly used in traditional household cooking, and this lead to associated issues of deforestation and impact on health. The demand for bioenergy is expected to rise by 11% by 2040 according to the International Energy Agency, and this serves to emphasise the rural imperative that is faced by India.

The budgetary share of rural energy in the Ministry of New and Renewable Energy (MNRE) has fallen from 15% in 1997-98 to less than 2% in 2016-17, and while MNRE is not the only source of energy support, this means that other sources of funding have to be found. Where is this money going? In 2015-16, the largest proportion has been invested in solar PV (almost 2000 crore rupees, US$300 million) and wind (about 400 crore rupees, US$60 million).

Budgetary share of rural energy in MNRE



from Ashok Mangotra, former Joint Secretary to Govt of India in the Ministry of New and Renewable Energy

Rural energy initiatives are not new, and many have been running in the past including biogas, improved cookstoves, and integrated energy and bioenergy programmes. The climate change challenge places fresh emphasis on agriculture because it is the second highest contributor of greenhouse gas emissions (19%). Yet this provides an opportunity, and agriculture has led the agenda with substantial adaptation funds offering vast opportunities for rural areas provided there is institutional coordination in addressing the different components of the climate change-food-land-nexus.

In addition to institutional leads, continuous funding support is necessary for the highly motivated NGOs and self-help groups that need bank loans, for barefoot engineers who are tempted to leave otherwise, and for microfinance for rural energy initiatives. Substantial funds are available in the corporate sector where firms are obliged to set aside 2% of their profits for CSR (already estimated to be US$5.2 billion) or the money would be paid directly to government if not used. Ashok Mangotra recommended that ICRISAT could try to go for support for biomass gasifiers and act as a model for others in the development of renewable energy.

The key question is whether there is sufficient effort to bring government and private agencies together in order to aggregate all the different types of funding as there is a risk that too many agencies are involved. An overhaul is necessary.

13. Discussion: Smart villages adding value to smallholder farmers?

John Holmes invited initial responses on three key topics:

1. What are the key challenges and opportunities for energy access to enhance agricultural livelihoods?

2. How can the Smart Villages concept help?

3. Initial thoughts on actions needed

Challenges were identified as including the availability of affordable capital for up-front investment, and the need for learning about energy investments. There is a need to create awareness about the issues, potentially using journalists and marketing, and for capacity building to educate and inform. There are opportunities to attract more funding from the private sector: big businesses may be interested more on a CSR basis than on a market basis. Linkages between energy and agriculture need to be established, which should be framed as part of a clear business plan for the private sector.

Some participants noted that there are lots of small companies ready to provide what is required. What is missing is not the initial investment but the demand side management, looking at social needs (health, nutrition, etc.). It was argued multiple solutions should be packaged in a holistic way and taken to the user to implement, creating all the cross-sectoral linkages.

Another challenge noted was the delivery mechanism. Often there is a whole host of organisations involved, from implementers to the state and government level. The difficulty comes from how these multiple stakeholders interact, the networks they form, and how they work together to produce effective organisation at the field level.

Policy integration was also seen as a key factor. For example, investment in an off-grid electricity system would not come to a locality if there was a possibility of the grid reaching there soon. The reality is that policy makers are inevitably reluctant to tell people that the grid will never come to them, making it difficult for governments to establish clear directives and plans for grid expansion. Often people say they want "real" electricity, which means they want the "real" grid, not a green, local solution.

Four breakout groups subsequently explored these and related issues, and the discussions are reported in such a way to capture the many practical insights.

14. Breakout Groups

14.1 Breakout Group 1: How can investors, banks, and co-operatives best engage to improve livelihoods and productivity in smart villages?

Participants at the workshop agreed that the key to smart villages was to generate employment possibilities in rural communities. The emigration of youth to the cities could only be stemmed if finding jobs in villages was made possible. Agro-mechanisation was considered as a way of enticing the youth to work in the agricultural sector. The development of smart villages should be considered foremost as an initiative to generate employment rather than distributing energy *per se*. Economic solutions are needed to address local problems. Businesses should be developed as a route to employment, and enterprises fostered to drive agricultural opportunities. Skill generation is essential so that the community can take responsibility for the village project and also realise economic benefit.

The group disagreed on whether access to financing is a key challenge. Some argued that the agricultural sector is well-funded, and energy for agriculture is also well financed. However, participants pointed to several problems. In the case of heavily subsided projects, such as the GIZ solar pump programme (see below), one challenge is that well connected and more affluent farmers tend to capture the technology, while it is more difficult for the poorest farmers to benefit from the same. Financing schemes should be tailored to the farmers the project aims to target, bearing in mind that poorer farmers may be unable to contribute even 20% of the cost of the technology solutions offered to them.

Another problem is that subsidies are often rooted through banks, which may not always understand the value of the solution and support it. This is a problem for pumps and even more so for refrigeration technologies. Many of the poorest smallholder farmers do not have a credit history, or may have been unable to repay previous loans and therefore they are no longer judged to be eligible. So while there is funding available, access to these funds is the real challenge. This problem is dramatically illustrated by the high level of suicide among farmers in India, usually related to their inability to pay informal loans (which charge 5% monthly interest rates) when production fails. This would not happen if formal and regulated financing for agriculture was more accessible. The high suicide rates also illustrate the fact that farmers choose to plant cotton in areas not suited to this crop (cotton requires a lot of water and has high input costs), a problem that needs to be addressed by training and information.

The group also discussed CSR funding. Despite a mixed track record because CSR funding often gets channelled back to the company, it is a relevant topic as corporate funding can be very powerful. This source of funding is most suitable for projects that also have a positive social impact and benefit the company, such as pilot projects that create shared value or investments in future markets. CSR funding is however not suitable for long-term funding, but rather it is a good source for discrete projects that may show the way.

The large-scale changes needed to achieve rural electrification at the national level cannot be achieved by isolated small projects. Scalable solutions are required, and therefore it is important to determine the characteristics that have made specific projects successful. This is a challenge since success is often localised, which means that what has worked well in one place may fail in another. A key problem is that ventures are often technology projects without due consideration for socio-economic factors. The group agreed that the solution is to replicate the success

of large-scale infrastructure projects for urban areas, such as the metro system of Delhi. These projects benefitted from long-term investments with very good interest rates. New start-ups are needed in this space.

To summarise, the group agreed that the main problem is not finance as such, but the market distortion created by the political economy which makes it unattractive to the private sector.

Part of the solution is to encourage farmers to organise themselves as a cooperative rather than acting individually, thereby increasing their chances of obtaining loans. The streamlining of the procedures for applying for finance is also required to simplify them and make them more focused on the target groups they are intended to benefit. Projects do well because there is a financial return. Financial solutions that are more flexible (including flexible subsidies, bridging funds, leasing, and soft financing) and not linked to one specific technological solution are needed together with greater political support and governance.

