SMART VILLAGES

New thinking for off-grid communities worldwide

Mini-grid power generation, storage, and transmission technology in India for the next 10 years

Workshop Report 22

July 2016

BANGALORE, INDIA

Key words:
India, Mini-grid technologies, Off-grid energy, Energy storage, Battery, Solar power, Smart Villages

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

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

Summary

A large portion of India's population lacks access to reliable energy. For many, the solution to this will involve decentralised energy infrastructure in the form of renewable solar, or hybrid solar, diesel, battery, and biogas mini-grids.

The Indian Institute of Sciences (IISc) together with the Smart Villages Initiative held a workshop focused on mini-grid energy generation, storage, and transmission technologies in India, and how they will be implemented. This was held at the IISc campus in Bangalore, on 21–22 July 2016. The workshop brought together academics, students, policymakers, business people, and NGO practitioners interested in sustainable energy and rural electrification.

The workshop aimed to look at the state of current research on the many aspects of mini-grid technologies, with a focus on control and storage technologies for mini-grids, which will have an effect on the future market (particularly the Indian market) in the next five to ten years. There was also a focus on how practitioners were implementing mini-grids on the ground in rural India. The first day of the workshop was a conference-style symposium with over 130 attendees. The second day was a more in-depth workshop-style discussion with 40 experts in attendance.

Key points from the workshop are summarised below:

- Solar power will play an increasingly important role in the next five to ten years, especially given the uncertainties around the future of carbon capture and storage and nuclear power on a large scale in India. One hundred square kilometers of solar PV could supply India's current electricity demand. Currently, the dominant technology is crystalline silicon. Thin-film technologies are becoming commercially available, and organic printable PV is a promising emergent technology. A systematic approach is needed to evaluate options, including a life-cycle analysis of new technologies that identifies the process and materials factors that limit cost and carbon intensity.

- Energy storage is a key technology constraint for renewable mini-grids. Lithium ion batteries are improving in affordability and performance, and flow batteries are becoming more feasible. There is more development needed for lead-acid batteries—cycle life is improving but needs to be further increased. Supercapacitors are emerging as part of an increased focus on battery control systems and lead acid battery lifetime enhancements. Developers need cost-effective integrated systems.

- More demonstration projects involving solar PV and technologies other than solar PV are needed. Complementing solar energy, further success stories are required that also include wind, hydro, and biomass. Successful implementation of mini-grids in a variety of contexts across the diverse regions of India will stimulate more investment in rural development and should provide much-needed case studies to research further key questions related to mini-grid deployment. More primary data on issues to do with people's ability to pay, the types of productive enterprises that are best suited to various contexts, and how to better involve local community government would be very helpful for governments and businesses in this sector.

- Typically, mini-grids need various forms of support to achieve financial viability. At present in India, government interventions are needed to support the spread of mini-grids. Off-grid energy should be treated as infrastructure and funds prioritised for off-grid installations: the ballpark cost for 10 kW solar installations in

50,000 villages is INR 150 billion (US$2.24 billion).

- For mini-grid financial sustainability without subsidy, reducing capital cost is a key challenge. An important objective is to reduce the cost of mini-grids by 30–50% over the next few years. Optimisation of the design and operation of inverters and batteries can make an important contribution to this cost reduction. In designing mini-grids, the focus should be on minimising life cycle cost rather than just the initial capital cost, but there can be problems in the way tenders are set up. Key challenges are: designing the system with plenty of room for growth to meet future aspirations, devising a sustainable tariff based on actual usage that will cover battery replacement in four to five years, and lastly, the provision of ongoing technical support.

- More management and communication is required to integrate mini-grid and grid developments. There is a need to think carefully about how power generated from a mini-grid can be put back into the grid in a reliable manner. It would be beneficial to have more transparency around which areas will be connected to the grid and how reliable that grid will be in the future. Good communication and collaboration between governments and mini-grid businesses can build consumer and investor confidence. Policy regimes should be simplified to encourage mini-grid uptake in grid-connected villages as well. Where there is a grid connection, transparent arrangements need to be in place for feed-in tariffs, capacity charges, and so on.

- Capacity building needs to be emphasised across all aspects of rural development. Better links should be fostered between developers and the Ministries of Agriculture and Education to develop villagers' skills that will be necessary to support new opportunities for livelihood generation. The aim should be to increase the GDP of each village by at least a factor of three. Energy, education, and employment (E^3) leads to empowerment. To empower farmers and villagers, moving them up the agricultural value chain requires the creation of micro-enterprise zones in villages to groom micro-entrepreneurs and increase incomes. A massive capacity-building programme should be launched to train rural youth and inform villagers about potential livelihood options.

- Practitioners must focus on the social aspects of mini-grid deployment. Apart from the technical challenges, there are also social challenges. To give an example: if someone defaults on their payment, by what means should they be pursued? Technology can help with problems like this as well. Many problems can be solved by making certain that there is an initial buy-in by the local community. This must be an integral part of any mini-grid developer's business plan.

- There must be a balance between government intervention and entrepreneurial developments. Government subsidies of 90% of the capital cost of a mini-grid are too high to be scaled up without huge government investment. The government needs to rethink requirements for parity in tariff charging between mini-grids and (subsidised) grid-connected electricity, but this must be done with careful management of expectations and through consultation with rural communities. Also, in India, there are uniquely large amounts of funding available through corporate social responsibility donations, but this funding can be difficult to access in large amounts and in a coherent way. With government encouragement, there is a need to have hundreds of entrepreneurs to accelerate system change for rural environments.

Introduction

Mini-grids powered by renewable energy technologies, in some cases operating in hybrid mode with diesel generators, are predicted to play a large role in the coming efforts to electrify homes without access to electricity. India currently has 240 million people living without electricity. Along with smaller-scale off-grid renewable energy technologies like "pico-solar lanterns" and solar home systems, mini-grids—systems between 1 and 1000 kilowatts—are already having an impact. Though the acceleration of the uptake of mini-grids faces a variety of barriers, much progress is being made in their roll-out. At the same time, a lot of work is going into fundamental technical research that may have an impact on future deployments. A lot has been made of advances in solar panel efficiency, including lower costs to manufacture silicon solar cells as well as potential for other photovoltaic materials. But there have equally been advances in smart electronic control technology and innovative progress in storage for mini-grids.

The workshop provided a wide-ranging discussion on the above topics, as well as attempting to answer some of the following questions:

- What are the advances in "smart" electrical control technologies, new types of storage, and new means of integrating photovoltaics with diesel/batteries/other technologies that might have a real impact on Indian rural electrification in the coming five to ten years?
- What are some on-the-ground characteristics of remote rural life of which technology researchers need to be made more aware to have impact?
- What would it take (reduction in cost, charging regimes, end to central grid electricity subsidies, and so on) to make mini-grids commercially viable in India? What are the key issues to do with grid integration? Many villages have a grid connection but it is poor. What is needed to ensure mini-grids can be integrated with the grid? What are the pros and cons of doing so?
- In Europe and North America there is much discussion about radically different electricity system architectures in the future, with much more local generation. Do these forward-looking views resonate with possible futures in India, though starting from a very different place?

