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Neha Makol
Ph.D. Scholar, Department of Home Science, University of Delhi, Delhi, India

Dr. Puja Gupta
Associate Professor, Department of Resource Management & Design Application, Lady Irwin College, University of Delhi, Delhi, India

Dr. Meenakshi Mital
Associate Professor, Department of Resource Management & Design Application, Lady Irwin College, University of Delhi, Delhi, India

Matt Syal
Professor, Construction Management, School of Planning, Design and Construction, Michigan State University, USA

Corresponding Author:
Neha Makol
Ph.D. Scholar, Department of Home Science, University of Delhi, Delhi, India

Government initiatives for solar home systems for rural electrification in India: Outlook and Challenges

Neha Makol, Dr. Puja Gupta, Dr. Meenakshi Mital and Matt Syal

Abstract
Rural electrification has been the cornerstone of the government's policies. India, being one of the fastest growing economy, realised that the rapid increase in electricity demands will need cleaner energy solution. India has been ranked 3rd for solar energy development in the Renewable Energy Country Attractiveness Index due to its geographical location, average temperature and policy environment (EY, 2019). Innovative off-grid solar technologies like solar home systems have found a huge market in the country since 2000s. Backed by strong policy support, solar home systems have been widely adopted by rural people for their basic lighting and electricity needs. This paper attempts to look at the initiatives taken by the government to increase the adoption of solar home systems for rural electrification and its challenges.

Keywords: renewable energy technologies (RET), decentralised energy solutions, off-grid solar technologies, solar home systems (SHS)

Introduction
Access to electricity is at the centre of rural development. Rural electrification has shown positive influence on indicators like health, education, livelihood, poverty reduction and food security (World Bank, 2018) [59]. The benefits of rural electrification have been realised in rural areas across a wide range, from increase in business opportunities, increased productivity, reduced mortality and improved health outcomes (Torero, 2015) [54]. India is predominantly an agricultural based country with almost 70% of the population living in rural parts of the country. The average electrification rate in India stood at 75.3 % in 2011 with only 66.9% of rural area with electricity access. Almost 77 million households were un-electrified in 2011 owing to weak policy measures and economy concerns (GNESD, 2014) [17]. Around 700 million people gained access to electricity between 2000 and 2018, supported by an enabling environment with strong and effective policy implementation (IEA, 2020) [22]. Across the developing countries of Asia, the access of electricity jumped significantly from 67% in 2000 to 94% in 2018, where two-third of this addition occurred in India (IEA, 2019) [21]. The vision to achieve universal electrification is one of India's major step towards the United Nations sustainable development goals (SDGs) 7, to provide affordable and clean energy by 2030 (Banerjee *et al*., 2015) [2].

With increasing electricity demands and the huge dependence on fossil fuels, the country shifted its focus towards renewable energy to meet its demands. India is solar rich country with almost 300 sunny days in a year. Considering the huge potential of solar energy in the country and for climate remediation, Jawaharlal Nehru National Solar Mission (JNNSM) was announced in 2008 as a part of National Action Plan on Climate Change (NAPCC) with an aim to generate 40% electricity from renewable sources by 2030. Further, it aimed to install 20 GW of solar capacity by 2022 which was revised in 2014 to a target of 100 GW by 2022. The efforts to increase the solar energy capacity in the country was also motivated by India's significant commitments in its Intended Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015 as part of the Paris Agreement (Down to Earth, 2019) [52].

The government through its flagship rural electrification schemes like Rajiv Gandhi Grameen Vidyutikaran Yojana (RGVVY) launched in 2005, Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) launched in 2014 and Power for All or Saubhagya scheme launched in 2017

transformed the sector (Dsouza, 2019) [10]. Due to the significant efforts to electrify villages across the country, India became the third-largest electricity producer in the world aggregating an installed capacity of 356 GW with coal as the dominant electricity source (CEA, 2019) [6]. In 2018, the coal consumption in India accounted for 70% of the global increase in consumption leading to 25% share of the total increase in global carbon dioxide emissions (BP Statistical Review, 2019) [5].

