Solar Energy for Rural Electricity in India
A Misplaced Emphasis

HIPPU SALK KRISTLE NATHAN

The urban-rural divide in developing countries is reinforced by unequal distribution of resources and amenities. Energy as a resource and electricity as an amenity are no exceptions. In this context, this paper questions the relevance of promoting solar photovoltaic systems for lighting in rural areas. It asserts that the basic electricity needs of rural areas are no different from urban ones, and there is a willingness to pay for reliable supply of electricity. Studies show that solar PV's failure in villages is primarily due to glitches in maintenance, arising from lack of money, materials, and skilled humanpower. The answer would be to give these systems an urban focus, bringing in a more balanced use of solar energy for electrification.

I am grateful to an anonymous reviewer, Dilip R Ahuja, Sudhansu Kumar, Aditi Malhotra, Anasuya Gangopadhyay and V S Ramamurthy for their comments on earlier versions of the paper. I am also thankful to those who gave feedback to a presentation at the Fourth National Research Conference on Climate Change held at IIT Madras during 26-27 October 2013. I thank the South Asian Network for Development and Environment Economics as involvement in one of its projects motivated me to dwell on the subject of this paper.

Hippu Salk Kristle Nathan (*hsknathan@nias.iisc.ernet.in*) is with the National Institute of Advanced Studies, Bengaluru.

1 Introduction

The urban-rural divide in India is well known. According to the Census of India (2011), 69% of the population is rural, and more than two-thirds (68%) of all households are in rural areas. In most socio-economic indicators, rural people are way behind their urban counterparts. The India Human Development Report – 2011 (IAMR 2011) has the urban-rural gap in terms of percentage points at 17 in literacy, 19 in child immunisation, and 38 in institutional delivery. In rural areas, the infant mortality rate and under-five mortality rate are 1.6 and 1.7 times more compared to urban rates (IAMR 2011). Inadequate service provisions in health, education, roads, sanitation, and other infrastructure has led to lower development in rural areas.

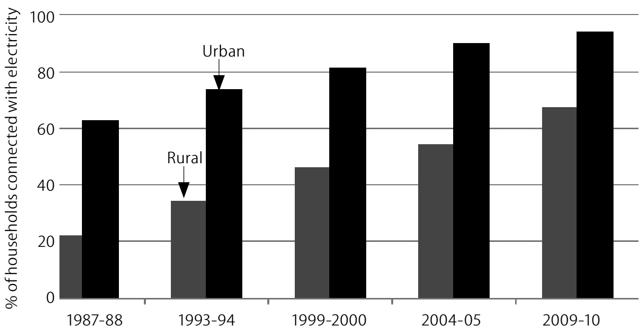
Given limited resources, it is often the case that cities grow at the cost of rural areas. Villages feed and provide water for the city population, provide labour for menial/unskilled work, and are a preferred place for dumping urban waste. This inequity is reinforced by unequal distribution of resources and amenities. Energy as a resource and electricity as an amenity are no exceptions. Close to 93% of urban households use electricity as their main source of lighting through the grid, whereas the corresponding figure for rural areas is 55% (Census of India 2011). This difference is more pronounced when one considers the quality of supply. Among those connected to the grid, the average consumption of electricity in rural areas was 96 kilowatt-hour (kWh) per person in 2009, which was one-third of the figure in urban areas, 288 kWh (MOSPI 2011).

Given the rural-urban disparity, this paper questions the emphasis on solar photovoltaic (PV) systems for rural areas, particularly for the lighting needs of the domestic sector. First, it looks into the rural-urban disparity in the supply of power for the domestic sector, both in terms of quantity and quality. It then reviews the electricity needs of rural households and their willingness to pay vis-à-vis their urban counterparts. It goes on to review the Government of India's policy priorities in electrification, and looks into the causes of failures of solar PV systems. The study critically examines the arguments for the promotion of solar PV for rural electricity and builds a case for making it a priority in urban areas.