With these opportunities and challenges in mind, the Indian Institute of Science (IISc) together with the Smart Villages Initiative held a workshop at the IISc Satish Dhawan auditorium in Bangalore on 21–22 July 2016 to take a "forward look" into mini-grid deployment in India.

This report summarises the presentations and discussions at the workshop.

Day 1 of the workshop was a conference-style symposium with over 130 attendees and students. The second day was a more in-depth workshop-style discussion with 40 experts in attendance, aimed at delving more deeply into the above key questions. This Forward Look workshop was part of a series of ongoing Forward Look workshops run by the Smart Villages Initiative and collaborators, hoping to learn more about what the new technology advances in the next five to ten years might mean for the rural, off-grid community.

Annex 1 presents the workshop agenda, and Annex 2 includes the lists of participants.

Session 1

Inaugural address

The workshop began with an inaugural address given by the director of the IISc, Anurag Kumar, and the co-convener of the workshop and organiser from the IISc, Satish Patil, who thanked everyone for their participation and gave an outline of the ambitions of the workshop.

The Smart Villages Initiative

John Holmes, SVI / University of Oxford

John Holmes outlined the objectives of the Smart Villages Initiative, which aims to address the energy needs of off-grid communities to catalyse their development. The initiative focuses not only on Sustainable Development Goal 7, which aims to "ensure access to affordable, reliable, sustainable and modern energy for all", but is also concerned with the achievement of most of the Sustainable Development Goals that require energy access to make them possible.

Smart villages are a rural analogue to smart cities, recognising that 47% of the world's population and 70% of the world's poor live in rural villages. In a smart village, energy access together with modern information and communication technologies enable the provision of key services such as education, health, clean water, and sanitation, and foster entrepreneurship in the provision and use of energy services for productive enterprises. Smart villages are more resilient communities that are better able to respond to shocks. Technological developments are changing the balance of opportunities between villages and cities.

The Smart Villages Initiative is focusing on sustainable local energy solutions for rural communities. Its aim is to provide new insights from the "frontline" on the challenges of village energy provision for development and how those challenges can be overcome. Workshops that bring together the key players are being held in East and West Africa, South and Southeast Asia, and Latin America. The outcome of the initiative will be better informed policies and more effective interventions in respect of energy access for development.

A key aim is to identify the framework conditions that will foster entrepreneurial activities in delivering and using energy services, and that will maximise the leverage of public sector funding. An underlying premise is that to maximise social benefit and develop impact, energy access initiatives need to be integrated with other development initiatives and a community-level approach is necessary. An important concern is to catalyse rapid progression through the various levels of energy access.

Prospects for 100% electricity access in India using renewable energy-based micro-grid and mini-grid systems

Leena Wadia, Observer Research Foundation

Leena Wadia indicated that off-grid communities in India would like to be treated on a par with urban users with 24/7 electricity and at similar subsidised prices—that is, IRN 3-5 (4.5-7.5 US cents)/ kWh, rather than IRN 20-50 (30-75 US cents) kWh, which is the typical cost of providing electricity to remote rural communities. The position of the Observer Research Foundation is that mini-grids are infrastructure and should be paid for by government. However, entrepreneurs can help. Purely commercial models are unlikely to achieve the goal of 100% electrification without government participation.

The 2011 census revealed that 350 million Indians have no access to electricity and over 700 million are without clean cooking options. 2015 estimates suggest that the number of people without electricity access has reduced to 240 million.

Distributed generation of electricity, especially solar photovoltaic mini- /micro-grids, have a big role to play in providing access to these people. There are 1,000 mini-grids operating in India at present.

Studies show that 230 million people without access to electricity live in grid-connected villages, but being grid connected does not mean energised: many grid-connected villages get fewer than six hours of electricity each day. 10 million people in villages or hamlets are too remote for grid connection. Solar PV mini-grids are optimal for such villages, but, at present, no truly viable entrepreneurship model exists without capital subsidies.

Vision and leadership are needed to bring about an energy revolution similar to the Green Revolution of the 1970s. PM Modi's call for 24/7 power for all by 2019 could be the required trigger. State electricity boards, state renewable energy authorities and DISCOMs will need to step up their efforts substantially.

The Observer Research Foundation has previously recommended:

- Funds should be prioritised for off-grid installations: the ballpark cost for 10 kW solar installations in 50,000 villages is INR 150 billion (US$220 billion).
- CSR funds should be steered to mini-grid deployments, and corporations can also provide on-the-ground support and monitoring.
- Policy regimes should be simplified to encourage uptake in grid-connected villages.
- A massive capacity-building programme should be launched to train rural youth and villagers more generally on potential livelihood options.
- A "war room" should be created for coordination among all stakeholders to ensure speedy implementation.

Leena Wadia gave the example of the village of Darewadi in Pune District, where a 9.6 kW solar PV mini-grid was installed by Gram Oorja in 2012 (upfront cost INR 300,000 (US$450,000)). Villagers pay INR 20 (13 US cents)/kWh—some four times what urban consumers pay—but so far there have been no payment defaults. Villagers also paid INR 1000 (US$15) as a one-time upfront cost per home. Key factors in the success of the Darewadi scheme included:

- Ensuring initial buy-in from the community
- Designing the system with plenty of room for growth to meet future aspirations
- Devising a sustainable tariff based on actual usage that will cover battery replacement in four to five years (the upfront capital costs are covered by Bosch Solar)
- Minimising battery backup
- Meeting safety and quality standards, with a grid-ready installation
- Completing transfer of ownership
- Training a local youth to service the system, manage feeder lines, and collect payment.

In the ensuing Q&A session, Leena Wadia indicated that most mini-grid projects in India are not profitable. Subsidies from the government of 90% of the capital cost are too high to be scaled up. The government needs to rethink requirements for parity in charging between mini-grids and (subsidised) grid-connected electricity.

Energy storage for micro-grids: poised for rapid adoption

Rahul Walawalker, India Energy Storage Alliance

In India, key drivers of energy storage are minimisation of the use of diesel engines, integration of renewables, supporting energy access, and providing ancillary services for grid reliability and power quality. Rahul Walawalker said that the field of energy storage is moving very rapidly at present, and, consequently, it is important to think ahead to anticipate future developments when designing micro-grids. The key is to provide flexibility in micro-grids to enable the balancing of supply and demand.

Micro-grids are dominated by inverter interfaced distributed sources that are inertialess, while, traditionally, power grids are supplied by sources having rotating masses that are essential for the inherent stability of the systems. Maintaining stability and power quality in the islanding mode of operation requires the development of sophisticated control strategies that need to be included on both generation and demand sides. The high level of IT expertise in India represents an opportunity for the design of appropriate control systems for which there is a substantial global market.

Transitions from an interconnected to an islanding mode of operation are likely to cause large mismatches between generation and loads, posing a severe frequency and voltage control problem. Unstable operation during faults and various network disturbances may occur if storage components are not there. The high resistance to reactance ratio of the low-voltage networks results in strong coupling of real and reactive power; hence the control of voltage and frequency can no longer be considered separately.

When diesel engines are used to provide backup, they often operate at low loads resulting in low efficiency and high emissions. Battery storage options are more cost effective and need to be incorporated into the overall design of the system, focusing on overall life cycle cost rather than capital cost.