100% village electrification was achieved by the country in 2018, however a village was termed to be electrified if 10% of the households and the public spaces of the village was connected. The next step of the government was to connect every household of the country with electricity as it had promised under Power for All scheme (D'Cunha, 2018) [8]. The vision to achieve 100% household electrification has been attained across all the states of the country except Chhattisgarh (Saubhagya Dashboard, 2019) [47]. It has been achieved as a result of grid extension, and villages that could not be reached via grid expansion, were covered via off-grid solar technologies such as solar mini-grids under the decentralized distributed generation component of DDUGJY (Akshay Urja, 2018) [30].

Researches have showed that many other countries have established high rates of grid expansion gradually over a long period of time, thus it is challenging for developing countries to connect remote areas through electricity grid, rapidly in a short duration. Also, in cases of grid connected electrified villages, the reliability and quality of electricity remains a deterrent to realise the benefits of electricity. Rural areas have many households living at or under poverty line, restricting them to continue electricity consumption even at very minimum amounts (Yadav, 2019a) [63]. The inability to pay for the electricity leads to a poor demand and poor revenue for the distribution companies to consider investment for rural electricity infrastructure (Yadav, 2019b) [64]. The poor health of the distribution companies in the country is also another contributing factor to the unviability of sustainable rural electricity network. Studies have shown Discoms perspective on the recent schemes of the government to provide grid-connected electricity to every household especially in far flung villages. The stiff targets set for the Discoms to achieve in very short period presented several challenges for them. Lack of adequate financial outlay, huge resource allocation for building distribution infrastructure, inability to keeping the aggregate technical and commercial losses within the prescribed limits, inadequate monitoring and billing systems are few of the challenges as specified by the Discoms (TERI, 2019) [13]. All these factors have compounded the need of decentralised energy solutions to compliment the present grid connected electricity infrastructure in the country (Palit, 2016) [42]. The socio-economic benefits of decentralised energy solutions such as stand-alone or mini grid systems are high reliability and resilience. Off-grid energy systems can cope up with the individual level failures without compromising the electricity distribution for others which is the not the case in centralised system (Vezzoli, 2018) [58]. Economically, it enables financial arrangement of special subsidies for low income households. The decentralised energy system is also necessary for the country to meet its rising electricity demands (Yadav, 2019b) [64].

Off-grid solar technologies have attracted most attention from the government and entrepreneurs in their policies and efforts to deploy electricity services in rural areas. They have been successful to support the rural electrification programs implemented in the country. Solar PV modules costs have rapidly declined in the past one decade, making it a very affordable technology in the market at present. Solar home system (SHS) is one of the very first technologies, initiated by the government through its initiatives to reach far flung villages in rural areas where grid expansion was not possible. The World Bank has identified Solar Home System as the cheap solution of rural electrification suited for developing countries (Yadav & Singh, 2018) [62]. Solar home systems, initially, comprised of a solar PV module with two sources of light, used for lighting use in a rural household, hence it was referred to as solar lighting system. Later, to expand the use of solar light system from only lighting purpose to use it as a source of electricity, it was modified to a solar system of higher capacity to run appliances on it, thereafter it was named to solar home systems. The benchmark cost for SHS has reduced by 30% over the past five years on account of falling solar module prices and shift from CFL to LED models for home lighting systems. The present benchmark cost for an SHS is INR 340 per Watt-peak (Wp) (GOGLA, 2019c) [16]. The solar home systems space is highly lucrative for investors as it a low risk market with higher return compared to other small or medium renewable energy businesses. They are also strong candidates for standalone commercial angel/equity funding (Climate Group, 2015) [7].

India is going to be at the centre of the world's energy stage underpinned by increase in population and economic development. It is expected, India is going to overtake China in population size (Ritchie, 2019) [46]. India will be a home to an additional population of 315 million people which is the population of US today, by 2040 (Niti Ayog, 2019) [41]. India is home to almost 18% of the world's population and uses about 6% of the global energy. The energy consumption grew with a rate of 7.9% in 2018, the fastest pace in the last one decade (Worldometer, 2020 [61]; BP Statistical Review, 2019 [5]; BP Energy Outlook, 2019) [4]. India has been making constant endeavours to provide electricity through RET and the trying to provide the right policy environment for facilitating easy adoption and implementation of its initiatives. This paper attempts to discuss the policy instruments of the government for rural electrification through decentralised solar home systems with the challenges faced by the stakeholders. An extensive research of scientific papers, government reports, government documents, international reports, conference proceedings, books was conducted to collect the information on the subject. Before discussing the policy instruments of India for solar home systems, initiatives by other developing countries for promoting solar home systems are discussed.

