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Comparative analysis of various means of rural electrification in India

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ABSTRACT

Economic development of rural India is the key for India to become Global Economic Super Power. But rural India would not flourish economically to its full strength until it gets electrified. The rural electrification in India gathers its first big momentum with the launch of Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in April 2005. In recent years schemes like Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) in 2014 and Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya) in 2017 accelerates the process further. It's not about government schemes only, but rather the various methods of rural electrification that has been in major focus since the late nineties. Once it was only traditional grid extension to electrify rural India. But with the advancement of renewable energy options, min-grid system and solar home lighting systems has been emerging as potential alternatives also. At present, these three methods i.e. traditional grid extension, mini-grid system, and solar home lighting system are in major focus for rural electrification. Each of them has their own merits and demerits. The present article is basically a relative pros cons analysis of these methods and an initiative to identify at the preliminary level the best suitable option to electrify rural India.

Keywords: *Rural Electrification, Grid Extension, Mini-grid System, Solar Home Lighting System.*

1. RURAL ELECTRIFICATION IN INDIA

India, one among the leading economies of the world, is predominantly rural. Almost 70% of its total population of 120 crores live in villages (Census 2011). India's overall social and economic growth is largely dependent on its rural economy. To come up to its full potential, rural India must have access to modern amenities especially the electricity.

At the time of independence, only 1500 villages were electrified in India. Till 1991, the rural electrification growth rate was rather slow as only 481124 villages were electrified by 1991 but due to de-electrification of some of the villages, this number came down to 474982 by 2004 *(Central Electricity Authority)*. High maintenance cost of transmission and distribution network in remote areas and lack of cash availability actually accelerated the de-electrification process.

In 2005, it was estimated that out of 13.8 crore rural households about 7.8 crore households are un-electrified *(as per 2001 Census)*.A major development expected in rural electrification with the launch of *Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)* in April 2005 with an objective to provide access to electricity to all rural households through development of rural electricity infrastructure comprising of Rural Electricity Distribution Network, Village Electricity Generation & Distribution Infrastructure and Decentralized Distribution Generation & Supply System. Under the scheme, households belonging to Below Poverty Line (BPL) are provided connections free of cost. Ninety per cent capital subsidy is provided by Government of India for projects under the scheme. RGGVY was initially approved with a capital subsidy of Rs.5,000 Crore for the last two years of the 10th Plan period ending March 2007 and continued in 11th Plan with a capital subsidy of Rs.28,000 Crore.

Under RGGVY scheme, as on 31st March 2012, electrification works in 104,496 un-electrified villages, intensive electrification in 248,553 partially electrified villages had been completed and free electricity connections provided to 194.25 lakh BPL households

Under RGGVY, for Twelfth/ Thirteenth Plan, 273 projects for electrification of 9012 un-electrified villages, 2.32 Lakh partially electrified villages, 1.42 Lakh unelectrified habitations, 4.17 Lakh partially electrified habitations and 1.32 crore BPL households were sanctioned.

The rural electrification further accelerated with the Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) in November 2014 with an objective like agricultural and non-agricultural feeder separation (for 24x7 power supply for non-agricultural consumers) and providing electricity access to all rural households.

As on 31.10.2016 under village electrification programme, electrification works in 1, 19,664 unelectrified villages, intensive electrification in 4, 02,248 partially electrified villages have been completed and free electricity connections to 249.89 Lakh BPL households have been released. Total subsidy released under the village electrification programme till 31.10.2016 is Rs. 43641.33 crore.

Further to accelerate rural electrification process, in 2017, GoI announced Rs.16, 320 crores Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya) with an objective to provide electricity connection to around 4 crore families in rural and urban areas by March 2019. Ministry of Power fixes the target to achieve universal electrification under the Saubhagya scheme in December 2018.

(Data Source: Ministry of Power, GoI)

2. RURAL ELECTRIFICATION-POLICY OVERVIEW

Rural electrification pace in India was never near the requirement until the first decade of the twenty-first century. According to the 2001 Census, 6.02 crore households use electricity as the primary source of lighting out of a total of 13.8 crore households in the country.