2 Rural-Urban Electricity Disparity

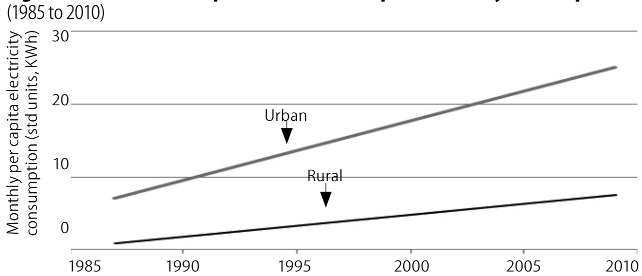
The domestic sector is the second largest in terms of consuming electricity, accounting for about one-fourth of total consumption (MOF 2012). The rural-urban disparity in domestic consumption of electricity is evident both in quantitative and qualitative terms. The shares of households with electricity connections in rural and urban area show that the gap, which was at 41 percentage points in 1987-88, was reduced to 27 percentage points in 2009-10 (Figure 1). However, this is not a story of convergence.

Figure 1: Rural-Urban Share of Households with Electricity Connections
(1987 to 2009)



Source: NSSO (1997, 2001, 2007, 2012).

Figure 2: Rural-Urban Gap in Domestic Per Capita Electricity Consumption
(1985 to 2010)



Source: NSSO (1997, 2001, 2007, 2012).

Having a power connection is important, but it is more important to have enough electricity for a household's needs. Between 2001 and 2011, the shares of households in rural areas using electricity as their prime source of lighting changed from 43.5% to 55.3%, and in urban areas from 87.6% to 92.7% (Census of India 2011). Although 67.3% of rural households consume some electricity (as per the National Sample Survey – NSS), about one-fifth of these (12%) do not use electricity as their prime source of lighting. Not having enough electricity to use for basic purposes such as lighting can be attributed to the lack of availability, which has remained an area of concern, particularly in rural areas (Planning Commission 2012). The lack of availability is largely due to the structural disincentive distribution companies have to serve rural consumers – in the form of low tariffs. Uncertainty of power supply, frequent load-shedding, and an extensive rostering schedule have remained the characteristics of rural electrification (ESMAP 2002a; Srivastava and Rehman 2006).[1]

The rural-urban disparity comes out more vividly in terms of per capita consumption of electricity, as shown in NSS reports (Figure 2).[2] Between 1987 and 2009, the rural-urban gap in monthly per capita domestic consumption increased from 5.88 units to 16.34 units.[3]

The increase in the rural-urban gap of per capita consumption contradicts the principle of development with equity Nathan and Mishra (2013: 2). This in principle means that "concern with inequality increases as a society gets prosperous since the society can 'afford' to be inequality conscious" (Sen 1997: 36). The increase in per capita domestic electricity consumption must simultaneously lead to a fall in the gap between rural and urban per capita consumption. Instead, the gap has increased almost three times in India.

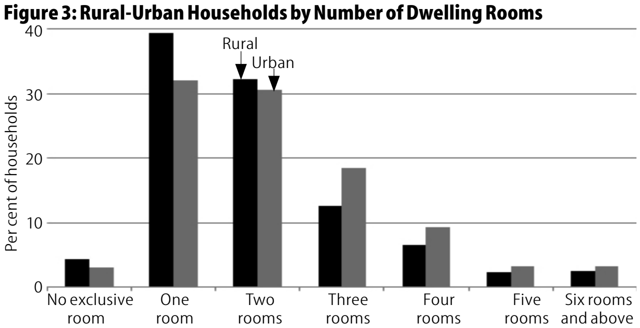
3 Electricity Needs of Rural Households and Willingness to Pay

The need to have electricity at home, irrespective of location, rural or urban, cannot be overemphasised. Electricity is recognised as a basic human need and it is key to accelerating economic growth, generating employment, eliminating poverty, and enhancing human development (WEC 1999; Modi 2005; MoP 2006; Kemmler 2007). Lighting is correlated to the productive hours of any household, that is, the hours children study and adults work (Reddy et al 2009; Reddy and Nathan 2011; Planning Commission 2012). The availability of electricity works to the advantage of women in particular (Modi 2005). Global evidence shows that proper lighting in the home and streets increases female literacy and educational attainments, their income-generating options and savings, and their safety and security in public places (UNDP 2001; Planning Commission 2012). According to Sen's capability framework (1997), energy carriers, particularly electricity, can be understood as an input that expands one's set of capabilities (by providing lighting and cooling, motive power, preserving food, and facilitating access to the mass media and telecommunications) and thus enables one to function effectively in society (Kemmler 2007). There is a large literature that shows rural electrification greatly contributes to the welfare growth of households and promotes rural-urban integration (Barnes et al 2002; ESMAP 2002b; Toman and Jemelkova 2003; Martins 2005; Valencia and Caspary 2008; World Bank 2008a; ADB 2010).