Initiatives by other developing countries for rural electrification through solar home systems

Although 9 out of 10 people living in the world are connected to electricity, but 87% of the 840 million people with no access to electricity live in rural areas (The Sustainable Development Goals Report, 2019) [56]. The off-grid solar technologies have succeeded to improve access in various developing countries in the last 15 years and have contributed to 10% decline in global deficit in electricity access (The Sustainable Development Goals Report, 2018) [55]. The importance of decentralised renewable energy sources has been recognised in several reports. It is estimated that by 2030, 60% of new electricity access will be derived from renewable energy sources, and stand-alone and mini-grid systems will provide the means for almost half of new access.

The countries around the globe have made efforts to push the market for off-grid solar products and from 2016 to 2018, more than 23 million solar off-grid products were sold. It is estimated that 2,458 million people have benefitted with improved energy access due to off-grid solar products (GOGLA, 2019b) [15]. Solar home system has recorded the highest percentage of growth across the globe in the first half of 2019 across various capacity segments (GOGLA, 2019a) [14]. Apart from the direct advantages of the off-grid solar technologies, the job market also gets disrupted through off-grid technologies in the market. An estimated 1.5 million full-time-equivalent jobs could be created in the off-grid solar value chain by 2022, excluding the manufacturing sector. The new job opportunities will arise for technicians, after sales services and in management and finance (IRENA, 2017) [24].

One of the major solar PV technology, solar home systems reached about 100 million people and 9 million people were connected with mini grids. East Africa has been one of the biggest contributors to this growth. The financing method of pay-as-you-go coupled with digitisation enabled many rural households to get access to solar home systems in Africa. Through pay-as-you-go method, individuals or households get a solar home system and the cost of the system is recovered by an initial down payment with subsequent tailored, periodic instalments transferred to the system supplier through a digital platform, leading to eventual ownership of the system at the end (IRENA, 2017) [24].

Bangladesh has successfully implemented the world's largest off-grid electrification scheme, solar home systems program, through the government-owned Infrastructure Development Company Limited (IDCOL) (IRENA, 2017) [24]. Under this program, about 4.13 million solar home systems have been installed in remote areas, which have provided access to electricity to 18 million people which is 12% of the population of the country which were dependent on kerosene for lighting (IDCOL, 2019) [20]. IDCOL acts as an intermediary between the funding agencies and local partner organisations that supply technology or finance to the rural households (IRENA, 2017) [24]. Key success factors for the programme have been the existence of a microfinance ecosystem, the design of tailored financing schemes for end-users, a focus on long-term sustainability and market development, and, importantly, the existence of a sector "champion" in the form of the IDCOL (IDCOL, 2019) [20]. With rapid uptake of decentralised energy solutions in the rural areas, the local communities got opportunities to skill them to provide services such as installation, repair, maintenance for the off-grid technologies. Several rural women in Bangladesh were socio-economically empowered by training them to install, maintain and repair solar home systems in their areas (Komatsu, 2011) [26]. A study conducted in Bangladesh found that installation of solar home systems has significantly improved the comfort and living standards of rural dwellers. The access to TV, cell phone and internet helped them to get connected to the national and global world, making them more aware and informed (Kabir *et al*., 2017) [25].

Peru had a large population living in electrified and remote rural areas where grid expansion was challenging and costly. The government tendered the contract in 2014 to install and operate 222,000 solar home systems for 15 years, to be transferred to state in the future. This enabled almost doubling the electricity coverage from 2006 to 2016 from 40% to 79%. The Peru's Rural Electrification Project developed online web tool and mobile platform to assist electricity distribution companies for lower cost servicing and monitoring to reduce the cost of using solar home system. The program also provided capacity building programmes for the distribution companies' officials (World Bank, 2019) [60].

Initiatives for solar home systems in India

Now, looking inwards, India made significant strides in electrifying rural part of the country through solar home systems and mini grids. India notified its Rural Electrification Policy in 2006 in compliance with its Electricity Act, 2003, where decentralised distributed generation and supply of power for providing electricity to the rural area were discussed.