Table-1: Countries with Highest Population without Access to Electricity

	2000		2016	
	Million	%	Million	%
Africa	532	66%	588	48%
North Africa	14	10%	0	0%
Central Africa	73	90%	98	75%
East Africa	164	90%	172	61%
South Africa	15	34%	8	14%
Other Southern Africa	108	86%	135	69%
West Africa	158	67%	175	48%
Developing Asia	**1059**	**33%**	**439**	**11%**
China	18	1%	0	0%
India	600	57%	239	18%
Indonesia	99	47%	23	9%
Other Southeast Asia	100	33%	42	11%
Other Developing Asia	242	68%	135	27%
Central and South America	56	13%	17	3%
Middle East	15	9%	17	7%
World	**1672**	**27%**	**1060**	**14%**

Source:https://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf

The above table shows, till 2000, India is at the top of the countries with highest no. of people without access to electricity. Apart from various techno-commercial reasons, one of the principle reason was proper well-directed policy framing. Most rural electrification initiatives were bundled with other rural development programmes and schemes, such as the Minimum Needs Programme, the Prime Minister Gramodyoy Scheme, etc. (Siddiqui and Upadhyay, 2011).

Until 2001, mini-grid technology was not established as a fully reliable one and mainly setup under technology demonstration programme of MNRE. In 2001, renewable energy-based decentralized generation technologies including mini-grids came into the forefront with Rural Electricity Supply Technology Mission. There onwards, it has been considered as a mainstream rural electrification method. Subsequently, Government of India took its first focused attempt to look into issues related to decentralized generation, particularly in the context of off-grid electrification, through the **Gokak Committee.** The Committee recommended considering the entire socio-economic benefits accruing to various stakeholders while evaluating the feasibility of mini-grids in remote areas.

Thereafter, the **Electricity Act of 2003** was enacted and it was a landmark step in the electrification of India. Perhaps the most prominent and well-directed step since the independence. For the first time **Electricity Act 2003** mentions rural electrification in a law. Section 6 of the Electricity Act, 2003 mandates the hitherto implied Universal Service Obligation by stating that the government

shall endeavor to supply electricity to all areas including villages and hamlets. Section 5 further mandates the formulation of national policy on Renewable Energy focusing especially on the management of local distribution networks through local institutions. Section 4 of the said Act also frees stand-alone generation and distribution networks from licensing requirements. This also increases the scope of Renewable Energy further.

Subsequently, the GoI has launched **National Electricity Policy in 2005** and the **Rural Electrification Policy in 2006.** The policies emphasized on wherever grid-based electrification is not feasible, decentralized distributed generation (DDG) together with a local distribution network, i.e. mini-grids, would be provided. DDG projects are also included as a part of the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), which was a pioneer in mainstreaming off-grid electrification technologies within the ambit of the national rural electrification strategy. In addition, the two policies also preserve that the benefits of subsidies should be passed on to the end consumers. The Rural Electrification Policy also provisions that the retail tariffs on electricity supply set by providers exempt under Section 14 would be based on mutual agreement between such persons and the consumers.

The rural electrification further received the highest level of acceleration with ***Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) in November 2014 and Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya) in 2017.*** With these focused policy framing, it is expected that the much desired rural electrification dream will come to reality to a large extent by 2018.

(Data Source: Ministry of Power, GoI)