Rural households need electricity as much as urban households. Though some estimates give different thresholds for rural and urban households, one can argue that the same normative value must apply for both. First, the average household size in urban and rural areas is about five (rural 5.01 and urban 4.80, according to the 2011 Census), which essentially means that the number of people requiring illumination per household in rural and urban areas is almost the same; rather, it is a little higher in rural areas. Second, the distribution of households by the number of dwelling rooms is not significantly different in urban and rural areas (Figure 3, p 62), which means that they require a similar level of power.[4] Third, with respect to consumption of electricity, we advocate similar levels for urban and rural households from an ethical point of view. We elaborate on this further.

Consumption patterns in rural and urban areas differ in practice and some estimates of the normative minimum take this into account. For instance, the World Energy Outlook (WEO) analysis of the International Energy Agency (IEA) (2012) considers 250 kWh and 500 kWh as the minimum consumption levels for rural and urban areas, respectively (with five people in each household). It is based on the assumption that this could provide for the use of a floor fan, a mobile telephone, and two compact fluorescent lamp (CFL) bulbs in rural areas, whereas it might include an efficient refrigerator, a second mobile telephone, and another appliance, such as a small television or a computer, in urban areas. We argue that it is unfair to assume that rural households on an average do not need a

Figure 3: Rural-Urban Households by Number of Dwelling Rooms



Source: Census of India (2011).

television or computer as a basic need.[5] In the National Youth Development Index Report by the Rajiv Gandhi Institute of National Youth Development (RGINYD 2010), mobile phones, televisions, and computers are considered essential for the development of youth, both in urban and rural areas. Also, from a social justice point of view, energy services are a right of individuals; and some have advocated making basic energy services a fundamental right (Narain 2010; Practical Action 2009). Energy poverty is universally recognised as a bottleneck in achieving the Millennium Development Goals (DfID 2002; Flavin and Aeck 2005; UNDP 2005; World Bank 2005; WHO 2006; Practical Action 2009). In terms of domestic electricity use, the normative thresholds for rural and urban households must not be different.[6]

The paying capacity of the average rural consumer is lower than the average urban consumer (Chaurey et al 2004; Ernst and Young 2007; Kamalapur and Udaykumar 2012). However, World Bank studies (ESMAP 2002a; World Bank 2008a, 2010a) show that the willingness to pay for electricity in rural areas is high, exceeding the long-run marginal cost of supply. Also, there is evidence from the field that rural communities are able to and willing to pay for reliable electricity services (Barnes et al 2002; Cust et al 2007; World Bank 2010b; Jhirad and Sharma 2011; CSE 2012a; Raghu and Reddy 2012). Electricity for lighting has a high value for rural households, and the willingness to pay for better quality supply is high, even among poorer households (Cust et al 2007; World Bank 2008a).

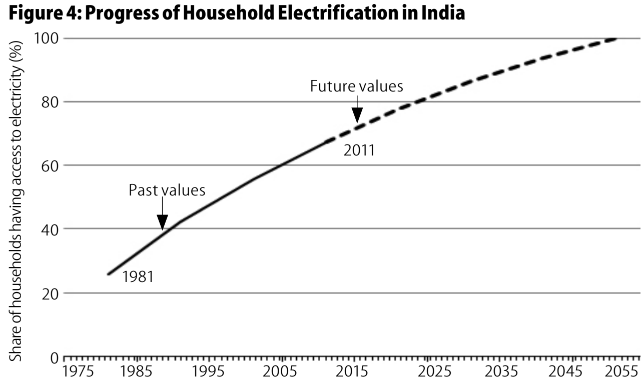
Having said that, one must note that the willingness to pay is not equal to actual payments. Off-grid consumers are often charged a higher per unit tariff than those connected to the grid (ABPS 2011; Bast and Krishnaswamy 2011; Gambhir et al 2012). In many cases, though rural people consider the cost to be high, they pay as there is no other option available (Gambhir et al 2012). They do it though they are not fully willing. The willingness to pay is relatively high for domestic lighting, but both the willingness and ability decline for additional loads (World Bank 2010b; ABPS 2011; Gambhir et al 2012). With efficient lighting equipment, the load can be as low as a few units per month even with a high per unit tariff, whereas it will be large for other uses such as agriculture, and hence not affordable at a high rate.