1. Aditya Solar Shops were started by the government in 1995 to create a network of a solar retail outlet in each district across India (MNRE, N.D.). In 2010, they were rebranded as Akshay Urja Shops to include wider range of renewable energy-based products along with solar products. There were around 400 shops set up before it was discontinued in 2017 (MNRE, 2017) [38]. These shops were set up with financial support from the government, through less rates of interest on loans, incentives, contribution towards their operational expenses. The state nodal agencies were given service charges for publicity activities for the shops (MNRE, N.D). This programme helped to establish a network of solar products distribution centres around the country, however many shop owners struggled to reach a large base of consumers with their products because of the high upfront costs for the rural consumers' despite of the subsidies provided, lack of skilled staff for maintenance and increasing competition with grid electricity (Richmond & Singh, 2017) [45].
2. Remote Village Electrification Programme (RVEP) was started by Ministry of New and Renewable Energy in 2001, to electrify remote villages which were not feasible to electrify through grid, using renewable energy sources and were not covered under Rajiv Gandhi Gramin Vidyutikaran Yojana (RGGVY) (TERI, 2015) [53]. This programme intended to provide basic facilities of electricity/lighting in distributed electricity mode, through RET such as solar hydro power, biomass gasification based electricity generation systems, solar power plants (SPP) and solar home lighting systems in areas where RET are not achievable in cost effective manner (MNRE Akshay Urja, 2013) [29]. RVEP provided households with basic lighting services for six to eight hours a day through solar based individual home lighting systems that included a 37 Wp module, 211 W CFLs and a battery. The achievements of the programme are mentioned below:

Table 1: Achievements of Remote Village Electrification Programme till 2014

S. No.	Year	Targets (No. of villages/hamlets)	Achievements (No. of villages/hamlets)
1.	Up to 10th five year plan period	-	3,254
2.	Total in 11th five year plan period (2007-12)	7,000	5,229
3.	12th five year plan period (up to 2014)	Not fixed	1,835

Source: MNRE as cited in CAG Report, 2015

Since the programme only provided households with electricity to support basic lighting needs, it didn't qualify for it to be called as an electrified household or village. The programme considerably slowed down after 2007-08. Many

states were not able to achieve their respective targets, and central government also showed less interest in the programme as the targets were not set in 12th five-year plan period. The programme was approved up to 31st March 2012 and then all the projects were continued under RGGVY (MNRE, 2012) [35].

3. Jawaharlal Nehru National Solar Mission was started with an objective to set up an enabling environment for increasing the penetration of solar technology both at centralised and decentralised level be deploying 20,000 MW of grid connected solar plants and 2,000 MW of off-grid solar applications by 2022. Under the Off-grid and Decentralised Solar Applications Programme, started in 2010, capital subsidies and incentives for solar home lighting systems were provided (MNRE, 2010) [33]. This programme provided central financial assistance (CFA) of 30-40% through the implementing agency, National Bank for Agriculture and Rural Development (NABARD), and for the rest of the cost, regional banks and commercial bank extended loans to the beneficiaries under the financing aspect of the programme (MNRE, 2017) [38]. The achievements of the National Solar Mission to deploy solar home systems since its inception is mentioned in the table below:

Table 1: Achievements of installations of solar home lights under JNNSM

S. No.	Year	Number of solar home lights
1.	2018-19	67,393
2.	2017-18	63,230
3.	2016-17	1,21,332
4.	2015-16	1,58,956
5.	2014-15	27,416
6.	2013-14	1,37,840
7.	2012-13	53,588
8.	2011-12	26,264
9.	2010-11	6,69,805
	Total	1,71,5214

Source: MNRE Annual Reports

1.7 million solar home systems have been provided under this scheme till the end of FY 2018-19. In phase III of the Off-Grid and Decentralised Solar PV Applications Programme, it is targeted to create 118 MWp equivalent solar power capacity by end of FY 2019-20, through off-grid solar PV applications such as solar streetlights, solar study lamps and solar power plants. The solar home systems have been excluded from the phase III of the scheme (MNRE, 2018) [30].