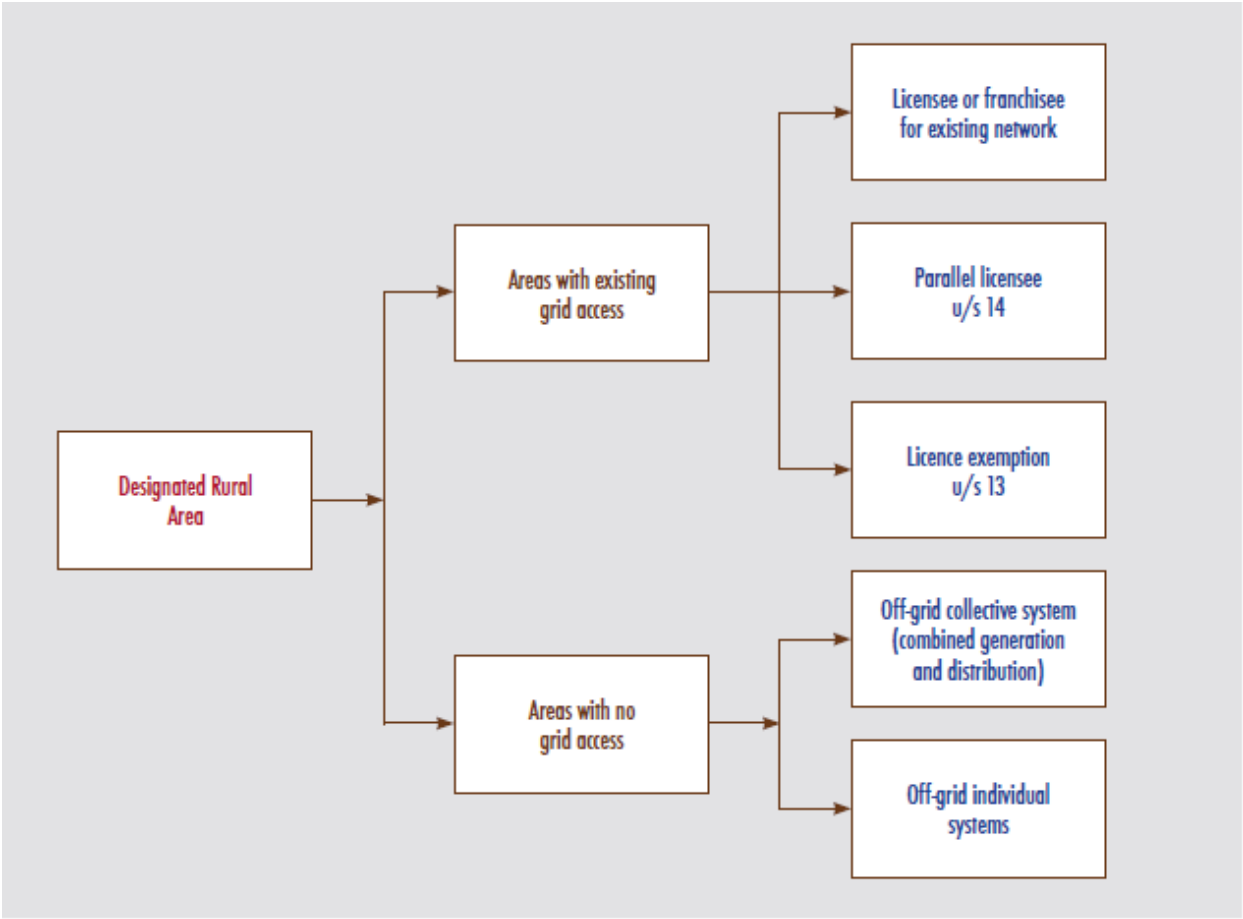

Fig-1: Options for Rural Electrification under the Electricity Act 2003

(Source: Renewable energy-based rural electrification: The mini-grid experience from India prepared for Global Network on Energy for Sustainable Development-GNESD, Debajit Palit and Gopal K Sarangi,2014).

3. TRADITIONAL GRID EXTENSION- A CRITICAL OVERVIEW

One way to electrify remote rural areas is traditional grid extension. But this, in fact, is a decision of the utility or government considering various factors like the techno-commercial viability of grid extension, whether additional capacity is available with the utility, availability of fund and whether the utility is at all interested in grid extension or not. Traditional grid extension ensures the following **advantages**:

a. With traditional grid extension, all village dwellers even those who can't afford electricity at home will harness benefit of electricity at shops, health centers, schools/colleges and also through water pumping system, street light etc.

b. Overall business and employment will increase leading to improvement in the economy.

c. Traditional grid extension is an investment for community development as well improvement in country's infrastructure and will pave the way for further economic development in future.

d. Increase in demand for electricity will actually bring the per unit cost down due to 'economy of scale'. Further pollution-related issues can be monitored centrally.