4 Government Policies towards Rural Electrification and Renewable Energy

Rural electrification has figured in various plans for the past several decades. However, it has been continuously neglected at the ground level owing to a combination of factors – low tariffs; the high cost of service; poor efficiency levels; inappropriate organisational frameworks; and the focus of state electricity boards on urban areas, metros, and industries (Padmanabhan 2003; Chaurey et al 2004; Ernst and Young 2007; Kemmler 2007). After the Electricity Act of 2003, the central government made an ambitious plan to electrify all villages by the end of 2007, and all households ("Power for All") by 2012 (MoP 2003; Modi 2005).[7] This goal was reiterated in several government plan and policy documents.[8] Towards achieving it, the government launched the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) under the Ministry of Power, and the Remote Village Electrification (RVE) division under the Ministry of New and Renewable Energy (MNRE 2004, 2006; MoP 2006; Bhattacharyya 2006; Cust et al 2007).[9] However, the goal of universal electrification has been repeatedly missed. In terms of villages, as on 31 November 2012, 94.1% were connected to the grid (CEA 2012; note that the target was 2007). However, with only 55.3% rural households using electricity for lighting (Census of India 2011), the household electrification target has been missed by a large margin.

In the latest Global Energy Assessment (GEA) report, the International Institute for Applied Systems Analysis (IIASA 2012) outlines the historical progress of electrification in some selected countries showing that India lags behind other developing countries such as China, Mexico, Brazil, and Thailand. If India's electrification continues at the same pace, it would achieve power for all by 2051 (Figure 4).[10]

Figure 4: Progress of Household Electrification in India



Now let us turn to the government's policy on generating electricity using renewable sources in rural areas. Rural areas can be divided into two categories – remote, and non-remote.[11] For remote villages, where it is difficult to provide electricity through a conventional power grid, renewable options must be prioritised with the necessary subsidies (Planning Commission 1997, 2002).[12] The RVE programme has been on since

October 2003 for this purpose. According to the latest MNRE (2013) report, about 30% of all remote villages have so far been electrified (the target was to electrify all remote census villages by 2007).

The large majority of villages that are non-remote and grid-electrifiable (of which about 95% are already grid connected) also get more priority in renewable energy applications than urban areas. The thrust area in renewable energy identified in the Eleventh Plan (Planning Commission 2011) is meeting basic energy needs in rural areas through locally available renewable energy resources. Though "renewable energy for urban, industrial, and commercial applications" also forms a part of renewable energy programme of the Eleventh Plan, expenditure on this was less than one-sixth of that for rural applications (Planning Commission 2012).[13]

For solar energy, the country has a target of 2 gigawatts (GW) of off-grid systems by 2022 under the Jawaharlal Nehru National Solar Mission (JNNSM), with intermediate targets of 200 megawatts by 2013, and 1 GW by 2017 (CSE 2012b). The JNNSM guidelines stipulate the promotion of "off-grid systems to serve population without access to commercial energy" (MNRE 2010; CSE 2012a), which, in other words, implies that the focus has to be on rural areas. According to the Centre for Science and Environment (2012a), about 85% of the projects sanctioned off grid by the JNNSM are for rural communities.[14] Also, as per the latest census of one million households that use solar energy as their main source of lighting, 84% are in rural areas (Census of India 2011). This shows that the government promotes off-grid solar PV systems largely in rural areas.

5 Causes of Solar PV Failure in Rural Areas

Though there has been an ongoing emphasis on solar PV systems for rural areas, it has not been very successful. Several studies indicate a high rate of failure (IRADe 2009; Kumar et al 2009; Palit and Chaurey 2011; Palit et al 2011; Buragohain 2012; CSE 2012a) and highlight difficult operating conditions, and unresolved technical, socio-economic, and institutional factors (Gambhir et al 2012). As noted in Practical Action (2009: 4), "In rural areas, small energy generation systems, installed to provide electricity to small villages or communities, frequently last a few months before being abandoned."[15] Here, we highlight some of the possible causes of this failure.

Un-affordability: Affordability is an important consideration in realising energy access. Energy poverty, indicated by the lack of access to modern energy services, is a direct outcome of income poverty (Balchandra 2011). The Planning Commission (2002) recognises that an important limitation on the shift to renewable energy is its high unit cost compared to other conventional sources. As systems become smaller, the cost of electricity production per unit becomes higher. The typical cost of electricity generation from a solar home system (SHS) is Rs 37-39/kWh and that of a micro-grid is Rs 55/kWh (Chaurey and Kandpal 2010).[16] The high cost is obviously because of high specific capital costs for small-scale projects and greater operations and maintenance (O&M) expenses in remote rural areas (Gambhir et al 2012).