4. Decentralised Distributed Generation scheme was started by Ministry of Power under DDUGJY in 2009, but the standalone solar home systems were added to the scheme only in 2016. It was approved on the grounds that if the cost of electrifying per household in a village is more than 1 lakh INR or there are less than 15 households in a village, it can be electrified by providing a standalone solar home system. The standalone solar home system consisted of 200 Wp panel, battery, 5 LEDs, fan, mobile charger, 25-watt power socket etc. to one household.
5. The Saubhagya scheme was launched in 2017 by Ministry of Power, with the objective of providing each household with electricity, which made a provision for solar power systems of 200-300 Wp capacity for the 0.5 million households in extremely remote areas. All the solar home systems provided under this programme were free of cost. Earlier programmes by MNRE were limited to meeting only basic lighting needs through solar home lighting systems. With the advent of energy-efficient LEDs and other efficient appliances, a panel up to 300 Wp was provided, which can easily power lighting for a number of rooms, energy-efficient fans and televisions, refrigerator, other communication devices with lithium-ion batteries. Taking in consideration from the challenges faced by the consumers with respect to absence of maintenance and repair services, the system providers are required to provide after sales service the SHS for a period of 5 years (MNRE Akshay Urja, 2018) [30].

Discussion

Solar home systems have illuminated several households in rural areas since the inception of the government initiatives for its adoption. Studies in states like Odisha and Karnataka have shown significant impact of SHS on the overall socio-economic condition of the people through improved children's education outcomes and quality of life, along with discontinuation of use of non-renewable resources like kerosene (IIT, 2017; Urpelainen 2015) [23, 57]. However, there were challenges faced by the users and also the implementing agencies as discussed below:

1. Grid-connected electricity affecting the market of off-grid solar products

As the government organised 100% household electrification under the Saubhagya Scheme in 2019, it has been observed to have directly affected the market of off-grid solar products. The government has remained more committed to the grid paradigm, ostensibly for political reasons (Singh *et al*., 2016) [49]. The competitive tariffs for the grid connected electricity especially for BPL households affected the penetration of off-grid products. However, as the grid connected electricity is still unreliable and intermittent, some of the rural consumers are driven towards the solar home systems to complement the erratic supply from the grid (GOGLA, 2019c) [16]. But the constant efforts of the government to provide the grid connected electricity may jeopardize the viability of solar home systems.

2. Ensuring quality standards

Under the Saubhagya scheme, the government invited bids from battery companies for lithium-ion batteries, which are easier to deliver to remote locations. It was observed that several unestablished battery companies participated in the bid and the quality of the batteries affected the performance of the solar home lighting systems resulting in overheating and burnout of the SHS in first few weeks after installation (IESA, 2019) [47]. In Bangladesh, IDCOL established a Technical Standard Committee, which is responsible for ensuring compliance with the quality standards of the solar home systems, and it is warranted through regular physical inspection (Feron, 2016) [12]. This points out to a need for standards and certifications for product standardisation and regular inspection of the systems being delivered to the users through monitoring authorities.

3. Gaps in implementation

Several instances of improper planning by the states before implementation of the scheme, RVEP were identified. Villages already covered under other schemes such as RGGVY or uninhabited villages, were in the list of villages identified for scheme implementation. Irregularities in collection of fees from the beneficiaries and irregularities in

release of central finance assistance to the states affected the financial viability of the programme. It has been often reported by the implementing agencies that the process of availing subsidies is very long, complex and cumbersome. In the implementation of the initiatives, sub-standard quality of the bulbs, award of contracts to ineligible contractor, instances of inordinate delays in completion of projects, irregular distribution or incomplete/non-installation of systems were reported in studies.

In the post-implementation stage, the implementing agencies were responsible for ensuring functionality of the systems and periodic monitoring, but data was found missing across many states for the same. MNRE was also responsible for its own independent monitoring and evaluation of the projects, which was not carried out. For the maintenance of the systems, collection of a fixed amount on a monthly basis was to be ensured by the village level agencies for future maintenance needs which was either not properly maintained or not collected (IIT, 2017) [23]. The implementation challenges can be addressed through enforcement of regulations and standards with dynamic portals for real time monitoring to ensure accountability and transparency of each of the implementing agency. Portals like Garv or Saubhagya dashboard, developed by the government for their initiatives, where proofs of the work (completed or in the ongoing stage) is regularly updated on the dashboard, should be maintained for decentralised energy schemes also.

4. Consumer awareness and interest

Solar solutions are relatively still new in the market which requires appropriate user training and capacity building to ensure its effective use, maintenance and sustainability of the systems (Palit, 2013) [43]. Chavani village, Raigad in Maharashtra was untouched by electricity till 2007 until Maharashtra Energy Development Agency (MEDA) provided solar lighting system on 100% subsidy but without educating the beneficiaries on its operation, maintenance and post sales service. The project aimed to increase the use of solar PV did not sustain due to unawareness among the people about the technology (Anand, 2016) [1]. Similar instances have been found in other states where due to absence of effective user training, the users could not maintain their systems and shift to solar solutions were unsuccessful.