Electrification of remote villages with traditional grid extension has numerous **demerits** also. Some of them can be summarized as follows:

a. One of the principle reasons for poor electrification status of rural remote areas is a higher cost of grid extension. The pay-back period is actually many times of that in an urban area.

b. The heavy transmission and distribution loss associated with the power supply in remote areas make it more unattractive.

c. The consumer base in rural remote areas is no way near that in urban or even semi-urban areas. As 22% of Indian population is of BPL category and 80% of the poor population live in rural areas ***(World Bank Group, 2016)***, therefore in spite of having electricity available, only a few can actually access it. In India, according to a report from the International Energy Agency, "the electricity network is technically within reach of 90% of the population, though only 43% are actually connected because people cannot afford the cost of connection" ***(Priddle 2002, p. 376)***.

d. A major portion of the grid is outdated and unfit to absorb any substantial increase in electricity demand. Grids may face many technical problems even grid failure, which is extremely costly for utilities and consumers.

e. The flexibility of grids is doubtful especially for renewable energy sources like solar wind etc.

All these factors are techno-commercial challenges for traditional grid extension to electrify rural India. And these are the reasons that rural electrification did not find the required pace till early 90's. However, socio-economic development of the country would never be possible until and unless rural India gets electrified. Therefore, govt. is focusing on alternative methods of electrification like Mini-grid system or solar home lighting system. The following paragraphs will highlight the relative pros cons analysis and their feasibility in electrifying India.

4. MINI-GRID BASED ELECTRIFICATION-A CRITICAL OVERVIEW

Off-grid and decentralized renewable energy technologies are finding its strong foot-print over the years in electricity-starved rural India. These are especially in demand in areas that are either inaccessible for grid connectivity or underserved by the grid (i.e. receive less than 4 hours of electricity per day) or are part of hamlets that are not recognized as villages as per the national census record (Palit and Chaurey, 2011).

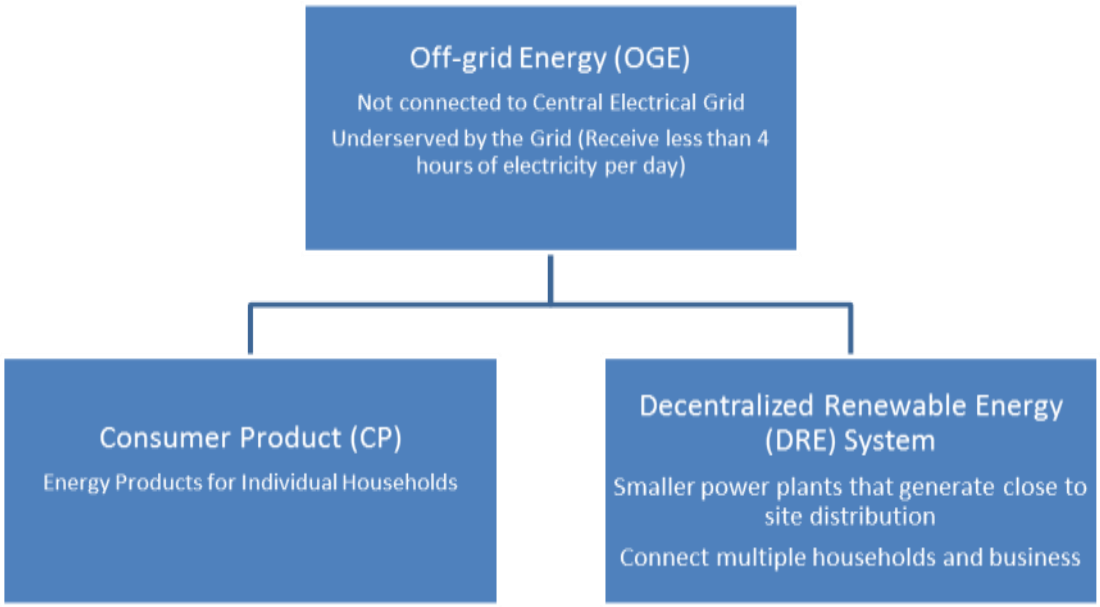

Fig-2: Off-grid Technologies

The common renewable energy-based decentralized technologies are solar PV, biomass gasifiers and mini/micro hydro. Ministry of New & Renewable Energy, GoI with the help of state renewable energy development agencies has been very much proactive in the implementation of many such projects. NGOs are also proactive in such project implementation with funding from different national and international agencies including as part of Corporate Social Responsibility (CSR) activities. Recently private investors are also showing interest as new business ventures.