Advanced lead acid batteries are available at US$200/kWh, with a cycle life of 1,200 and cycle efficiency of 80%. Sodium and sulphur batteries cost US$500/kWh but offer a cycle life of 4,000, though cycle efficiency is 70%. Lithium-ion batteries can provide a cycle life of 2,000 and a high cycle efficiency of 90%. Currently they cost US$400/kWh, but it is anticipated that this price will reduce to US$150/kWh over the next five to ten years. Flow batteries are relatively expensive at US$500/kWh and have low cycle efficiency at 60%, but offer a high cycle life of 5,000. We may expect to see them commercialised in the next two to three years.

Rahul Walawalker went on to discuss the "Micro-grid initiative for campus and rural opportunities", which is a platform for scaling technically and financially sustainable micro-grids. A key objective is to reduce the cost of micro-grids by 30%–50% over the next few years. Optimisation of the design and operation of inverters and batteries can make an important contribution to this cost reduction. The initiative provides reporting services for funding agencies and micro-grid developers, and data analytics for better energy management and system modelling. A database of existing and potential micro-grids and efficient equipment is being developed.

Responding to questions, Rahul Walawalker indicated that he expects micro-grids to be able to generate electricity at INR 10-15 (15-22 US cents)/kWh within the next three years. This price is comparable to unsubsidised grid electricity which costs around INR 10 (15 US cents)/kWh. In designing micro-grids, the focus should be on minimising life cycle cost rather than minimising the initial capital cost, but there can be problems in the way tenders are set up. Lithium-ion batteries can provide the lowest life cycle cost: India has one of the world's largest deployments of lithium-ion batteries. Many micro-grids designed for a five-year life fail within 18 months.

Diverse storage technologies for climate change mitigation

Ashok Shukla, IISc, Bangalore

Ashok Shukla described a variety of energy storage technologies that are currently under development and will be useful for on- or off-grid applications now and in the future. He began by stating that energy demand increased 50% between 2010 and 2015 due to economic development and population growth. In 1947, energy usage was 1 gigawatt for the entire world; by 2014, it was 254 gigawatts.

He described an interesting new case study of using compressed air to store energy in caves and caverns during off-peak energy price hours. The system has a round trip efficiency of 70%, which is quite good. He showed an example where this was used in Alabama. The system has a slow, 15-minute response time, an initial price point of $600/kWh, and a peak power 110 MW. It is estimated that facilities like this could provide around 1.1GW of storage capacity, which is still a small portion of the total storage needed.

Pumped hydroelectric energy storage is currently the cheapest option for large electric storage, and is widely deployed. The idea is to simply pump water uphill during off-peak times, and run that water downhill during on-peak demand to generate power through a turbine. The total installed capacity currently is around 142 GW. These systems have a very long life but are dependent upon local geography.

Flywheel energy storage is a storage technology with a high power storage density and a round trip efficiency of 93%. It also has a long life (20 years), but the need to use vacuum fittings and magnetic bearings adds significant cost, preventing rapid uptake.

Superconducting magnetic energy storage is a promising storage technology. Because superconductors have zero resistance, electrons can flow freely and create magnetic fields, and energy can be stored in these magnetic fields. These systems have extremely fast response times, but they need very low temperatures (between 10 and 70 kelvins) to run, so are expensive, and thus their applications are limited to niche power balancing systems at the moment.

For electrochemical energy storage, the "work horse" is the lead acid battery, which is an old and trusted technology that provides the majority of off-grid storage needs. These batteries have an efficiency of 70%–90%. Systems are available with capacities of up to 40 MW, and life cycles of around 2,000 cycles. Ashok Shukla noted how this lifecycle can be improved by adding a supercapacitor to work in conjunction with the lead acid batteries, which can help to properly charge them. This avoids sulphation—the build-up of crystalline lead sulphate on negative electrodes—and can also avoid "positive shedding", which is the loss of lead from the positive electrode over time. Lead is highly recyclable, so the issue of recycling a lot of lead acid batteries should be solvable.

Lithium-ion batteries have higher efficiencies (85%–90%) and higher energy densities (75–200 Watt hours per kilogram), with life cycles of more than 4,500 cycles. They are still more expensive than lead acid at the moment.

Redox flow batteries have flexibility of capacity—enabled by increasing or decreasing the number of storage tanks that store the liquid electrolytes. The systems have a long cycle life and have attracted significant funding internationally and in the U.S. A nickel ion flow battery is being developed, along with other earth abundant material systems, which will be efficient for over 5,000 cycles.

Supercapacitors, as mentioned before, have a role to play in off-grid energy storage. By incorporating 'lead-carbon' into a battery similar to a lead acid battery, one can combine some of the fast-discharging and long-lifetime properties of supercapacitors with the high energy density of batteries. Developers start with conventional lead-acid chemistry and add carbon components to the negative electrodes. The carbon used for applications like this, and in other super, or ultra, capacitors, is very cheap (around 40–50 INR/US$0.75 per kg).

Smart NanoPower™ for smart villages: Sustainable socioeconomic development

Ashok Das, SunMoksha

Ashok Das explained that the vision of SunMoksha is to develop Smart PURA villages, where PURA stands for "Provision of Urban Amenities in Rural Areas". Energy is one of the main enablers for achieving PURA, which in turn enables local socio-economic development and impacts on migration, reducing the infrastructure burden on cities. The Smart Villages and PURA concepts are closely aligned.

SunMoksha's solution addresses "hard" interventions in villages, notably: energy sufficiency, smart grids, and digital connectivity; agriculture, water, and waste management; and livelihood and rural industries, education, and skill development. The PURA concept also requires "soft" interventions on governance, public health, sanitation, civic services, and climate change adaptation. To create smart villages, a balanced approach is needed and development must be sustainable; hence the service provider must be profitable, solutions must not clash with the planet, and people must have access to the resources required for development. Energy access in smart villages is an essential enabler of most of the Sustainable Development Goals.

Energy, education, and employment (E^3) leads to empowerment. SunMoksha's goal is to empower farmers and villagers, moving them up the agricultural value chain. This requires the creation of micro-enterprise zones in the villages to groom micro-entrepreneurs and increase income. It reduces the pressure on agriculture and land, resulting in triple bottom-line impact, and it reduces pressure on cities as more and more people find opportunities in the villages. The Smart Villages Initiative must align with "smart economic development".

Decentralised generation and consumption using micro-grids is the best option for sustainable energy access in villages. SunMoksha's intervention—"Smart NanoPower™"—involves reliable and predictable access to green energy, the creation of an ecosystem to develop skills for livelihood and energy access, and business models for livelihood and economic development. It requires holistic system thinking and catalytic infrastructure. Energy access is based on: hybrid renewable local generation; IT-based monitoring, operations, and maintenance; customer interface over mobile devices; and demand-supply optimisation. The technology provides for real-time monitoring of usage and equipment, the control of power for each load, and scheduling of streetlights, pumps, machines, and so on. Interventions are founded on close partnerships with villagers and grassroots organisations.