Even if the installation is provided almost free, at times the cost of replacing components turns out to be higher than what villagers can afford.[17] Battery replacements remain the most crucial challenge for the long-term sustainability of solar PV (Gambhir et al 2012). For decentralised systems, maintenance costs are generally higher than what is expected during project appraisals (Gambhir et al 2012). A recent CSE report (2012a), based on field assessments, says that battery failures in solar home lighting systems (which cost several thousand rupees to replace) are forcing villagers to fall back on kerosene. This raises the question why we continue to serve urbanites with cheaper electricity, and how rational it is to prioritise expensive systems for people who cannot afford them. The inability of villagers to afford systems should not be confused with their willingness to pay. Rather, this shows that their income pattern is not suited to the payments they have to make.[18] Also, most mini-grid projects suffer from financial unviability and this results in their closure after a few months of operation (Palit et al 2011).[19]

Want of Skills: The service life of small decentralised energy systems is critically dependent on proper maintenance, which requires technically trained personnel (Ramamurthy and Kumar 2012). Lack of such skills leads to frequent stoppages of systems in rural areas, and solar PV systems are no exception. Also, as much as the rhetoric praises community involvement in electrification projects, this is often not followed in practice (Valencia and Caspary 2008). It is strange but true that while urban households are considered as customers, rural households are expected to be energy producers, managers, scientists and engineers (Balchandra 2013).

Lack of Supply Chains: The maintenance of renewable energy systems suffers due to the lack of supply chains for components and spare parts in rural locations. For instance, an evaluation report of the RVE scheme in Rajasthan by the Integrated Research and Action for Development (IRADe) (2009) shows that 37% of SHSs are not working, and in 80% of the cases, the level of distilled water was below the prescribed limit. Supply chain constraints result in repairs being delayed. And if tariffs are involved (as in case of micro-grids), these delays lead to non-payment, which turns into a vicious cycle of operator's negligence and consumers' non-payments, and finally a defunct system (Gambhir et al 2012). The access and follow-up difficulties in rural areas lead to renewable technologies being abandoned (Valencia and Caspary 2008). The closure of projects not only de-electrifies villages, but also renders these projects, set up with capital subsidy from the government, dead infrastructure (Palit and Chaurey 2011).

The above causes mostly deal with the locational aspect of solar PV installations. Urban areas do not suffer from the issues of affordability, maintenance skills, or supply chains as much as rural areas. Still solar PV is advocated and more efforts are made to promote it in rural areas for the reasons that are critically examined in the next section.

6 Arguments for Promotion of Solar PV for Rural Electricity

6.1 Space Argument

The availability of solar energy is generally linked to the availability of open space. Solar energy being a diffuse form of energy, space is required to instal panels that can collect sunshine. "The real issue is not the availability of solar radiation as much as the availability of open land" (Sukhatme 2011: 627). The Planning Commission (2006) has also noted that land will be a critical constraint to the development of solar energy. Rural areas are preferred for solar energy because land is cheaper there compared to urban locations. However, this has been contested by Mitavachan and Srinivasan (2012) who show that the land area required for solar energy is small compared to that for hydroelectric power, and is comparable to that for coal and nuclear power generation. But all this is beside the point if we have distributed rooftop solar PV installations, as Chokshi (2012) points out. It would not only provide the energy needed, as projected by Sukhatme (2011), but also eliminate transmission and distribution losses. So, the "space, hence no to urban" argument does not hold water. Rather, urban areas with their concrete buildings are more suited for rooftop PVs.

6.2 Remoteness Argument

A strong argument for promoting solar PV systems in rural areas is that they are relatively remote, making grid extension expensive. Nouni et al (2008) have worked out that the cost of electricity delivered to a typical village located 5 km from the grid (with approximately 20 households) is Rs 26 per unit. Hence, there has been an emphasis on identifying remote areas where power supply from the conventional grid will be prohibitively expensive so that they can be provided with an off-grid source of supply such as solar PV (Planning Commission 2011). The argument of "remoteness" is valid, but only for remote villages, which are at most about 25,000 to 50,000.[20] The number of households in these remote villages must be around two million.[21] However, India has 75 million houses not using electricity as their prime source of lighting (estimated from Census 2011 data).[22] So, the remote argument does not hold good for 73 million houses, almost all of which belong to electrified villages.