Among the available alternatives, biomass mini-grids are highly dependent on technical skills and requires a considerable load to operate the gasifier successfully. Decentralized wind power projects are not that viable. Large and small-scale hydro-power is mature technologies, but are highly dependent on the geographical location and have an indirect long-term impact on the environment. These projects also need sufficient load to be viable projects.

On the other hand, sufficient solar irradiation is available all over India, solar is a well-tested technology and price of solar PV cells is coming down drastically. ***Therefore, considering the techno-commercial feasibility, solar looks much attractive than another form of renewable energy for the mini-grid application. The discussion here would be mainly confined within the periphery of solar mini-grid based technology.***

The concept of solar PV mini-grids in India was pioneered by the 1990s in the Sagar Island, West Bengal and in the forested region of Chhattisgarh (then in Madhya Pradesh).

Sagar Island lies on the continental shelf of Bay of Bengal about 150 km (80 nautical miles) south of Kolkata, in West Bengal. The *District Statistical Hand Book of South 24 Parganas* (2003) mentions that the area of the island is around 300 km² with 43 villages and a population of over 180,000. The Island, popularly known as Ganga Sagar, is a famous Hindu pilgrimage. Every year on the day of Makar Sankranti (middle of January) thousands of people from all over India gather to take a 'holy dip' at the confluence of Ganga and offer puja in Kapil Muni Temple.

Apart from its religious importance for the annual 'Ganga Sagar Mela', the Sagar island is noted for early initiatives to explore renewable energy opportunities, especially solar power. A study ***(The International Journal of Engineering and Science-IJES-2013)*** highlights that the first solar power station was set up in Sagar Island in 1993 followed by the country's first 25 kW solar power plants at Kamalpur village of the island in 1995.

Similarly, in Chhattisgarh, the first solar power plant was installed at Lamni village in Bilaspur district that is still reportedly operational.

These two are the most successful models of mini-grids implemented by government agencies in India. WBREDA has set up more than twenty mini-grids based solar power plants with an aggregated capacity of around 1 MWp, supplying stable and reliable electricity to around 10,000 households in Sunderban areas of West Bengal. CREDA, on the other hand, has electrified around 35,000 households across more than 1400 villages and hamlets with low capacity (1-6kWp) solar mini-grids in Chhattisgarh ***(Renewable energy-based rural electrification: The mini-grid experience from India prepared for Global Network on Energy for Sustainable Development-GNESD, Debajit Palit and Gopal K Sarangi,2014).***

With these two successful mini-grid initiatives, many such mini-grids implemented in different states, viz. Bihar, Chhattisgarh, Lakshadweep, Madhya Pradesh, Odisha, Uttar Pradesh, Uttarakhand and West Bengal. Depending on capacity, mini-grids provide electricity for households, small commercial activities, for community requirements such as the supply of drinking water, street lighting, vaccine refrigeration, and schools. Ministry of Power and Ministry of New and Renewable energy has been playing a key role in this mini-grid based electrification of rural India. The Remote Village Electrification Programme (RVEP) and the Village Energy Security Programme (VESP) under MNRE electrified more than 12,700 remote villages and hamlets (MNRE 2013). Most of these villages are not suitable for electrification through traditional grid extension.

The mini-grid system has several merits as summarized below

a. The principle advantage of the mini-grid system is its techno-commercial feasibility in remote far-flung areas where traditional grid extension is not feasible.

b. Mini-grid system also eliminates the huge T&D losses associated with traditional grid extension. Even in electricity under-served areas, they are a more reliable option. Due to their small scale in nature, local ownership, and better local control, power theft (a big problem with traditional grid systems) can be avoided.

c. The hybrid mini-grid systems like solar & wind hybrid systems are more reliable as in case of temporary unavailability of one source or technical problem with it, the other one can perform. This also brings down the per unit cost over life time of the project.

d. The central grid system supplies electricity from large-scale generation. In most cases, it is fossil fuel based thermal power or hydro electricity. Whereas mini-grid systems are renewable energy based ensuring reduction in carbon emission and no environmental impact.

e. As the renewable energy is getting cheaper, mini-grid systems are becoming more attractive as the source of energy is also eco-friendly and ensures sustainability. This even is attracting private investors.