5. Post-sales service

The consumers of SHS have constantly struggled with the maintenance and repair of the systems. As found, during the inspection of few of the solar home lighting systems installed, large number of system were missing or in non-functional condition due to issues such as lack of maintenance, non-availability of spare parts, non-availability of service personnel. This requires the system installers and providers to make the maintenance, servicing and replacement of the systems less cumbersome by deploying approachable service centres or providing skills to the local communities. Selco India established since 1995, has successfully provided 450,000 solar solutions, provides door-to-door service, through 67 energy service centres by empowering local youth which can be replicated by the government to provide seamless post sales services (Anand, 2016; Selco, 2019) [1, 48]. The post-sale services should be available to the users at an affordable price at their convenience.

6. Innovative business model

Solar home systems are provided on 100% subsidy through government's aggressive rural electrification schemes. These schemes are important to introduce new innovative technologies to users, which will otherwise, take a long time for adoption especially when there are several risk factors attached to it. However, free systems are often less valued. It affects the investment of the user with the product, as the user has not gone through the decision making process where the need and the relative importance of the product is analysed rationally. Also free products create a perception of entitlement to free power. The end point of free electricity system is the continual expectation of subsidised replacement and free service (Yadav, 2018) [62]. Therefore, for below poverty line households, there is a need for more innovative models to provide access to electricity without giving it for free. Pay-as-you-go (PAYG) is one such innovative viable model which can be established between banks or system installer and the user with customised instalments based on the income level of the household. This method has proven successful in other countries. India's socio-political environment is deemed fit for PAYG penetration using the country's unified payments interface (UPI) (Yadav, 2019c) [65]. The subsidies can also be structured in a way that every stakeholder gets incentivised to participate. The stakeholders involved in implementation can be provided with performance linked incentives which will increase their willingness and participation.

7. Lack of investor's opinion

The viability and success of SHS markets depend upon the banks, as they play an important role of intermediaries between system providers and users. The off-grid and decentralised solar applications programme under JNNSM underwent through several iterations in the framework such as the capital and interest subsidies were replaced by only capital subsidies. The subsidies are given on the benchmark costs of the SHS, which were set lower than the actual costs of the system. The banks had to change their funding mechanisms with the changes in policies. Due to lack of maintenance services available to the users, many customers also defaulted on their loan payments. It was observed, that the sales of SHS dropped after the launch of JNNSM in Karnataka (Harish *et al*., 2013; Singh, 2016) [18, 50]. It is important to include the stakeholders responsible for implementation during the stage of policy formulation, and providing them suitable aid to implement.

Conclusion

India's share of total global primary energy demand is set to roughly double to 11% by 2040. With increasing energy demands, need to shift to renewable energy has been realised globally and India is already walking on that path. With a large section of the population in the country living in rural areas, it is imperative to find reliable, clean and affordable energy solutions for them. As a result of government's consistent efforts, the country has declared itself, 100% household electrified. However, with grid connected electricity, government has not been able to provide a reliable and constant source of electricity, which makes the need for decentralised energy solutions more crucial. As the decentralised energy solutions have been established to compliment the grid electricity infrastructure, government needs to focus on creating robust market for off-grid products supported by strong policy tools. Solar home systems have connected several households in rural areas with electricity. The use of solar home systems has shown significant impacts

on the lives of beneficiaries. However, in order to ensure success of any RET in any environment, it must be supported by preparing the society to adapt to it economically, politically and technically. The local capacities must be built to provide the services across the entire value chain of the RET from manufacturing, installing, maintaining and repairing. The technology hardware must be complemented by developing the local communities to learn the software of the technology. This is a huge challenge for the users in the rural areas of the country for solar home systems. The system providers should be committed to provide the know-how to the users, in addition to spreading awareness about the RET. Sustainable innovative models are required for increasing the penetration of RET among rural customers as 100% subsidies are not sustainable and fails to get a sense of ownership by the users with the product. With the right kind of market and policy support by the government, off-grid products can really find a place in every household.

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