Members of Breakout Group 3 in discussion

14.2 Breakout Group 2: Who needs to be involved in initiatives to develop sustainable productive enterprises in villages, and what should be their roles?

The group identified four key points for the development of smart villages: the facilitation of local entrepreneurs, improved knowledge sharing amongst actors, designing according to the local context, and the role of central governance using key experts.

Village entrepreneurs were identified as key actors with regards to developing sustainable productive enterprises – this should include women entrepreneurs. Often villagers do not know or are not capable of utilising local skills if the finance to purchase agricultural equipment is not available. More work has to be done on awareness creation and establishing a link between available finance and entrepreneurs so they can fully utilise the power available.

Communication between the different stakeholders was highlighted. There is a clear lack of knowledge sharing and different stakeholders have different experiences, but there are few platforms for knowledge sharing between different actors. Collated information on best agricultural practices should be available to rural villages. To classify a village as a "smart village", all village-related data should be available online in a structured way so that practices can be optimised using this information to achieve sustainable enterprises.

The third point concerned the need to *understand the local context* prior to project initiation and the use of this information to design appropriate projects. Participants highlighted that there is still a problem in identifying the real needs of communities. Each specific community is different and thus there is no such thing as a one-size-fits-all value chain. For this reason, it is paramount that a gap analysis is conducted.

The final point raised is that there needs to be a *governing body*. Project implementers cannot be responsible for every step and everyone should play to their own strengths. Thus, there is a need to bring together different experts to work towards a common goal. However, overseeing this is time consuming and cannot be done by the project implementer, i.e., the energy provider. Therefore,

there should be an independent body that oversees and coordinates the efforts.

In regard to the experience to date of engagement between the various actors and how engagement between the actors can be improved, the group identified a number of key actors which included governments (federal and state), NGOs and self-help groups, corporate organisations, academia, village committees, and micro financing institutions (banks and international funds). This collective of stakeholders sets the foundation for the supply chain whatever the enterprise. Each institution has its important role and governments and international institutions have to empower local actors and provide the platform for facilitating them.

A top-down approach does not work and interventions where everyone is working individually and towards their own goals are unsustainable. Presently there is a disconnect between local villagers and the markets: villagers are not aware of activities in urban areas which makes it difficult for them to enter the market. There has to be improved communication between scientists and practitioners so that learnings from research and academia are shared with practitioners and translated into practice.

14.3 Breakout Group 3: What additional steps can be taken to communicate, incentivise, and regulate the adoption of renewable energy for agriculture?

The participants in this breakout session also recognised that it is necessary to make people aware of renewable energy and why it has a role in smart villages and agriculture in particular. First, the benefits of renewable energy have not yet been communicated so that some technologies are seen as second best (for example, solar cookers) or have failed to work in India's extreme heat. People want reliable technologies that will work for the next 20-30 years. Participants differed in opinion regarding the technology—some found that issues with batteries are important limitations to solar technologies, while others noted that technology is not the fundamental issue. In India, particularly for solar pumps, there is a robust industry with numerous successful companies.

In terms of off-grid energy and the extension of the grid in India, participants noted that the government would never say that the grid will not reach certain villages. This creates a problem for entrepreneurs and startups which stand to lose their entire investment if a grid extension unexpectedly appears. However, mini-grid companies are now creating "grid-ready" projects that can be linked to the grid if and when it arrives.

Turning to the reasons why solar panels have not always been a sustainable solution, one participant added that even when villagers are trained to repair them, spare parts are often lacking or there is a lack of follow up. In one example, women moved from roasting cashew nuts, which created a lot of oil and gases, to boiling them. But within two seasons—only 18 months—the plant could no longer run since it consumed so much fuel and electricity. It was a good initial investment by the Renewable Energy Agency but did not finish well.

Some of the other important aspects of communication concern understanding local communities and their languages. A number of credible local NGOs are able to help people to own and accept new technologies. Barriers include language, education, and negative experiences with the introduction of new technologies. Digital Green has worked with a video-based extension system not only in different languages but in local dialects. These videos cover value chains, health, nutrition, reproduction, etc. and are used in 1,500 villages.

In another example of capacity building and training, one participant gave the example of gasifiers in 12 remote and inaccessible villages in Orissa. The gasifiers are complex and require

a great deal of maintenance. The initial methods of training people did not work, so a new method was introduced whereby one person was trained, and they made a video recording showing the operation step-by-step. This worked much better in terms of keeping the system maintained.

Participants also highlighted that webinars and offline methods of communication can help raise awareness. In one case, 500-700 people in each state used a video projector with a lithium battery for 7-10 minute videos where there was no grid connection. Digital Green has found that these videos and discussions work very well, and farmers have been persuaded to adopt new practices because they understood the technology and they had their questions answered. Another approach by KVK, a farmers' science centre, trained farmers from five villages in the hope that they would train other farmers and share practices by word of mouth. However, farmers that did not go to KVK risked being left behind.

Participants also discussed technology deployment versus technology adoption. Deployment was seen as a government activity that aimed to reach certain numbers. But the users' perspective must be developed first. Villagers need to be trained and this has been accomplished through awareness camps in which people learned about and tested the technology first-hand.

Energy for agriculture startups must consider how do you attract the end user, and how to create the early adopters whose experience will go viral? There has to be a "pull" factor—even for the greatest product. Trust must be built because even if a company comes from India, it is still an outsider in many communities. Education and schools are viewed as important ways to attract end users and to build an understanding of the relevance of the technology. In one example, it was found among farmers that only about 10 of 160 farmers had smartphones, while 100 had basic mobile phones. In contrast, 97% of young people (18-35 years) have phones, of which 60% are smartphones. The people most likely to have smartphones are the young studying outside the village.

Regarding communications, a central question is "who is the audience?" Grandmothers, early adopters, and young people may be the audience, while others may be rural bankers. Bankers in particular were a source of discussion since participants felt that the loans for renewable energy technologies could be improved. Others noted that there are guidelines in place encouraging banks to lend, but the implementation is very poor due to perceived risk. There could also be new, flexible solutions such as private lending institutions that are non-traditional.

It was agreed that there needs to be a policy push with targets, but the central government and Ministry of New and Renewable Energy (MNRE) focus on large-scale rather than decentralised systems. MNRE do not mention renewable energy in the context of agriculture on their web site. Agriculture could be integrated better into their work, and there are state agencies mandated with implementation which should become more aggressive in this regard. While some participants emphasised the role of government, others noted that in the U.S., entrepreneurship is viewed as an asset. It is important to have the latest technologies and not to be ten years behind everyone else or to be treated as guinea pigs.