Mini-grid system has several demerits also as mentioned below:

a. Unskilled or semi-skilled local labors and lack of proper maintenance thereof are big challenges for renewable energy based mini-grid systems. Often faults can't be addressed in proper time due to lack of technical skills.

b. The non-government initiatives are often hit by lack of funding. Poor quality materials actually affect the life span of such projects.

c. Poor assessment of demand actually hit the pay- back period and viability of the overall project and sometimes the projects called off even. Population density and their economic capability in the mini-grid serving area are decisive factors on the load factor and therefore economic viability of projects.

d. Development of effective supplementary schemes dealing with issues such as market access, **small medium enterprise (SME)** development and working with local financing institutions, has often resulted in lack of demand and inability to sustain the schemes.

e. Poor assessment mainly due to lack of data on the local physical parameters affect the power output and economic viability of projects. This is especially true in case of wind power projects.

f. Solar or solar-wind mini-grid systems are affected by seasonal fluctuations like a change in solar irradiations, wind speed etc.

g. Lack of well directional policy like traditional grid extension plan, commercial solar subsidies etc. make the scenario unclear and discourages the private players from investment in mini-grid systems.

Mini-grid system is definitely a convenient solution where traditional grid extension is not possible. But neither has it given that infrastructural achievement that can bring considerable economic development, nor it gives the privilege of enjoying a stand-alone system like benefits. Its success rate depends on a community. If the number of the consumer is not big enough, it will not survive commercially even though some are interested. On the other hand, even a highly successful renewable energy based mini-grid systems could be completely dumped if traditional grid extension happens for various socio-economic-political reasons. For example, the solar energy based mini-grid systems at Sagar Island, West Bengal. Asia's first 100 kW level solar plant installed here followed by a number of such plants. The entire framework was highly successful based on community-level initiatives of operation, maintenance and payment collection. But, State Government decided to go for traditional grid extension to make Sagar Island an important port. As the grid extension took place, the solar energy based mini-grid systems became useless. The investment made into them did not pay off completely.

The situation, therefore, demands a new alternative like Solar Home Lighting Systems where ownership lies with individuals only and even grid extension takes place, it can be used as a back-up system.

5. SOLAR HOME LIGHTING SYSTEMS-A CRITICAL OVERVIEW

Solar Home Lighting Systems (SHLS) are stand-alone photovoltaic systems that offer a cost-effective solution for lighting and small electrical appliances in remote households where grid system is not available. SHLS usually operate at a rated voltage of 12V **direct current (DC)** and provide power for low power DC appliances such as lights, radios and small TVs for about three to five hours a day.

Table-2: Details of Various Solar Home Lighting System Models

System Capacity	No.of Lights	Tubular Battery
37 Wp	2 nos. – 9W CF Lamps	12V, 40 Ah
37 Wp	1 – 9W CFL + 20W DC Fan	12V, 40 Ah
74 Wp	2 – 9W CFL + 20W DC Fan	12V, 75 Ah
74 Wp	4 nos. – 9W CF Lamps	12V, 75 Ah

(Source: https://geda.gujarat.gov.in/application_solarhome_lighting_system.php)

SHLS typically includes one or more PV modules consisting of solar cells, a charge controller which distributes power and protects the batteries and appliances from damage and at least one battery to store energy for use when the sun is not shining. The PV module is installed in the open on roof/terrace - exposed to sunlight and the charge controller and battery are kept in a protected place in the house. The solar module requires periodic dusting for effective performance. It also comprises of appliances such as cables, switches, mounts, and structural parts. SHLS are best used with efficient appliances like LED technology so as to limit the size of the array.