Ashok Das described a case study: Chhotkei in the Satkosia Tiger Reserve in Odisha. Chhotkei was an unelectrified village of 140 scattered households (total population 600), 65 km from the nearest town. The village had only one functioning streetlight. Agriculture was only undertaken during the rainy season, and there were few employment activities. SunMoksha has installed a Smart NanoGrid™, which provides for real-time monitoring and load control. Initiatives have been undertaken in the village on education, agriculture, and livelihoods for development. A village energy committee has been established, and attention has been given to youth empowerment for sustainability and scalability. SunMoksha is now planning a smart village pilot in the state of Jharkhand.

Solar power as a tool for emissions mitigation and development

Jenny Nelson, Imperial College, London

Jenny Nelson introduced the work of Imperial College on basic and applied research into the science and engineering of new energy materials, devices, and systems and the work of the Grantham Institute for Climate Change and the Environment on evaluating the role of technologies in achieving low-carbon pathways.

Delays in the deployment of low-carbon technology will result in the need for significantly higher rates of deployment in the years to come. Electrification is needed to reduce emissions in all sectors. Given the uncertainties around the future of carbon capture and storage and nuclear at large scale, solar power is anticipated to play a crucial role, especially in India; 100 km^2 of solar PV could supply India's electricity demand.

Currently, the dominant technology is crystalline silicon. Thin-film technologies are becoming commercially available, and organic printable PV is a promising emergent technology. A systematic approach is needed to evaluate options which must include a life cycle analysis of new technologies as projected in production and the identification of process and materials factors that limit cost and carbon intensity.

Jenny Nelson discussed work undertaken to find the optimum mini-grid system in India for a given PV type, battery type, and fractional demand met. It is important to evaluate the costs of the whole system. She concluded that PV is expected to play a key role in decarbonising the power sector in India. A wide range of technologies and implementation options exist. In order to embed energy efficiency in design, design tools should be used which undertake life-cycle analysis and take a systems approach considering the application context. The cost of storage and usage patterns is critical in determining the effectiveness of mini-grids, which can act as a transition technology to wider grid connection.

Session 2

Current renewable energy solutions in India

Gaddipati Prasad, Ministry of New and Renewable Energy (MNRE), New Delhi

Dr Gaddipati Prasad described the Indian national government's plans for renewable and village-level energy generation.

The current electrification rate in India is low, with several states showing electrification rates of less than 50% (as measured by households using electricity as a main source of lighting, in 2011). The government has a dual strategy to tackle this problem: through grid and off-grid solutions.

For the off-grid strategy, there are the following government programmes:

- Remote Village Electrification Programme
- Off-Grid & Decentralised Solar Application Scheme
- Biomass Gasifier-based Distributed / Off-grid Power Programme for Rural Areas
- Water mills and micro-hydro projects
- Programme on Small Wind Energy and Hybrid Systems
- The 24x7 Power For All (PFA) initiative

The PFA initiative aims to provide 24-hour energy access to all households and homes as well as industrial and agricultural consumers. It has been taken up in the following regions: Arunachal Pradesh, Assam, Bihar, Goa, Jharkhand, Meghalaya, Telangana, Uttarakhand, and Uttar Pradesh.

India is the biggest off-grid market in the world. Census data shows there are 18,500 unelectrified villages, and it is planned that 3,200 of these will be electrified through off-grid programmes. There is a budget of US$150 million for the government's off-grid programme. This programme is administered through banks, the state nodal agencies, NABARD bank, and other government organisations.

Among the various options for rural electrification, India has not yet fully exploited mini-grids. Each stakeholder has a role to play in mini-grid implementation and use: government, service providers, community, women and children, telecom towers, and anchor loads. Mini-grids offer multiple benefits to all of these stakeholders.

Off-grid support is channelled through the Central Financial Assistance (CFA) facility for mini-grids. The CFA provides:

- 30% capital subsidy to end-users
- 90% for special category states
- 40% through banks coupled with loans

A number of conditions must be met for attaining CFA. Gaddipati Prasad detailed an example of a specific case of a mini-grid in the Sundarbans.

The issues and challenges for mini-grids are people's capacity and willingness to pay (people expect free power), a lack of guidelines for co-existing with the grid, and no "exit options" if the grid does arrive.

In the Q&A session, it was mentioned that many things in India tend to be state dominated, so how are the state and national governments working together?

The national government wants to stop state governments from being a hindrance to progress, which can happen sometimes if the state is too controlling when facilitating projects. The national government just provides a subsidy and then gets out. Some states have their own legislation.

Effective use of technology and content to enhance rural education

Ranjani Sriram, Technology Integration Specialist, Wellesley Public Schools, Wellesley, MA, USA

Ranjani Sriram spoke about the potential technology has for aiding education, and how that technology might be applied in a smart village in India. She has 21 years of teaching experience, and her experiments with technology within the classroom has led to her becoming an instructional technologist, someone who helps other teachers use technology in schools.

Students and teachers often have tools that are not used effectively. Teachers must take a step back to think about their responsibilities and teach students how best to use technologies.

Ranjani Sriram uses the SAMR model for technology integration. SAMR stands for substitution, augmentation, modification, and redefinition. For a given technology, first there is substitution—the technology acts as a direct substitute with no functional change. Then there is augmentation, where there is a functional improvement in the specified task; then modification allows specific task redesign. Finally, the technology is able to "redefine" the given task entirely. As an example of redefinition she mentioned www.todaysmeet.com, a web tool that can make presentation interactive. This is using technology to do something that couldn't be done before.

Applying SAMR in a smart village requires a good Internet connection. This opens the classroom to the whole world. It can make a classroom more collaborative and accessible, for instance, through students accessing materials at home (assuming they have Internet at home). Teachers must teach responsible researching to hone students' "googling" skills by showing them how to research and how to navigate the web.

Ranjani Sriram demonstrated a variety of online tools, such as padlet, which allows children to learn from each other, and Skype. Instructional videos can be paused and rewound, which makes them very useful teaching tools.

Tablets, perhaps low-cost tablets for a smart village, can add a lot to an educational experience, particularly when combined with a projector. A projector can create a much more collaborative learning experience. There are apps for everything, and many of these enable assessments of children as they go rather than through periodic tests.

When new technology first arrives in a village, teachers need initial and continued follow-up training to ensure its effective use in the classroom.

Mini-grid implementation: Challenges and observations from the field

Senthil Kumar, SELCO

Senthil Kumar of SELCO spoke of the challenges and opportunities for implementing mini-grids across India.

SELCO was established by Harish Hande, who realised that the true challenge for solar development is about how you take technology to the field. SELCO has been in the field now for 20 years and wants to share the knowledge it has gained in an open source way.

Senthil Kumar and his colleagues have "brutally" analysed every solar installation they have done over the last few years to understand what was and was not successful.

There is no denying there are technical challenges in mini-grid implementation. Battery technology needs to be improved for better outcomes. Better methods for solar panel production should be found. There is a need to come up with better transmission technologies. But these are challenges to the solar industry as a whole, not specific to mini-grids.

Apart from the technical challenges, there are also social challenges that are specific to mini-grids. For example, if someone defaults on payment, SELCO has the technology to detect and cut them off from the mini-grid. But there are questions over what is the best action in this instance.