A lesson to be learned came from one example of an organisation that tried to implement renewable energy via thermal solar dryers. There was a communications gap because the organisation did not understand agriculture, and the farmers did not understand renewable energy. Initially, there were a lot of tomatoes that could be dried, and from a technical standpoint it was successful. When farmers looked at the outlets, there was no market for tomato powder. They decided to dry ginger instead since there was a much bigger market. Therefore, market research is crucial; it is not just about technology uptake.

Breakout group discussion

14.4 Breakout Group 4: How can the use of renewable energy for agriculture in smart villages help to mitigate, and adapt to, the effects of climate change?

Discussions began by considering the presence of some scepticism around climate change internationally. However, climate change is being felt in India at the ground level with extreme weather events, changes in the frequency and intensity of rainfall, and in the need for air conditioners and fans. Impacts of climate change on villages include reduction in crop yields and crop losses, reduction in forest products, a lack of availability of fodder, seasonal migration of labour and depletion of water levels with its impact on water and sanitation.

If fuel is produced from alternative sources, the need for forest products is reduced with benefits for deforestation and the loss of biodiversity. If people in these areas only took what they needed and did so sustainably, it would reduce forest depletion. One participant noted a case in Kenya where charcoal was being made from a particular forest on an annual basis where they were using a tree species that re-generated fast. However, problems arose when replanting was not happening fast enough and there was insufficient time for regeneration. This emphasis on agro-forestry and the conservation of forests would help to address climate change through the absorption of carbon dioxide emissions.

At the policy level, there is progress in building up climate change resilience at state and national level, and there are now mandatory climate change mitigation plans in all states. Furthermore, policy changes are pushing for a significant reduction in coal usage, the scaling back of the coal industry, clean coal technologies, as well as big investments in solar energy nationally with a focus on attracting a large number of private investments in solar panels.

Other ways in which renewable energy can assist in the mitigation of agriculture's effect on climate change include biogas and biofuel production. Biogas produced from biomass and waste resources can also produce good quality slurry as

an alternative fertiliser or compost. Experiences of some participants suggest that biogas plants reduce the need to use traditional energy sources such as firewood and forest products, and facilitate waste management by reducing methane production. Some controversy exists over the burning of biomass instead of forest products and whether it really does reduce greenhouse gas emissions (GHG). The Royal Netherlands Academy of Sciences published a controversial report recently showing that there was no reduction in GHG emissions from biomass. Biofuels such as bioethanol and biodiesel with 5% blending are now being expanded in India for use in transportation and railways, though transport in airplanes required the high energy density fuels derived from fossil fuels. Questions persist about the efficacy of the switch from diesel to solar pumps and whether it improves efficiency.

Innovative farming practices can contribute positively to GHG reductions. A drum seeder improves farming efficiency by bringing down the use of seeds by a quarter enabling them to be sown directly. More efficient farming practices reduce the need for tractor use; typically bullocks are used to farm the land, but there is a distinct trend towards tractors even in smallholdings. Farmers pay to rent tractors to gain more time for other activities but a question was raised as to what is actually done with this time. On the other hand, practices to improve farming practices can lead to requirements for better roads and transport to take the food to market. Therefore, it is essential to consider whether developments will reduce or increase emissions overall. The implications for smart villages need to be considered all the way down the value chain to establish the real impact on the environment.

Other innovations that may influence climate change in the agriculture sector are the growing use of e-markets and farmer producer organisations (FPO). Increasingly, India is moving towards e-markets where the product is graded with fixed pricing which reduces the role of middle men. FPOs enable negotiations to take place at the bulk level. By aggregating things at a local level, combining products and activities, and having a fixed price from e-markets, there could be greater security for farmers. If farmers feel more secure then they may be more likely to adopt and trial new technologies and practices

Ashok Mangotra and Brian Heap discuss India's renewable energy plans.

that reduce emissions as in the case of reducing methane production in rice paddies. Another related benefit is that by federating farmers' individual usage of facilities such as agricultural equipment this can help to minimise harmful emissions.

An interesting assumption was noted: that farmers actually want to stay working in rural areas and to continue working in agriculture. However, there are some countries where people prefer to return to rural communities and the extent to which this is happening needs to be established. Related to this is whether increasing the quality of life in villages more broadly would help to stem the trend of rural to urban migration.

Climate change can also have knock-on social impacts through extreme weather conditions affecting health, education and food security. Smart villages will have to adapt to these negative impacts and in the case of agriculture, innovative farming practices along with crop breeding activities (helping crops to cope with changing weather conditions) could help communities adapt. ICT connections can also give farmers access to weather forecasting and agricultural information and help communities to cope with disasters. A caveat to this discussion is the issue of employment because when practices and processes change, peoples' jobs and livelihoods also change. For example, if you stop people taking wood from forests to make charcoal, what are they going to do instead? This act could worsen migration to slums. There is a potential tension between what should come first: energy access or jobs. Ultimately, technologies can work to reduce human involvement and therefore people would need to be re-skilled in certified skills that could help employability. Some participants believed that there are skilled job opportunities in smart villages as well as in the cities.

15. Elevator presentations

In common with other Smart Village Initiative workshops, short presentations were invited to enable participants to engage directly with some of the personal and practical experiences in rural communities.

Kelly Mermuys (MPower): Schools inspire villages

The vision of M-Power is to eradicate poverty via access to energy using innovative decentralised hybrid renewable energy solutions (solar, wind, biomass, mini-hydro, and geothermal) in schools. Even where villages are electrified the power is often so unreliable that it cannot support initiatives which require an electricity supply. MPower seeks to create awareness of renewable energy by utilising real life examples. Part of the awareness raising is necessary as a result of the up-front investments needed for renewable energy systems. Ultimately the aim is to develop 100% sustainable villages with involved stakeholders.

The presentation by MPower focused primarily on a primary school project in six schools in Telangana state. The project provided a 19 kW solar rooftop PV system with battery backup at each of the schools. The provision of solar PV counteracted frequent power cuts from the grid and helped to enable the use of a water pump. The government subsidised 32% of the school solar system supported by the local education officer. The project is consistent with national and state level policies. It could aid companies in making them compliant with India's CSR law, and its implementation needs many stakeholders and an investment network. The project is looking for CSR funds for investment in its final funding phase (it could be installed in less than three months).

Pritam Kumar Nanda (Digital Green): Extension through innovative ICT

Digital Green originated out of Microsoft research in Bangalore and is an independent trust. It aims to take expert developments in agricultural information to farmers and provide farmers with a tool to do their work better, in a way that can be done remotely and jumps the language barrier. This is done through a video-based extension system with the videos not just being shown to communities but also mediated. Since 2012, the project has reached 6 countries and over 1 million farmers. The Digital Green mission is to integrate innovative technology with global development efforts to improve human well-being. It acts as an effective knowledge management platform, builds community-to-community knowledge transfer, shares knowledge on agriculture, health, and nutrition, provides better practices, and enables people to learn from each other. The use of video in particular has increased the reach of targeted information and maximised the impact of social workers.