The Planning Commission (2012) concedes that connectivity by itself is not the whole issue. In many states, there is a real shortage of power to supply electricity for the minimum required six to eight hours daily in rural areas. Excessive shortfall has led to severe power cuts and uncertainty, which have traditionally dampened electricity demand in rural areas (Planning Commission 1982; Srivastava and Rehman 2006). Rural areas, because of their lower population density, cannot match urban ones in terms of concentrated electricity demand. There are also issues related to greater transmission and distribution losses, power theft, and difficulties in bill collection. But the foremost challenge is about the lack of availability because of the structural disincentive distribution companies have in supplying electricity to rural areas. Even if some households have the ability and willingness to pay for a continuous supply, they cannot obtain it. Urban areas do not suffer from this limitation.[23] So, it is not remoteness but the unavailability of electricity that is behind a darker rural India.

6.3 Subsidy Argument

One common argument in favour of solar PV in rural areas is that these installations are highly subsidised. Kemmler (2007) has shown electrification is better extended by improving supply quality rather than subsidising consumption by a non-cost-effective tariff. There are recent field-based studies that have attributed the failure of solar PV systems in rural areas to capital subsidy. A CSE report (2012a) on the RVE scheme describes how heavy subsidies have led to leakages, ultimately resulting in failure. In an assessment of the draft policy of the JNNSM, Phase II, another CSE report (2012c) suggests that the MNRE move away from capital subsidy. So, the subsidy-based argument for promoting solar PV systems in rural areas needs to be reappraised.

6.4 Climate Argument

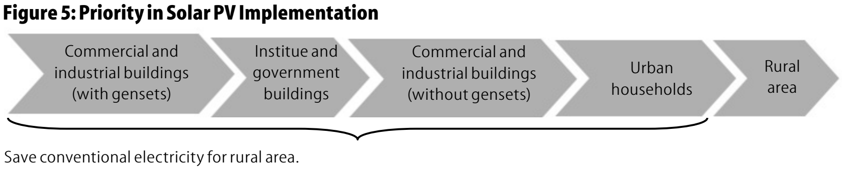
The emphasis on using solar PV systems for rural electricity comes partly from the climate perspective. The Planning Commission (2011: 335) discusses renewable energy for rural areas under the heading "climate change concerns". This raises the question of how far the emphasis on supplying electricity to rural (non-remote) areas through renewable sources is justified to achieve the climate objective. Shifting the climate burden to rural areas is the opposite of "common but differential responsibility".[24] Developed economies need to take a larger share of burden in mitigating climate change as they are primarily responsible for climate deterioration and have greater financial and technical capacities to deal with the situation. The principle of inter-country differentials can be extended to the intra-country regional level as well. Urban areas need to take the prime responsibility for avoiding climate change through the greater use of renewable energy instead of conventional fuels, whereas rural areas need to be allowed to make energy choices more freely. A similar argument was made by a Greenpeace report (2007) entitled "Hiding Behind the Poor", which averred that while India has the right to demand a common but differentiated responsibility at the international level, there is also an urgent need for common but differentiated responsibility at the intra-national level. If the upper and the middle classes do not manage to check their CO_2 emissions, they will not only contribute to global warming, but also deny hundreds of millions of poor Indians access to development (Greenpeace 2007). This is unjust.

7 Way Out

Focusing on urban areas for promoting solar PV systems can be a way out. Urban areas can potentially provide the attention and care required by them. The supply chain infrastructure and the technical and human capacity needed to maintain and sustain these systems can develop better in urban areas than rural and remote locations. Solar energy connected to the grid would not require a storage system (battery), which would decrease the system cost and maintenance challenge. It is expected that solar PV systems will succeed in urban areas because of higher affordability, better infrastructure for the supply chain, and greater human capacity for repairs. Also, once the uptake of solar PV systems increases, there will be mass manufacturing, which will drive down costs further. And the technology could then penetrate villages. Like other technologies, this way, solar PV systems will have a natural entry to rural areas.[25]

In terms of priorities, urban commercial and industrial buildings must be roped in first because solar energy with a little support will compete well with diesel generators. Next, government and institution buildings must be considered as they have greater capacity to maintain the system and can serve as examples for others to emulate. Urban households must be targeted last. Consequently, the technology will organically move to rural areas (Figure 5).[26]

Figure 5: Priority in Solar PV Implementation



The urban focus would be in the interests of both the future of solar PV systems and rural electrification. It needs to be noted that as more and more commercial complexes, industrial houses, institutional and government buildings, and households in urban areas adopt solar PV, there will be more saving of conventional power for rural areas, which will offset some of their availability gaps.[27]

In short, an urban focus in solar PV would help the rural electrification strategy both directly and indirectly. First, greater success of solar PV systems in urban areas would allow rural areas to take the advantage of scale. Solar energy will supplement conventional power in urban areas and thus save electricity to fill some of the unavailability gaps in rural areas. Last, but not the least, from an ethical point of view, it would assign the burden of climate conservation to those who ought to bear it.