A key challenge is conducting an efficient survey of a local population to determine what they want from a mini-grid project. It is vital to set realistic expectations. The context of the rural poor is different from the urban poor, which is different again from the tribal poor. SELCO has different rural and urban laboratories. For the surveys, how does one generate the right questions to encourage discussion? If their initial expectations are not met, people will not pay. The project will then have an uncertain future without funds for maintenance.

Fostering ownership is another challenge—how does one add value to a commodity? By ensuring that the commodity is perceived as an asset. People must have a sense of ownership of the mini-grid project. Anchor load models need to be incorporated at the same time as the home-based loads.

Operations, maintenance, and collections require a number of questions to be answered: what is the implementing agency? What is the cost of collection? How flexible is the collection—how many instalments will people pay? What are the actions to be taken in the case of default by a customer? Solutions involve working with a strong local NGO with effective community leadership. Without strong community leadership, any project will fail.

The fee collection model must be consistent with a pragmatic project lifetime of around 15 years. Operations skillsets for implementers are extremely important. Projects need to have someone trained locally to help with maintenance, and he or she does not need to be a qualified engineer.

Data logging is also an important factor. Senthil Kumar described an example of having problems with an inverter at a mini-grid during the rainy season. Remote logging allowed engineers to work out what the problem was to avoid sending an engineer to this and other remote places multiple times.

Senthil Kumar described a metrology and composite number system to help evaluate the financial sustainability of mini-grids.

In the Q&A session, Senthil Kumar proposed working with institutes like the IISc to help refine an index and other key numbers and metrics for evaluating the feasibility of mini-grids.

Implementation of micro-grids in the northeast region – a case study

Vijay Bhaskar, Mlinda

Vijay Bhaskar talked about his experiences in rural electrification through micro- and mini-grids in Jharkhand and West Bengal.

Mlinda started off as an environmental organisation trying to reduce degradation in the Sundarbans. Poverty alleviation can help environmental problems in islands in the Sundarbans. The project that initially took off was a replacement of rickshaws with electric vehicles. These vehicles were charged through solar powered recharging stations.

However, the islands in the Sundarbans are large, and stations and villages are widespread. So Mlinda tried to create a series of small grids for the islands. They started an innovative financing mechanism with the National Bank for Agriculture and Rural Development (NABARD) that provided 100% debt to families over a period that was affordable for them. The mini-grids were for the bottom-of-the-pyramid population, then they expanded to families with higher incomes who wanted more than just lighting who could pay more than 200 rupees (US$3) a month.

Today Vijay Bhaskar and Mlinda work in six islands in the Sundarbans. The government asked them to move into an area with a high level of Maoist activity. Mlinda did this, and consequently electrified 23 more villages. This then expanded and Mlinda now work in five districts. These areas also form part of the elephant corridor and are home to many tigers.

The ownership model for these systems is based on joint liability groups. Single ownership has its own problems. Capital expenditure is paid completely by equal monthly instalments. There is a trained electrician in each village (trained by Mlinda) who has access to spare parts.

Vijay Bhaskar then showed some images of examples of electrified houses and villages. The first village houses were charged 240 rupees (US$3.60) per month on equal monthly instalments. Households alone could not quite afford this, so the deficit was made up by selling to shops.

This worked in some places in West Bengal, but not in Jharkhand. Design of Jhakhand grids is therefore based on productive anchor loads, such as rice hullers and water pumps. Mlinda owns these grids, which is a different business model. It is anticipated that financial breakeven will be achieved in —eight to ten years. Four villages have been reached in this way: two that were initially completely off-grid and two that already had some grid access. Interestingly, Mlinda has seen the most demand from the grid-connected villages.

Mlinda has incubated women's' groups to use rice hullers. These women will no longer sell unhulled rice, but only the more expensive hulled rice. They receive 2-3 INR (3-4.5 US cents) per kilogram, so every farmer thus gains 1 INR(1.5 US cents) extra per kilogram. It is not enough to just provide light; people need money in their pockets. In this way Mlinda promotes people, planet, and profit.

In the Q&A session, questions were raised about how to make a mini-grid feasible using productive activities and how to upscale this success. Vijay Bhaskar noted that success was all about breaking even and using productive enterprise to get payback times of 11 years or less. Seasonality is a very big factor for productive loads and so must be accounted for.

Recent strategies in solution-processed solar cells

K. S. Narayan, JNCASR, Bangalore

K.S. Narayan is a professor at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR). He described his work on new materials for energy applications that he feels could make a difference to the world. He started by noting that India is not yet over-invested in silicon.

He has carried out research into the field of organic photovoltaic (OPV) solar cells, which are solar cells made out of cheap, carbon-based polymers or small molecules. The energy payback time for organic solar cells is much less than silicon solar cells—75 days compared to a couple of years—due to the ability to process OPVs at low temperatures.

OPVs consist of two organic semiconducting materials (an electron donor material and an electron acceptor) in intimate mixed contact. This forms a heterostructure that enables charge separation—the splitting of electrons and their positively charged counterparts called "holes". There are a number of important steps to get the mix of materials right and the most efficient devices, for example blend concentration and annealing conditions. An interesting example is using electric fields to process the devices, rather than thermal annealing (heating). This strategy is viable for large-scale manufacturing.

K.S. Narayan is interested in how to make larger cell module sizes to aid commercialisation. Generally, the smaller the solar cell, the higher the efficiency for a number of reasons. However, bigger cells are cheaper and provide more power. Clever engineering and design can enable a better and larger module.

K.S. Narayan showed a special low-melting temperature alloy that was used as a top electrode to be printed on a solar cell, rather than evaporated, which is more expensive. He also showed how a new lamination process could be used to make a larger module. There was no drop in solar cell efficiency using the procedure, and the structure showed good stability.

Organic metal halide perovskites have been hitting the headlines in the last couple of years as another alternative for cheap and solution-processed solar cells with amazingly high efficiencies. They have some drawbacks such as containing lead and having low stability. The scientific community is working through a large number of stability issues for perovskites to improve air, moisture and UV instability. The technology must stabilise or perish.

K.S. Narayan demonstrated his team's research into using electronic signal noise as a tool to investigate microscopic transport and degradation processes in OPVs. There is a background fluctuation associated with normal DC output of these cells. Using this fluctuation, one can distinguish different potential problems such as delamination, contact issues, and inherent structure degradation. It is also possible to analyse cells with a scanning procedure to identify weak spots in solar cells. The spatial scan has a resolution of between 200 nanometres and 3 micrometres and can scan around 0.5 metres for spatial characterisation details.

In the Q&A, K.S. Narayan speculated on the applications for organic photovoltaics for the grid. It may be worth attempting to use OPVs on lightweight bamboo scaffolds, for instance. There are a lot of potential applications.

Session 3

Scene setting and context
John Holmes, SVI / University of Oxford

After giving an introduction to the Smart Villages Initiative (SVI) in Session 1, John Holmes introduced Session 3 on the second day of the workshop and provided an overview of SVI's findings to date. The aim is to get the concept of smart villages accepted widely and to provide recommendations to policy makers. The following points were drawn from an interim report written by John Holmes based on engaging with 700 frontline workers.