Social workers train 4-6 people in the community to create videos and then share these via projection. Videos provide resource-savings in terms of cost, time, and human resource, particularly because the technology is more affordable. Through videos, those who are illiterate can also understand the processes at work. As the videos are made by the community themselves, there is a personal element: by seeing a technique work for their neighbour, other community members have the confidence that it could work for them too. At each video screening, data are collected, and learning and reflection provide the basis for future work and informed video developments. Digital Green also runs randomised control trials to ascertain how practices impact areas such as

quality of life. They are also looking at measuring the increase in incomes of farmers and reductions in costs. The Digital Green approach is empowering rural communities and improving quality of life.

Alfred Arunkumar Daniel: The SAFE Network, Vellore

Marginal farmers represent 67% of India's farmland with holdings below one hectare but for half of the country's farmland, irrigation has yet to reach farmers who consequently rely entirely on rains for their crops. How does a farmer explain climate change? "*There are no rains when they are wanted, but when they aren't wanted, they come, and in excess*". India's agro-climatic regional planning has documented the zones of maximal opportunity for diversified agriculture on smaller farms. Planning is needed to utilise such opportunities and to provide the supportive agro-processing and market and communication facilities that involve all stakeholders, for example cooperatives, farmers' representatives, NGOs, and researchers, etc.

Pritam Kumar Nanda of Digital Green (from www.digitalgreen.org)

Farming in smallholdings is becoming unviable as such farmers need to use mechanisation but cannot afford to. Consolidation of farmers into groups is required to integrate the use of new technologies. The SAFE network aims to conduct a baseline survey of poor farms in different parts of India to understand off-grid situations and promote sustainable models and replicate best practices. The SAFE network promotes water conservation methods such as drip and sprinkler irrigation and the use of millet seeds in drought. It also promotes deep water and lodging resistant varieties of paddy in floods, and diversified farming practices (e.g. livestock, orchards) to improve income streams. There is an existing network of NGOs that have already established agricultural activities among nearly 12,000 farmers across five districts, which are always at the forefront of calamities caused by climate change.

Anshuman Lath (Gram Oorja): Energy access in rural India enabling agriculture

Gram Oorja aims to fulfil the electricity, cooking, fuel, and water needs of tribal communities in the remote, off-grid regions of India using solar PV micro-grids, biogas-based cooking grids, and solar pumps. The organisation ensures operational and financial stability through an effective metering and tariff mechanism, and organises appropriate finance working in the tribal villages of Maharashtra, Jharkhand, Odisha, Rajasthan and North Karnataka, with plans to expand into the tribal belts of Madhya Pradesh, Chhattisgarh as well as the North-East. Clients include some of India's largest foundations (Tata Trusts, ICICI Bank Limited, policy and research institutions worldwide). They are also founded by entrepreneurs from premier institutions like the Indian Institutes of Technology (IIT) and the Indian Institutes of Management (IIM) with professional experience in social, financial and energy sectors.

Gram Oorja works to ensure delivery of sustainable projects, working with funders, community partners, customers and beneficiaries from proposal through to implementation. Their products include solar micro-grids (14 total and 10+ ongoing), biogas grids (three total and one ongoing), solar water pumps (50+) and solar electrification of education and health institutions (10 and 11, respectively). Their first solar micro-grid for 39 tribal households was initially a smaller size system (due to funder preference) but the organisation fought for the larger size, primarily for agricultural reasons. Policymakers and researchers have visited from 35 countries to observe this site as an example of tribal electrification. The idea is

that once people have seen people like them with such access, demand will be created. In terms of sustainability, data are collected on generation, usage, and billing, and local community partners are used for longer-term handholding. Furthermore, the idea is that by the time the community needs to replace a battery, the village has enough in the "kitty" to afford it themselves.

Solar pumps intended for drinking water have an agricultural spin-off benefit. They are monitored monthly looking at efficacy, money collections, and maintenance costs covered for drinking water. Solar PV can be used for productive enterprises such as a flour mill or rice huller. Deep interaction with the community is essential to identify inherent leadership, to get women involved, and to build trust. The system also has to be designed to take into account future aspirations and lifestyle changes and livelihood opportunities that warrant high loads. The tariff needs to be designed so that it is sustainable with metered consumption to help load management. Creating billing collections is essential for battery replacement and day-to-day management. Other considerations include minimising battery back-up, meeting safety and quality standards, and ensuring the effective transfer of ownership from the entrepreneur to the community.

Anshuman Lath, Founder of Gram Oorja

In relation to biogas cooking stoves, the benefits include being cleaner and healthier, a reduced burden on women for firewood collection, increased time for family and productive cottage industries, and less burden on forests. Where cattle are present in villages the availability of cow dung can enable biogas production. Anshuman Lath concluded by noting the need for acceptance of the idea that energy and mini-grids are becoming part of village life.

Abishek Jain (CEEW): Solar-based sustainable irrigation – strategy

The Council on Energy, Environment, and Water (CEEW) is one of India's leading think tanks, and Abishek Jain focused on the need for irrigation (and energy) to improve food security and farmers' livelihoods through solar based sustainable irrigation. About 45% of the net sown area in India is irrigated and the rest is rain-fed. A lack of irrigation limits the potential for a second or third crop during the year. Three options for irrigation were described - electrical pumps, diesel pumps, and solar pumps. For farmers, electrical pumps can be unreliable because of odd hours of supply. They are highly cost effective, but for the state, they require high consumptive subsidies. There are difficulties in load management, and environmentally, there may be excessive groundwater depletion.

Diesel pumps, though requiring a small one-time outlay, produce high cost irrigation and difficulties in regular diesel supplies for farmers. For the state, they involve consumptive subsidy, and environmentally they contributed to CO_2 emissions. Solar pumps act as a positive alternative, they can aid climate change mitigation and adaption and reduce inequity in access to irrigation.

CEEW created a framework of factors that impact the sustainability of solar based irrigation (e.g., economic, social and environmental) and used an indicator of a solar-powered irrigation system (SPIS) to evaluate government and state-based policies by a systematic review of the literature, semi-structured interviews and on-field visits. Different parameters were looked at such as inadequate access to affordable and reliable irrigation, economic viability of solar pumps, the purchasing

capacity of farmers, access to banking facilities, subscription to long term loans, and farmers' attitudes towards adoption of new technology. CEEW rated the districts in terms of these parameters and grouped them into four categories for solar pump potential: high potential, moderate potential, moderate potential but water constrained, and low potential districts. A tool was then developed to access this information efficiently. CEEW have set out immediate, short term and medium term strategies to ensure the solar pump irrigation system's sustainability.