8 Concluding Remarks

This paper returns to the debate on the urban-rural gap by highlighting the differences between rates of electrification and consumption in urban and rural areas. It shows that though electrification rates in urban and rural areas show a converging trend, there is divergence in terms of the monthly per capita consumption of electricity. The urban-rural gap in electricity consumption has increased threefold in the last two and half decades. Against this backdrop, the paper questions the emphasis on solar PV systems for rural areas, asking whether promoting it in rural areas mitigates rural-urban disparities in electricity supply or aggravates it.

Given similarities in family sizes, number of dwelling rooms in households, and the need for basic amenities in urban and rural areas, the paper argues for the same normative requirement for household electricity. Though solar PV systems in rural areas are considered a response to the issue of energy access, the paper asks whether it is fair to thrust uncertain, unaffordable systems requiring skilled humanpower on rural households while feeding urbanites with conventional, convenient, and cheaply produced power. The study finds that the causes of failure of solar PV systems have to primarily do with their location in rural and remote areas, which are characterised by households that cannot afford to pay much. These places also lack supply chains and the human skills required for maintaining PV systems.

The paper revisits government policies related to solar PV systems and highlights some of the fallacies in the arguments used for and against them. It shows that of the 75 million households in the country not connected to electricity, only two million are in remote villages, while the rest are in villages already connected to grids. So, more than remoteness, it is the unavailability of electricity that is behind rural households not being able to use electricity for lighting. Based on other works, this paper shows how the space and subsidy arguments do not hold much water. It also critiques the reasoning behind promoting solar PV systems in rural areas by invoking the intra-country "common but differential responsibility" argument.

Overall, the study attempts to open a dialogue on the emphasis placed on solar PV systems for rural electrification, both in the public domain and in policy discourse. Barring really remote areas (about 25,000 to 50,000 villages), the study reccomends prioritising urban areas for off-grid solar PV installations. This would help rural electrification in the following ways:

(i) With the success of solar PV in urban locations because of greater affordability and better maintenance, rural areas will benefit from scale.

(ii) A reduction in the use of conventional power in urban areas will save electricity for rural consumption.

(iii) Rural consumers will be relieved of shouldering a disproportionate share of the climate burden.

NOTES

1 Theft of electricity another is common characteristic in rural areas. However, certain studies report electricity theft to be more prevalent in urban than in rural areas (Kemmler 2006, 2007).

2 These per capita values, unless otherwise specified, are calculated for connected households, not the total population.

3 We understand that consumption data from NSS surveys need to be used with caution; however, one would agree with the overall trend.

4 The *p*-value of χ^2 test for these two distributions is 0.841, indicating one cannot reject the null hypothesis that the two distributions are not significantly different. An increase in the number of rooms would require more electricity for lighting and electric fans.

5 As per World Bank (2008b) estimates, by 2031, the number of TVs and refrigerators in rural India will be 162.2 million and 100.3 million, respectively; whereas the corresponding figure for urban areas will be 133.6 million and 101.1 million.

6 Sanchez (2010) suggests the same threshold value for rural and urban area; 120 kWh per capita, 600 kWh per household.

7 A village is deemed to be electrified when it is provided with basic electricity infrastructure, and connections to public places and at least 10% of households (MoP 2006). The traditional criteria of

village electrification did not include households, because energisation of irrigation pump sets was for a long time the principal aim of rural electrification (Bhattacharyya 2006; Kemmler 2007).

8 The Eleventh Five-Year Plan (2002-07) asserted, "The legal provisions of the Electricity Act 2003, National Electricity Policy, Tariff Policy, and the Integrated Energy Policy provide an appropriate legislative and policy framework for the development of the power sector. The provisions of these policies must be implemented within the stipulated time in order to make power available at affordable cost to all by 2012" (Planning Commission 2007: 362). The Rural Electrification Policy (MoP 2006) reiterated the goal to provide all households with electricity by 2009 and a minimum lifeline consumption of 1 unit per household per day as a merit good by 2012.