Several key issues for smart villages are common to pico solar, solar home systems, cookstoves, and mini-grids. These cross-cutting issues are:

- **Access to affordable finance:** The difficulties faced by companies in accessing affordable finance were a consistent message across the countries and regions.

- **Support to entrepreneurs**: Governments should establish supportive policy and regulatory environments that simplify licensing frameworks, cut red tape, and provide sufficient breathing space in respect of taxation regimes for businesses to get off the ground.

- **Capacity building**: Training is needed at all levels from local technicians to engineers, product designers, and university researchers. In parallel, training is needed for local entrepreneurs in how to run a successful business, for the financial community to familiarise them with the issues associated with off-grid energy schemes, and for government institutions to build capacity in policymaking and regulation.

- **Creating awareness**: There is an ongoing need for initiatives to increase villagers' awareness of the available off-grid technologies, and the benefits and ways of using them.

- **Gender and age**: Men and women tend to prioritise energy uses differently, so both need to be involved when communities are approached regarding energy initiatives and in subsequent decisions.

- **Giveaways**: Many examples were given where the free distribution of pico-solar lights and solar home systems had "spoilt the market", undermining the business activities of local entrepreneurs and creating an entitlement mentality that jeopardises the prospects of future commercial initiatives.

The key factors that have enabled good progress on home-based supply of off-grid energy are that PV costs have reduced substantially; there is increased availability of efficient direct current appliances; and pay-as-you-go business models get over the initial cost hurdle.

In parts of East Africa, there has been a successful roll-out of solar home systems, but governments and businesses need to consider how to accelerate this progress. In Bangladesh, there are four million solar home systems—more than anywhere in the rest of the world. This has been enabled by government support.

Poor quality and counterfeit products have become an issue. Efforts from governments and the creation and implementation of international agreements will be needed to combat these potential market spoilers.

There is a series of technical matters that should be improved to facilitate the roll-out of solar home systems. These include improving batteries, improving recycling of various systems, promoting plug and play technologies, better control systems, and focusing on improving appliance efficiency.

Mini-grids have shown more limited progress than solar home systems, with costs still generally greater than revenues. There is an extremely important question regarding how we can balance the books without grants and government support.

Reducing the cost of mini-grids can be achieved through technical advances, economies of scale, incorporating anchor loads, reducing set-up costs, reducing finance costs, and capital cost subsidies.

To increase revenues, it is important to get the tariffs right based on principles of affordability and equality, whilst understanding that getting electricity to rural areas costs more than for urban areas. Stimulating productive enterprise should in turn increase load factors and revenues. Another last-resort option is an operating cost subsidy, although this will not be sustainable without significant government support.

Villagers should be the main drivers of projects, and projects should build on local knowledge and customs. The poor must have a voice: there is a saying that projects should be 70% social and 30% technical.

The Smart Villages Initiative can assist with improving collaborations between frontline workers, as well as with universities. One of the key issues going forward is the link between energy access and key development outcomes; this is not clear from the literature. The Smart Villages Initiative hopes to answer the question regarding the complete package that needs to be put in place in a village.

Expert panel discussion of key questions

Experts: Leena Wadia, Vijay Bhaskar, Ashok Das, K.S. Govindrash, AK Shukla

An expert panel was chosen to answer three key questions related to the future of mini-grids in India. Panellists answered each question in turn.

Q1 What are the key technology challenges for mini-grids in India for the next five to ten years?

Energy storage is a key challenge which is just coming into play, not just in India but also in the rest of the world. Peak load alleviation is critical as more intermittent renewables come online. Batteries are key but have issues with life cycle and size. Hybrid storage solutions will be important going forward.

Complementing solar, more success stories are needed that also include wind and biomass. We need to think about how power can be put back into the grid in a reliable manner.

One of the biggest issues is the governance of the grid, which is poorly run in India. The grid has enough power but is not able to reach the right people at the right time. There is a need to optimise the whole system. Transmission and distribution also have to be optimised. We also need to work on energy-efficient appliances, e.g. TVs sold as 30 W often require 70 W. Finance needs to be long term.

Energy distribution is mature; generation remains the main issue. People require 24/7 access, so they need to have a very reliable supply. Inverters are critical components which could be removed with DC appliances, but this is still some time away. We require smart batteries that can predict failure. No one has discussed fuel cells, and biomass gasification is not being developed. The use of biomass needs to balance demand for fuel and food. More research is needed to make this a mature technology. There is considerable potential to use biowaste, and there is too much focus on solar. Wind turbines are also not developed either. New technologies will take time, probably more than five to ten years.

Pico hydro has good potential, with an advantage being that it does not need storage.

Lithium batteries are coming up, supercapacitors are emerging, and control systems are important. Developers need a cost-effective integrated system. People have been working on fuel cells for 20 years, but cost has been a continuing issue, although flow batteries are becoming more feasible. More development is needed for lead-acid batteries, such as bipolar options that increase efficiency and could reduce cost. Cycle life could also be improved.

Grid companies have issues with old transmission lines and are looking at mini-grids. They are thinking of multiple sources of feedback back to the grid.

Q2: What are the key challenges in implementing mini-grids? What would be on a practitioner's wish list?

Traction with government is improving, but there is a great need to get more of the government's attention.

Villagers do not have a say in many of the processes that happen with regards to energy infrastructure. Education must be improved.

The current energy system is led by large companies, but new practitioners are coming on line and should be encouraged.

There needs to be better links fostered between developers and the Ministries of Agriculture and Education to help villagers develop skills that could improve livelihood generation. The aim should be to increase the GDP of each village by at least a factor of three.

Capital costs are too high, requiring 10 years to pay back for large systems. Smaller systems have high costs as well and one cannot expect this to be paid back in three years. Business models must revolve around the services.

Q3: How can we make smart villages happen in India?

Ashok Das began by noting that he initially did not want to work with the government. However, he has now realised that the cost is so high that he needs to. A large amount of funding goes to smart cities but not enough to smart villages.

Kannankote Sriram gave some suggestions for the implementation of smart villages in India. He suggested that the group select five different locations, based on different climatic conditions. He gave suggestions the type and amount of funding that will be needed and what the success criteria for each village might be. The goal is to start a conversation on how these five initial smart villages might be achieved.

Final thoughts on how to ramp up activates included: the need to educate the local people, to include new aspects into each new project, to test effectiveness, the importance of finance, and the importance of livelihood generating activities.

Implementation needs to begin soon.

Control technologies for solar power

Pallavi Bharadwaj, IEEE

Pallavi Bharadwaj described her research into photovoltaic control technologies.

She was able to develop a solar irradiation meter that only costs 1,000 rupees (US$15 USD). This is important for getting the most power from PV installations.

She also looked into new maximum power point tracking (MPPT) technologies and described a model of impedance estimation to prevent impedance losses in the solar electrical system. She constructed a model to predict the effect of energy storage on the cost of PV micro-grid systems, and used it to compare a grid-tied system with and without local loads, and with and without storage.

In her model, the grid-tied system is cheaper than a dual mode (battery plus diesel) storage system, but this relies on several assumptions. When grid outages are taken into account, the situation is different. For daytime power outages, the battery plus diesel system can become cheaper for a given number of hours of grid outage.