Nilanjan Ghose of the Indo-German Energy Programme (IGEN Access).

Nilanjan Ghose (IGEN Access, GIZ): Solar-based sustainable irrigation – practice

Nilanjan Ghose focused on the approach and experience of the German-based enterprise, GIZ, within the off-grid space and their attempts to support a market-based system. The market status for solar-powered irrigation pumps in India is that they are primarily driven by government programmes, with a capital subsidy by central government and varying subsidies at the state level. Different departments may provide different subsidies, and it is a regulated market with limited involvement of banks. The main challenges that are faced are: 1) awareness (among farmers and bankers); 2) affordability (high up-front costs and limited involvement of financial institutions); 3) availability (in terms of technology and financing options). Farmers are not convinced that the incremental income a pump brings is significant enough to offset the initial investment required.

Currently, this is not an off-the-shelf technology, although different manufacturers are moving into this space. NABARD is the Ministry of New and Renewable Energy (MNRE) scheme for solar-powered irrigation pumps in India, and GIZ is supporting the roll out of this scheme. It involves greater participation of banks, a capital subsidy by central government (40%), a loan (40%), and farmers' down payment (20%). The choice and selection of the pumps in this programme is with the farmers, which marks a change from what has been done previously.

The approach of GIZ through the Indo-German Energy Programme is the promotion of solar powered irrigation pumps facilitating demand by working with farmers and cooperatives to demonstrate the pump, and to gain an idea of frequently asked questions to design appropriate communication materials such as mobile phones with a purpose-designed app. GIZ look to improve the supply chain and support the market ecosystem by developing better relations with last-mile bankers so that they are more willing to provide loans. There was very little awareness about the pumps among the sales team of the private sector that interacted with farmers.

In terms of challenges, the issue of theft is prevalent, so security issues have to be taken into account. Since the subsidy is high and done on a first-come, first-served basis, there are difficulties in farmers accessing regional rural banks to provide the loans. However, the private sector is starting to reach out directly to farmers. In terms of financing solar pumps, there could be more private sector bank involvement by better understanding of the sector. Bankers are apprehensive about the issue of theft and what happens to the asset if farmers stop payment of the loan. A further problem is that solar pumps work best when radiation is at its highest, a time when farmers do not want water, so the potential options are to have a storage tank which incurs additional operational costs. DC pumps offer greater efficiency than AC

pumps. The government subsidy scheme does not allow the use of a battery for solar pumps.

Lata Shukla: Sustainable biofuels from large-scale algal culture using bioprocess technology.

Algae can be used as an efficient biological producer of oil, biomass, and biofuels. They have high photosynthetic efficiency and a faster growth rate than other plants, they can grow in treated wastewater, and cheap fertilizers can be used to provide the nitrogen source. The technology can utilise non-arable land to grow the algae. The production is not seasonal and can be harvested daily. The energy return on investment for algal biofuel production coupled with waste-water treatment and the thermodynamic analysis of algal biocrude production is also known. An algal photobioreactor can provide continuous production of biomass and advanced technologies are available for the isolation of oil from biomass.

A tubular bioreactor was described with three key merits: waste water usage, carbon dioxide fixation, and oxygen generation. The system has a higher yield than other biodiesel feedstocks, less spatial requirements and does not compete with food production. Microalgae are considered one of the main biodiesel feedstocks for the future, but to be competitive in the bioenergy market, the cost and production capacity must be better than other biodiesel feedstocks.

During the general discussion that followed of new developments for smart villages, it was noted that GIZ are developing cooling systems based on green energy technologies. Others noted ongoing work using renewable energy and DC technologies for cooling, air cooling, and localised freezing of materials which can be applied to the storage of liquids, vegetables, and medications. This is an area that has not yet been properly developed and opportunities exist for hybrid solutions using biogas and solar technologies for refrigeration.

A further discussion centred on how villages could become smart in countering natural disasters arising from climate change. Resilience was seen as an important component and was identified as a gap in the current smart villages programme. Special infrastructure could be used in planning smart villages such as remote sensing, GPS, and ICT, and India is now active in climate change mitigation. However, it is important that one organisation did not try to address every single issue; collaboration is the key to success.

16. Chhotkei: India's exemplar smart village

Ameet Deshpande (Sun Moksha): India's exemplar smart village

An interactive session after dinner with Ameet Deshpande focused on Smart Nanogrid™, which is a flagship solution from SunMoksha for comprehensive management, maintenance, and remote monitoring of mini-, micro- and nano-grids for sustainable development of communities. A unique feature of Smart Nanogrid™ is the integration and comprehensive management of diverse resources such as energy, water, air and agriculture into a single source platform. The Smart Nanogrid™ can be customised for diverse communities such as villages, cities, townships, campuses, industries, and institutions. SunMoksha has established a network of smart nanogrids to enhance the sustainability and scalability of the platform, and to bring about knowledge sharing for its stakeholders.

Ameet Deshpande described how the Smart Nanogrid™ was implemented in the village of Chhotkei, Odisha, which is a small remote village inside the hilly and scenic terrain of Satkosia Tiger Reserve, about 5km from its Gram Panchayat, Purunakote (information on the scheme is available at http://www.smartnanogrid.net/Smart-VillageNanogrid/). It is 65km from its district town, Angul, and 160km from the state capital, Bhubaneswar. Angul is one of the most developed districts of Odisha, but grid electricity is yet to reach Chhotkei. Lack of electricity precludes people from the privilege of voice communication as the village has no mobile tower access. The nearest health centre is 35km from the village, which makes it extremely difficult for the villagers to travel for their health needs.

"Chhotkei is situated amidst rich natural resources. There was no electricity to set up microenterprises, the primary livelihood was rain-fed paddy cultivation once a year, there was no irrigation system for lack of electricity, and the lack of year-round agricultural activities and local employment compelled people to work as daily labourers in local and distant places. The village has now been supplied with a 30 kWp solar-powered Smart Nanogrid™ to meet the energy demands of 140 households, 20 streetlights, a temple, and three community centres consuming about 20 kWp. The rest, 10 kWp, has been set aside for day-time use by irrigation pumps and microenterprises such as poultry, stitching, rice-puff machines, provision stores, refrigerators, oil mill, welding machines, etc. to improve agricultural output, generate employment, and enable value-addition

Chhotkei, Odisha smart village (by kind permission, Dr Ashok Das)

to agriculture. Power is supplied to the distribution boxes, spread throughout the village. Fibre optic cables are used to communicate to these meters and controllers from the local server at the power plant control room.

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

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

Ameet Deshpande's presentation was received with much interest and extensive discussion as it represented a novel exemplar of how to build a smart village in a remote area of India.

17. Concluding messages about the smart villages concept

17.1 John Holmes: Lessons to date from Africa, South East Asia, and Latin America

Five key messages from the first half of the three-year Smart Villages Initiative were summarised by John Holmes.