Solar Home Lighting Systems has its own merits as summarized below:

a. These systems are ideal for village electrification where neither traditional grid extension nor mini-grid system exists.

b. These systems will never be useless as even after adopting SHLS systems if grid extension takes place, these systems will act as a back- up the system.

c. SHLS systems are also very useful in electricity underserved areas or where frequent power cut occurs.

d. Irrespective of geographic location, SHLS is operational everywhere.

e. Environment-friendly clean energy source.

f. No regular cost of purchasing the system. Though now a day, various financial schemes are offered by SHLS manufacturers/ suppliers in which initially customer has to pay a low amount and thereafter monthly installments for a certain period.

g. Stand-alone system. Unlike mini-grid system viability not dependent on entire community participation.

h. Not only lighting, but the system also allows small DC appliances like fan, radio, television and mobile charging also.

The Solar Home Lighting System (SHLS) poses some demerits also as summarized below:

a. SHLS is more suitable for domestic consumer. They are not suitable at all for the commercial consumers.

b. The initial investment is high. This problem is mitigated by and large with the adoption of monthly installment schemes.

c. Quality and after-sales service is a big issue with SHLS. Especially the early stage SHLS were of poor quality and created a very negative impression on the market.

d. People with low economic back-ground are reluctant to invest in a relatively high amount in a new technology like SHLS.

e. Battery with SHLS demands for a regular maintenance.

f. Not so useful on rainy days.

g. The efficiency level of the system deteriorates over time.

h. PV panels can be damaged relatively easily due to their fragile nature. Once damaged, the system becomes completely useless.

6. DISCUSSION

Throughout the ongoing decade, rural electrification has been on top priority for Government of India. Perhaps the most proactive approach since independence. Until and unless, rural India gets electrified, the economy will not even come near about its full potential.

However, as discussed in earlier paragraphs, the three most prominent form of village electrification identified are

a. Traditional Grid Extension,
b. Solar Energy Based Mini-Grid System
c. Solar Home Lighting System

Each of the systems has its own merits and demerits. Their relative priorities depend a lot on geo-demographic and socio-economic conditions. Whereas, some characteristics look advantageous in a particular condition, as the condition changes the same characteristics come out as hindrances.

Again, having grid/ mini-grid electricity connection will not serve the purpose of development if the village dwellers can't afford it on regular basis. The irregular income and lower paying capacity of villagers often raise this problem.

According to a report (IEA's Energy for All (2011)), only 30% of the world's rural populations currently without access to electricity are best served by extending the traditional main grid. The remaining 70% are better served either through mini-grids (52.5% of total un-served) or stand-alone systems (remaining 17.5% of total un-served).

The following matrix presents a comparative analysis of leading methods of rural electrification considering various techno-commercial factors.

Table-3: Comparative Analysis of Leading Methods of Rural Electrification

	Traditional Grid Extension	Solar Mini-grid System	Solar Home Lighting System
No Geographic Barrier	1	2	3
No/ Less Technical Losses for Utility/ Service Provider	1	2	3
Renewable Energy	1	3	3
Low/ Reasonable Initial Investment for Consumer	3	3	1
Low Recurring Expenses	1	2	3
Standalone System	1	1	3
Helps in Big Scale Socio-Economic-Community Development	3	2	1
After Adoption, System would never be Useless due to Other Decision	2	1	3
Technical Compatibility of High Rating Electrical Appliances	3	2	1
Not Weather Dependent	3	1	1
Complete Ownership of the System	1	1	3
Total	20	20	25

Strong
Medium
Weak

The above matrix could be helpful in deciding the right alternative for electrification of a, particularly remote place. 11 factors have been identified as key factors. For, each factor, a weight scale is there indicating a value between '1' to '3'. Whereas, '1' signifies 'weak', '2' signifies 'medium' and '3' signifies 'strong' weight. Now, each mode of remote electrification has been analyzed considering all the 11 factors and their assigned weight with respect to each factor. Whereas a strong acceptance of a particular statement/factor draws a weight of '3', a medium acceptance is assigned with '2' and a low/ no acceptance with '1' weight.

Further, the analysis shows that for remote electrification, Stand Alone Solar Home Lighting System poses more preferential factors than Traditional Grid Extension and Solar Mini-grid System. This also establishes the logic behind Government's plan to promote Stand Alone Solar Home Lighting System in remote areas.

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