Current and future implementation for rural micro-grids

Simran Grover, Boond

Boond's mission is energy access for the rural and urban poor. The company has installed 2 MW of capacity in the last two years, 80% of which is in off-grid locations. Simran Grover explained that achieving low-cost capital expenditures is a big challenge.

They are focusing on "hamlets", as these are the biggest section of the energy underserved in India. They are collecting lots of data that is open source, and will share it to inform research.

The current model provides a central station for charging 50 households. They have a small USB-like "energy stick" that people can recharge with money easily, in exchange for more electricity. For one of these stations, including capex and community engagement, the investment is 4 lakhs (US$6,000).

Boond is optimising its system design through the data they obtain. For instance, they are trying to understand the optimal system size. They are also doing remote complaint logging. The system is chosen to be installed on the rooftop of one of the village residents; this villager gets incentives through financial profit sharing. Micro-grids are paid back in about five to seven years.

Currently Boond has received grant funding. Regarding competition with the grid, they have not had serious issues yet. They came across one case where the government grid arrived, but it was not activated for some reason.

Going forward, the focus is especially on community-oriented services like clean drinking water.

Solar micro-grid model for an integrated rural development through CSR partnerships

Shyam Patra, Naturetech Infra

Naturetech Infra started to provide energy access to off-grid communities five years ago. The advent of CSR provided the much-needed financial support to social businesses working for rural development. By setting up decentralised solar micro-grids in rural Indian villages, it acts as an integrated model for sustainable development, encompassing solar energy for electricity, water pumping, irrigation, sanitation, healthcare, smart classrooms, safe drinking water, and clean toilets.

The current business model for generating revenue uses a recharge agent to collect money from villagers. The team previously tried pre-paid collection, but this is difficult to implement as the cost of energy from a micro-grid is high compared to grid energy, reducing the desire to pay with the pre-paid collection system. Developers need to work with the grid, rather than in direct competition, and they need to complement an unreliable grid with reliable solar.

In India, there are large amounts of funding available through CSR, and there is a need to have hundreds of entrepreneurs to accelerate system change for rural environments.

Hybrid ultracapacitors

Satish Tembad, Mesha Inc.

Satish Tembad gave a quick overview of the opportunities for using hybrid ultracapacitors (HUCs) in rural mini-grids, as exemplified by the technologies being developed by Mesha Inc.

Compared to standard batteries, ultracapacitors have high power densities and lower energy densities. They handle deep discharge more easily, and have a longer life (they are capable of more than 100,000 cycles). They are faster at charging and discharging, and are designed as a single unit with a 12V interface. Challenges for employing ultracapacitors stem from variations in capacitance, higher price, and the fact that they are more prone to self-discharge.

Mesha, Inc. was formed in January 2012. They have licensed, patented, and commercialised the HUC technology. They have also combined HUC with battery storage systems that are available in the marketplace and have developed their own smart energy management system (EMS) which controls the charging/discharging of the hybrid-based energy storage system.

They have developed the Mesha Integrated Storage Technology (MIST) that consists of the following components: Hybrid UltraCapacitor (HUC), Battery (Lead Acid or Li-Ion), and Energy Management System (EMS). The MIST technology is the first of its kind to address the requirements of the users in the off-grid marketplace. It brings the following benefits: leverages and smoothens the load, improves overall efficiency of the system, extends the life of the battery, has quick charging capability (under variable weather conditions), and makes more usable watts available for daytime applications.

Concluding comments

Satish Patil of the IISc and John Holmes of the Smart Villages Initiative thanked the participants for their involvement, and outlined the future plans going forward from the workshop. They hope these plans will include further collaboration between the participants, organisers, and others to set up and study further smart villages across India.

Annex 1: Workshop programme

Day 1

08:30 Registration

Session 1

09:00 **Inaugural session,** Welcome and Introduction

Anurag Kumar, IISc, Satish Patil, IISc and John Holmes, Smart Villages

09:30 **Prospects for 100% electricity access in India using renewable energy-based micro-grid and mini-grid systems**

Dr. Leena Wadia, Observer Research Foundation

10:00 **Energy storage for micro-grids: poised for rapid adoption**

Rahul Walawalkar, Customized Energy Solutions India Pvt. Ltd.

10:30 Coffee Break

11:00 **Diverse storage technologies for climate change mitigation**

A. K. Shukla, IISc, Bangalore

11:30 **Smart Nanopower™ for smart villages: Sustainable socioeconomic development**

Ashok K. Das, SunMoksha Power Pvt. Ltd., Bangalore

12.00 **Solar power as a tool for emissions mitigation and development**

Prof. Jenny Nelson, Imperial College London

12:00 Lunch Break

Session 2

14:00 **Current renewable energy solutions in India**

Dr. Prasad, MNRE, New Delhi

14:30 **Effective use of technology and content to enhance rural education**

Ranjani Sriram, Technology integration specialist at Wellesley Public

Schools, Wellesley, MA, USA

15:00 **Mini-grid implementation: Challenges and observations from the field**

Senthil Kumar, SELCO

15:00 Coffee Break

15:30 **Implementation of micro-grids in the northeast region – a case study**

Vijay Bhaskar, Mlinda India

16:00 **Recent strategies in solution-processed solar cells**

K. S. Narayan, JNCASR, Bangalore

16:30 **Closing comments**

16:45 Poster presentation and exhibition (will be available from 9AM to 6pm)

19:00 Dinner

Day 2

Session 3

09.30 **Introduction and agenda setting**

09.40 **Scene setting and context, The Smart Villages Initiative**

Dr John Holmes

10.00 **Expert panel discussion of key questions**

11.00 Coffee

11.15 Control technologies for solar power,

Pallavi Bharadwaj, IEEE

11.50 **Current and future implementation for rural micro-grids**

Rustam Sengupta, Boond

12.15 **Solar micro-grid model for an integrated rural development through CSR partnerships**

Shyam Patra, Naturetech Infra

12.30 **Hybrid ultracapacitors**

Satish Tembad, Mesha Inc.

12.30 Concluding Comments

12.45 Lunch

ANNEX 2

Participants of Day 1 Workshop

Veeresh	Anehosur	Bos-AG
Rangan	Banerjee	Indian institute of technology, Bombay
Vijay	Bhaskar	Mlinda India
Anantha	Bhat	Ecoserv Lights
Mr.	Bhimsen	Independent Entrepreneur
Mr.	Bikasita	SERC
Priyam	Bora	Gramoorja
Mr.	Chandramohan	Go Shakthi
Akanksha	Chaurey	IT power, TERI
Ashok	Das	SunMoksha Power Pvt. Ltd
Bhaskar	Deol	Mynergy Renewables Pvt.ltd
Ameet	Deshpande	SunMoksha Power Pvt. Ltd
S.A.	Gafoor	NED Energy
Neetu	George	ABB
Sudipta	Ghosh	SELCO
K.	Gopakumar	IISc
Ashok	Gopinath	Independent Entrepreneur
Simran	Grover	Boond
Makesh	Gujar	TERI
Deeksha	Gupta	Royal Society of Chemistry
Mr.	Harikrishna	Idein Lab
Keshav	Hebbale	Shashwathi
John	Holmes	Smart Villages
Mr.	Jayaram	KSCST
Rakesh	Jha	Maghraj Capital Advisors Private Limited
S.K.	Sangal	Independent Entrepreneur
A.	K. Wadhwa	Independent Entrepreneur
Sachin	K.L.	Mesha Energy Solutions
Sriram	K.S	Mesha Energy Solutions
Govindraj	K.S	Mesha Energy Solutions
Gulshan	Kapur	Independent Entrepreneur
Prashante	Karhade	CTO - Maxpower