Cross cutting issues. Meeting 2030 targets for rural electrification will require a significant increase in the level of investments. However, access to affordable finance remains a problem for many companies since banks view rural energy as a high-risk investment area. Currently, it is very hard for small- and medium-size companies to obtain even relatively small amounts of financing. It is therefore important for private sector companies to do more to build up and share their profile and track records to convince banks to lend money with more affordable interest rates, especially for scaling up operations. Capacity building is central. In addition to being required for businesses and financial institutions to improve their knowledge of the rural electrification sector, it is essential in rural communities to know how to correctly install, use, and maintain energy systems, and also to encourage productive use of the newly available energy sources. It is also very important to involve women and the youth to ensure they benefit. Awareness creation is therefore central: "seeing is believing" demonstrations are very powerful. Another key message is "don't give things away for free" as free technology often falls into disuse, and handouts distort the market and discourage private sector involvement.

Home-based supply. Substantial advances in the technology in particular areas comprise both reduction in costs and increase in the efficiency of appliances (such as third-generation solar systems distributed now in South America). Two success stories were presented. In East Africa, solar electrification projects have been largely business driven. Their success could be improved by facilitating access to finance, improving leverage of existing distribution networks, and building the skill base. In contrast, rural electrification in Bangladesh has been led by the government. The reasons for success include ownership of the projects by the stakeholders, subsidised finance, the possibility of repayment in instalments, effective technical standards and adequate post-sale support. A big problem in all instances is the presence in the market of low quality and counterfeit products. There is a need for national governments to set and enforce standards, and also for an international initiative that addresses this issue across borders. Technical developments needed include improved batteries, a larger number of plug and play systems, new PV technologies, efficient appliances, and recycling programmes for disused parts.

Mini-grids. The story for mini-grids is less positive. Many pilot schemes have been developed, but successful scaling up operations is not very common. One problem is that low usage of electricity in the absence of industries makes costs higher than revenues. Set tariffs do not usually reflect real operation costs, and an environment of changing policies could increase the financial risks. A greater convergence of policies and practices is required, together with more flexible and supportive financial schemes (such as partial subsidies, although these can be perverse for the sector in the long run if not properly designed). The importance of community engagement cannot be overemphasised. It is essential to build on local knowledge and customs and identify "local heroes". It is very important to ensure that poor people in the village have a voice and a stake in the project and benefitted from it. Projects tend to be mostly social in nature, rather than technical, and recognising this mix is critical for success.

Cooking. Cooking with unsustainable and polluting sources of energy has many negative impacts: on individual health (in particular women and children); on the environment (responsible for the accumulation of black carbon in the atmosphere, which is a significant contributor to climate change) and on society, since collecting firewood and other types of combustibles requires time, physical effort and is linked to increased exposure to risks, especially for women. A key message for improved cooking technologies is the need to be aware of the use and demand for technologies (such as the time of the day when the preparation of food takes place), which may vary according to the communities involved. Financing schemes and subsidies are required to ensure the viability of the value chain. The varying quality of products in the market is also a challenge in this sector.

Sustainable Development Goals (SDGs). Ambitions need to be higher if the SDGs are to be met, and better integration between different initiatives addressing other development needs is required. Better coordination and the sharing of information needs to be promoted (for example, between different agencies, experts and stakeholder groups). More applied research projects in universities are required, and better linkages between university and energy practitioners. It is also very important to carry out a thorough and systematic evaluation of development outcomes, to learn both from successes and failures.

During the ensuing Q&A session the necessity for standardisation was mentioned, although a challenge was deciding the time at which standards need to be introduced. The importance of increasing awareness of rural communities of the opportunities and technologies available was also raised. How do you share the knowledge accumulated during the project? Perhaps the role can be fulfilled by an organisation sharing best practices. It is important to develop a model of the elements of best practice in a smart village.

17.2 Shailaja Fennell: Lessons from the smart villages state-level workshops

Shailaja Fennell introduced her presentation by observing that the concept of the Smart City has dominated public discourse and state-level governments met the smart villages concept with initial scepticism, mainly due to the fact that development is often related to energy provision, and coal is still a very important source of energy in India. At the same time the country is committed to reducing carbon emissions to mitigate climate change. This situation offers an opportunity: the development of smart villages can result in a win-win situation: the creation of rural jobs and an improvement in the environment.

The state of Jharkhand exemplifies some of the contrasting conversations between development objectives and the preservation of cultural values and beliefs. The state is home to a large proportion of tribes and has both a very low level of rural electrification and one of the highest proportions of rural inhabitants with very high rates of population growth.

Smart cities mean different things to different people, and this makes them an opportunity as much as a challenge. Smart cities need smart villages, and energy access is key for both smart cities and villages. After the launch of the 100 Smart Cities Mission, the Government of India is now shifting its focus towards building smart villages with its recently launched programme Shyama Prasad Mukherji Rurban Mission (SPMRM), aimed at making villages smart and growth centres of the nation. Currently, the government is preparing its plan for 2,500 smart villages by 2019. To ensure a standard of development, 14 components have been included in a list of 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 man-

agement, 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 connections.

The concept of smart cities based on smart grids and devices is proposed as a mechanism to generate economic growth, and to create wealth and sizeable demand for rural and agricultural products, thereby enabling the shift from subsistence to commercial agriculture. However, in rural areas, this shift to commercial activity requires higher agricultural productivity and diversification to include non-agricultural, income generating activities (for example, food processing, construction, businesses and services). For a sustainable transition of the entire economy, there needs to be a linkage of networks, both human and technical, between rural and urban areas to sustain growth and to promote the convergence of living standards for all citizens.

17.3 Suhas Wani: Messages from ICRISAT

Reflecting on key messages from the workshop from ICRISAT's perspective, Suhas Wani indicated that energy is a fundamental component of the requirements for rural development, and one that ICRISAT has not fully considered up to now. The key message from the meeting, however, is the need to take a holistic approach: in smart villages, energy services need to be integrated with improved agricultural production, food security and all the other aspects that make a village "smart". Energy alone is not sufficient for development. No single solution will suffice to achieve the goal.

A key challenge is to improve economic prospects for the rural youth so that they are able to choose a life in their village instead of having to migrate for survival. Water is critical: the average per capita income can be twice as high in rural communities with adequate watershed management practices than in poor urban settings. It is also important to maximise the utility derived from renewable energy sources by the direct use of DC power and appliances with improved efficiency.

Coalitions and consortia between agencies with complementary expertise should be established with a dual purpose: to share expertise and learn from experience; and to increase recognition and support for rural development from policy makers.

17.4 Concluding comments

David Bergvinson emphasised the benefits of bringing together two constituencies that do not meet as frequently as they should—energy and agriculture—because it is at the interface that new and exciting interactions emerge. ICRISAT has a strong international focus at its two main centres in India and sub-Saharan Africa on plant-based agriculture for the semi-arid tropics and on the promotion of agri-businesses. It was clear from the workshop that by introducing the dimension of renewable energy for which the semi-arid tropics are well placed, there are synergies that are particularly relevant to farmers who live off-grid.

Brian Heap confirmed these sentiments and commented on the immense value of learning from international, national, and local experts, and in particular frontline people who are having a remarkable impact by exploring the positive ways in which renewable energy can transform and enable off-grid enterprises. The findings of the workshop have expanded those of the Technical Report number 7 which had been circulated in draft form before the meeting. The Smart Villages Initiative team were deeply indebted to all who had contributed to the success of the workshop and in particular to our ICRISAT hosts.

18. References

1. *Poor people's energy outlook 2016* National energy access planning from the bottom up. Practical Action: Rugby Warwickshire UK

2. International Energy Agency 2015

3. http://www.se4all.org/content/webinar-multi-tier-framework-tracking-energy-access

4. http://www.irena.org/publications/REagrifood/

5. Tracking Clean Energy Progress (2016) International Energy Agency. http://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2016.pdf

19. Appendices

Appendix 1 Press conference

On Thursday, 22 September, ICRISAT and the Smart Villages Initiative co-organised a press conference with 40 journalists from local, regional, and national media outlets, including print and television. ICRISAT was represented by David Bergvinson, the Director-General, and ICRISAT Asia Director Suhas Wani. The Smart Villages Initiative was represented by Brian Heap, Senior Scientific Advisor, and John Holmes, Project Co-Leader. Ameet Deshpande represented Sun Moksha and its pioneering smart village at Chhotkei, Odisha.

Brief opening statements focused on the importance of closer links between energy and agriculture particularly in India's "last mile" villages. The panelists noted that India is highly dependent on agriculture: 56% of the overall population relies on agriculture for their livelihoods, while in some states, it can be as high as 75-80%. A holistic approach to development is crucial and must take into account the nexus of water, energy, and poverty. Even in areas where there is grid access, more water via pumps does not necessarily lead to more agricultural productivity; water must be utilised at the right time, and farmers must have a reliable supply of energy for pumping water at the right times. This could increase farmers' prosperity. The smart villages concept is gradually becoming a reality because of new technologies and lower prices for components such as solar panels.

Ameet Deshpande of Sun Moksha spoke about a solar-based power plant in Odisha that provides 30 kW of power to 150 homes via a "smart nano-grid". The project is managed via software and allows for energy to be scheduled when it is needed; loads and irrigation pumps can be scheduled, for example, as can the energy needs of micro-enterprises and homes. Moreover, there is a WiFi facility so that villagers can access the internet.

John Holmes, Smart Villages Project co-leader, responds to questions

In the question and answer session, journalists asked whether villagers' ways of life and economic models are being considered. John Holmes replied that an integrated approach, addressing ways of life, productive enterprises, healthcare, education, and water, is essential to building smart villages. Energy access does not necessarily result in development by itself. The Smart Villages Initiative team itself is diverse and includes economists, sociologists, physicists, engineers, and anthropologists. The big question is not simply technological but how to ensure that energy access initiatives are accepted by villagers and that they have the right support to make them sustainable. Brian Heap added that democratic participation is another aim underlying the Smart Villages Initiative; 600,000 villages needed to be drawn more closely into democratic participation.

Journalists also asked whether smart villages and decentralised energy are financially viable. John Holmes responded that in many parts of the world solar home systems are selling commercially, especially with pay-as-you-go (PAYG) models. In other cases, where electricity is supplied at the community level, there are a number of companies implementing mini-grids, which provide more power for productive uses in villages. Costs are coming down and viable business models emerging. They should be economically sustainable without government or philanthropic subsidies in a few years. Once they reach that point, they will move along very quickly.

Following this question, another journalist noted that the trend of villagers moving to cities is not stopping and that agriculture is not an economically viable source of income. Are smart villages really economically viable? John Holmes responded that once a good level of opportunity exists in a village—especially for livelihoods and a decent level of life, with connectivity via the internet—more young people will want to continue living there. The key is to find a way to make smart villages happen and ease the trend of migration; an important part of this is ensuring that farmers are part of the value chain and profit from their crops, fish, or livestock. Brian Heap gave the example of Terrat, a Maasai village in Tanzania where a smart village exists and where migration to cities has decreased once jobs were created and connectivity was established. Suhas Wani emphasised that the basic question concerning the viability of an agriculture-based lifestyle and income is: what price do farmers receive for their products? The prices are often set by the government. So governments must change their policies and then farmers must be linked to the market and get the part of the profits that currently go to intermediaries in the agricultural value chain.

Appendix 2. Workshop Programme

SMART VILLAGES
New thinking for off-grid communities worldwide

Smart Villages, Energy and Agriculture
21-23 September 2016
ICRISAT, Patancheru, Telangana, India

The Smart Villages Initiative is a global initiative that aims to help policymakers, donors, and development agencies concerned with rural energy access across the Global South with new insights on the barriers to energy access in villages in developing countries – technological, financial and socio-political – and how they can be overcome. We focus on off-grid villages, where local solutions (home- or institution-based systems, and mini-grids) are usually more realistic and cheaper than national grid extension. Our concern is to explore how energy access can result in development and the creation of 'smart villages' in which rural communities have access to healthcare, education, clean water, ICT, and livelihoods. **See our recent publications and workshop reports: http://e4sv.org/resources/**

Thursday 22 September

9.00 Welcome and introductions
Dr David Bergvinson (ICRISAT) and Prof Sir Brian Heap (Smart Villages Initiative)

9.10 Video message
Dr M S Swaminathan (ICRISAT and Chennai)

9.15 What is a smart village?
Dr John Holmes (Smart Villages Initiative)

9.45 Smart villages and agribusiness
Dr Kiran Sharma (ICRISAT)

10.15 Tea break

10.45 Women entrepreneurs to smart villages
Dr Shailaja Fennell (Smart Villages Initiative)

11.15 Smart villages: Renewable energy and mini-grids for agriculture
Dr Debajit Palit (TERI, New Delhi)

11.45 Smart Food
Joanna Kane-Potaka (ICRISAT)

12.00 Discussion: Smart villages adding value to smallholder farmers?
Dr John Holmes (Smart Villages Initiative)

12.30 Lunch

14.00 Break-out groups
i. How can investors, banks and co-operatives best engage to improve livelihoods and productivity in smart villages?
Leader: Dr Raj Dravid (New Delhi)

ii. What are successful models for engagement to develop sustainable productive enterprises in smart villages?
Leader: Ashok Mangotra (New Delhi)

iii. What additional steps can be taken to communicate, incentivise and regulate the adoption of renewable energy for agriculture?
Leader: *Dr Shailaja Fennell (Smart Villages Initiative)*

iv. How can the use of renewable energy for agriculture help to mitigate and adapt to the effects climate change in smart villages?
Leader: *Sir Brian Heap (Smart Villages Initiative)*