Sharath	Kaul	Solar Apps
Mr.	Kavya	Mesha Energy Solutions
Yashraj	Khaitan	Grampower
Jayasimha	K.M.	Shashwathi
Bhaskar	K.N.S.	IISc
Purnima	Kumar	Lumeter Networks
Deepak	Kumar	Lytyfy
Uday	Kumar	IISc
Srikantha	Kumar	Infosys
Shiv	Kumar	IISc
Umanand	L.	IISc
Mr.	Lakshminarayana	Ex MESCOM
Anshuman	Lath	Gram Oorja
Soham	Maity	IISc
Mr.	Manikandan	Mesha Energy Solutions
Deepak	Mathur	IEEE, india
Rachita	Misra	SELCO Foundation Urban Lab
Mr.	Mithali	Independent Entrepreneur
Nihar	Mohan	Rotary Spandana Bangalore
Aiswara	Mohapatra	IISc
Dileep	M.S.	UV Energy India Pvt Ltd
Tushita	Mukhopadhy	IISc
Amogh	Mukunda	Mesha Energy Solutions
Mr.	Muralidhar	Mahatma Gandhi Institute for Rural Energy Development
Dr.	Nagamani	CPRI
G.D.	Naidu	ABB
Sameer	Nair	Gram Oorja
K.S.	Narayan	JNCASR
Jenny	Nelson	Imperial College London
Gyanesh	Pandey	Husk Power
Rajesh	Parishwad	Royal Society of Chemistry
Lalith	Parmar	Event Management - S/W companies
Nalin	Patel	Winton Programme, University of Cambridge
Satish	Patil	IISc
Shyam	Patra	Naturetech Infra

Mr.	Pradeep	CPRI
Nikita	Pranab	Mesha Energy Solutions
Dr.	Prasad	MNRE
Gowtham	Prasad	IEEE, india
Mike	Price	Smart Villages
Vishnu	Raghunathan	Lytyfy
Pratim	Raha	SELCO
Sashidhar	Rajarao	Ex-Infosys
Mr.	Rajarao	Ex- KEB
Chandana	Ramprasad	Solution Kraft
Prashanth	Rao	Independent Entrepreneur
Vinay	Rao	Bang Id
Sreedhar	Rao	SunMoksha Power Pvt. Ltd
Sarraju	Rao	Omnigrid Micropower Company
Nagendra	Rao	IISc
Sreedhar	Rao	SunMoksha Power Pvt. Ltd
Mr.	Ravi	Mahatma Gandhi Institute for Rural Energy Development
Amardeep	Roy	Zinco Electric
Srikanth	S.	Mesha Energy Solutions
Phil	Sandwell	Imperial College London
Amit	Saraogi	Oorja Solutions
Rustam	Sengupta	Boond
Brian	Shaad	Meragao Power
H.N.	Sharan	Desi Power
Nidhi	Sharma	IISc
Shikha	Sharma	IISc
Sanjith	Shetty	Soham Renewable Energy India Pvt. Ltd
Vinay	Shinde	UV Energy India Pvt Ltd
Ravi	Shivanna	IISc
Mr.	Shivaprasad	ERI
A.K.	Shukla	IISc
Ms.	Shwetha	SELCO
Mr.	Simon	UV Energy India Pvt Ltd
Keshav	Singh	Zinco Electric
Neha	Singhal	IISc

Sandip	Sinha	ABB
Dr.	Sridhar	Mesha Energy Solutions
Mr.	Srikanth	NED Energy
Ranjani	Sriram	Wellesley Public Schools
Dr.	Swamy	KSCST
Satish	Tembad	Mesha Energy Solutions
Sudarshan	Thirumalachar	Mesha Energy Solutions
Raunak	Tiwary	SELCO
Ramesh	Udupa	Emmvee
Mr.	Umesh Ganjam	Ganjam Group
Mr.	V. Ramesh	Ex-KPTCL
Dr.	Venkateswaran	ABB
R.K.	Viral	IIT Uttarakhand
Leena	Wadia	Observer Research Foundation
Rahul	Walawalkar	India Energy Storage Alliance

Participants of Day 2 Workshop

Rangan	Banerjee	Indian Institute of Technology, Bombay
Vijay	Bhaskar	Mlinda India
Akanksha	Chaurey	IT Power, TERI
Ashok	Das	SunMoksha Power Pvt. Ltd
Deepak	Kumar	Lytyfy
Bhaskar	Deol	Mynergy Renewables Pvt.ltd
Sudipta	Ghosh	SELCO
Simran	Grover	Boond
Makesh	Gujar	TERI
John	Holmes	Smart Villages
Sriram	K.S	Mesha Energy Solutions
Govindraj	K.S	Mesha Energy Solutions
Mr.	Kavya	Mesha Energy Solutions
Yashraj	Khaitan	Grampower
Umanand	L.	IISc
Anshuman	Lath	Gram Oorja
Mr.	Manikandan	Mesha Energy Solutions

Deepak	Mathur	IEEE, india
Amogh	Mukunda	Mesha Energy Solutions
Sameer	Nair	Gram Oorja
Jenny	Nelson	Imperial College London
Gyanesh	Pandey	Husk Power
Nalin	Patel	Winton Programme, University of Cambridge
Satish	Patil	IISc
Shyam	Patra	Naturetech Infra
Dr.	Prasad	MNRE
Gowtham	Prasad	IEEE, india
Mike	Price	Smart Villages
Vishnu	Raghunathan	Lytyfy
K.S.	Narayan	JNCASR
Phil	Sandwell	Imperial College London
Rustam	Sengupta	Boond
Brian	Shaad	Meragao Power
H.N	Sharan	Desi Power
Sanjith	Shetty	Soham Renewable Energy India Pvt. Ltd
A.K.	Shukla	IISc
Dr.	Sridhar	Mesha Energy Solutions
Ranjani	Sriram	Wellesley Public School
Satish	Tembad	Mesha Energy Solutions
R.K.	Viral	IIT Uttarakhand
Leena	Wadia	Observer Research Foundation
Rahul	Walawalkar	India Energy Storage Alliance

Image Credits

The women of Tinginaput village, Orissa, India, perform a tribal dance in celebration of the arrival of solar power. Beyond the direct benefits for the inhabitants of electric light, clean energy and increased incomes, is a more confident community of women who look after the solar power supply.

As Meenakshi Dewan says, “It’s changed so much. Now the women in the village ask things, they speak up, they help each other.”

The UK’s aid in India is focussed on the poorest people in three low income states - Madhya Pradesh, Bihar and Orissa - reinforcing the deep, productive partnerships we have built over the last decade.

To find out more about how we’re helping to reduce poverty and improve the lives of some of the poorest people in India, please visit:

www.dfid.gov.uk/india

https://flic.kr/p/7bAegP

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.