15.30 Tea Break

16.00 Report back on Breakout Sessions

17.00 Finish

Dinner to include interactive discussion about smart villages case study *Ameet Deshpande and Srinivas Andoluri (Sun Moksha)*

Friday 23 September

9.00 Plenary: Smart villages: A new industry for electrical engineering
Prof Ashok Jhunjhunwala and Dr Prabhot Kaur (IIT Madras)

9.30 Plenary: Smart villages: Role of ICT in agricultural productivity
Dr Suhas Wani (ICRISAT)

10.00 Elevator Presentations: Making villages smart and climate resilient
i. Schools inspire villages - *Kelly Mermuys (MPower)*

ii. Extension through innovative ICT - *Pritam Kumar Nanda (Digital Green)*

iii. The SAFE Network, Vellore - *Alfred Arunkumar Daniel (Vellore)*

10.45 Tea Break

iv. Energy access in rural India enabling agriculture - *Anshuman Lath (Gram Oorja)*

v. Solar-based sustainable irrigation - strategy - *Abishek Jain (CEEW)*

vi. Solar-based sustainable irrigation - practice - *Nilanjan Ghose* (IGEN Access, GIZ)

vii. Sustainable biofuels from large scale algal culture using bioprocess technology - *Lata Shukla* (Pondicherry)

12:00 Press Conference
Dr David Bergvinson & Dr Suhas Wani (ICRISAT); Dr John Holmes & Sir Brian Heap (Smart Villages Initiative); Mr Ameet Deshpande (Sun Moksha)

12.45 Lunch

14.00 Plenary session
a) Lessons from Africa, South East Asia, and Latin America (Interim report) –
Dr John Holmes (Smart Villages Initiative)

b) Lessons from Hyderabad workshop
Dr Shailaja Fennell (Smart Villages Initiative)

c) Messages from ICRISAT
Dr Suhas Wani (ICRISAT)

16.00 Finish

Exhibition of Posters

Empowering women and Girls: *Shiva Chandna (University of Cambridge)*

Connecting Dreams Foundation: *Amit Tuteja (Connecting Dreams Foundation)*

Indian Green Building Council Village Rating: *S Srinivas (Hyderabad)*

Schools Inspire Villages: *Kelly Mermuys (MPower)*

ICRISAT Village Advisory Dashboard

ICRISAT Smart Food Programme: *Jane Kane-Potalka (ICRISAT)*

ICRISAT Golden Agriculture Village Scheme for farmers in Karnataka

Wonder in waste management: Traditional rural waste management: Dr Mohammed Ataur Rahman (Dhaka)

Sustainable biofuels from large-scale algal culture by using bioprocess technology: Dr Lata Shukla (Pondicherry University)

YouGrowCulture - Discovering that farm near you: *Sandeep Prakash (Bangalore)*

Sustainable energy and agriculture: *Vidya Devabhaktuni (SKG Sangha)*

Appendix 3. List of participants

Srinivas Andaluri, Sun Moksha
David Bergvinson, ICRISAT
Shri Krishna Byre Gowda, Karnataka
Claudia Canales, Smart Villages
B Kalyan Chakravarthy, EPTRI, Hyderabad
Shivi Chandna, Smart Villages
K Chandrasekhar, ISRO Agriculture
Alfred Arunkumar Daniel, Vellore
Sudhansu Sekhar Deo, Regional Centre for development and Co-Operation, Odisha
Vidya Sagar Devabhaktuni, SKG Sangha
Raj Dravid, EcoDev
Sandy Evans, Smart Villages
Shailaja Fennell, Smart Villages
Nilanjan Ghose, IGEN-Access
Brian Heap, Smart Villages
Stephi Hirmer, Smart Villages
John Holmes, Smart Villages
Molly Hurley-Depret, Smart Villages
Rama Iyer, T-Hub, Hyderabad
Abhishek Jain, CEEW
Ashok Jhunjhunwala, IIT Madras
Joanna Kane-Potaka, ICRISAT
Prabhjot Kaur, IIT Madras
Nigel Kerby, ICRISAT
D Ram Kiran, ICRISAT
K Krishnappa, ICRISAT
Anshuman Lath, Gram Oorja
Ashok Mangotra, New Delhi
Kelly Meymuys, M Power
Pritam Kumar Nanda, Digital Green
Debajit Palit, TERI
Pazhaya Veetil Pradeep, Dubai
Sandeep Prakesh, Yougrowculture

JVNS Prasad, ICAR Hyderabad

Thomas Pullenkav, Basic Energy Services (HERA)

Mohammed Ataur Rahman, IUBAT University, Dhaka, Bangladesh

K V Raju, ICRISAT

P V Raju, ISRO Water sensing

Subrata Rana, EcoDev, Kolkata

Ramesh Rao, T-Hub, Hyderabad

Kishore Reddy, SKG Hyderabad

K SaiLakshmi, ICRISAT

Hari Sharan, DESI Power

Kiran Sharma, ICRISAT

Lata Shukla, Pondicherry University

PRK Sobhanbabu, DevGreen Energy Consulting

Ch Srinivas, CRIDA

C N Swammy, Bengalaru

Parmeshwar Udmale, Research Institute for Humanity and Nature (RIHN)

Suhas Wani, ICRISAT

Alicia Welland, Smart Villages

Image Credits

Cover: Solar irrigation and community participation (photo by permission of Anshuman Lath)

SMART VILLAGES
New thinking for off-grid communities worldwide

The Smart Villages initiative is being funded by the Cambridge Malaysian Education and Development Trust (CMEDT) and the Malaysian Commonwealth Studies Centre (MCSC) and through a grant from the Templeton World Charity Foundation (TWCF). The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the Cambridge Malaysian Education and Development Trust or the Templeton World Charity Foundation.

ICRISAT
INTERNATIONAL CROPS RESEARCH
INSTITUTE FOR THE SEMI-ARID TROPICS

The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, nonpolitical organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market-Oriented development (IMOD). ICRISAT is headquartered in Patancheru, Hyderabad, Telangana, India, with two regional hubs and six country offices in sub-Saharan Africa. ICRISAT is a CGIAR Research Center. About ICRISAT: www.icrisat.org; For ICRISAT's scientific information see: http://EXPLOREit.icrisat.org

CGIAR is a global research partnership for a food-secure future. Its science is carried out by 15 Research Centers in close collaboration with hundreds of partners across the globe. www.cgiar.org