9 Though a significant number of connections have been provided under the RGGVY in a short period of time (about 1,00,000 villages and about 20 million rural BPL households), "lack of reliable and sustainable electricity supply remains a persistent problem" (Gambhir et al 2012).

10 The forecast is through using auto regression (AR) data on electrification in 1981, 1991, 2001, and 2011 from the census figures (Reddy 2002; Infraline 2004; Census of India 2011). The intermediate values are interpolated using the same compound annual growth rate between decades. The best fitting model turns out to be (AR-2), which is given below with its statistical parameters (t-values in parenthesis).

$Y_t = 0.932 + 1.556\ Y_{t-1} - 0.563\ Y_{t-2}$

(2.91) (10.36) (-3.79)

Adj. R-square: 0.9998; DW Test: 1.86

The Twelfth Plan re-emphasised village electrification and connecting rural households to power supply under the RGGVY (Planning Commission 2012).

11 Remote villages are unelectrified census villages and unelectrified hamlets in electrified census villages, where electrification is not feasible or cost effective, and these villages are not covered under the RGGVY (MNRE 2012).

12 Remote villages have difficult terrain and dispersed households, making the conventional grid highly uneconomical (Nouni et al 2008; Valencia and Caspary 2008; World Bank 2010a).

13 The expenditure during the Eleventh Plan on renewable energy for urban, industrial, and commercial applications was Rs 147.28 crore, whereas for rural applications it was Rs 910.95 crore (Planning Commission 2012).

14 This figure is arrived at assuming at least half of the projects meant for banks, theatres, telecom towers, and industrial/commercial units are in rural areas.

15 One may find fault with the operation or financing model of these systems, however here we examine the more fundamental question of whether the promotion of PV in rural areas is justified in the first place. For a review of the literature on the failure of rural off-grid systems, see Gambhir et al (2012).

16 The cost figures calculated by Chaurey and Kandpal (2010) for 35 Wp and 70 Wp models of SHS and the figures on micro-grids correspond to a village having 100 households in a 1-km grid network. The average capital cost of a solar PV plant is about Rs 1.5 lakh/kWh (ABPS 2011).

17 On the contrary, urban consumers connected to the grid do not worry about maintenance of the system, except replacing user-end electrical appliances such as electric bulbs.

18 The preferred payment frequency must depend on the income flow pattern of the consumer (Selco 2013).

19 Additionally, mini/micro-grid projects, being community based, suffer from the "tragedy of commons" problem.

20 MNRE (2004) reports 18,000 remote villages, while CSE (2012a) reports 19,471. Buragohain (2012) and Singh (2009) estimate it to be about 25,000. MNRE (2005) reported the state-wise division of 24,418 remote villages. The uncertainty comes from that the RGGVY does not extend to villages with a population less than 100 (MoP 2013), leaving 45,000 villages out of its purview (as per Census of India 2011). Hamlets (with no firm definition) add to the confusion over numbers.

21 The average size of remote village is considered to be 40. It is reasonable to assume so. Data from Odisha shows that the average size of villages, which were covered under the RVE scheme from 2006 to 2010, was 36 to 37.

22 Gambhir et al (2012) have noted that though only 6% (~35,000) of Indian villages are not connected to the grid, about 45% of rural households lack access to electricity supply according to the 2011 Census.

23 For residential consumption, there are slabs of tariff depending on the level of consumption. However, if consumers are connected to uninterrupted power supply, and have the ability and willingness to pay, consumption will not be a constraint. However, for rural areas, the supply is limited.

24 The common but differential responsibility principle recognises historical differences in the contributions of developed and developing states to global environmental problems, and differences in their respective economic and technical capacity to tackle these problems (CISDL 2002).

25 Such urban to rural movement of technologies happened in the case of televisions and mobile phones in India.

26 In a companion paper, the author is working on the details of this transition.

27 At the same time, a lot of effort needs to be taken to strengthen the grid to make reliable round-the-clock supply possible in rural areas. This is an effort in the right direction because grid electricity is as much the right of villagers as it is the duty of a welfare state.

REFERENCES

ABPS (2011): "Final Report on Policy and Regulatory Interventions to Support Community Level Off-Grid Projects", ABPS Infrastructure Advisory, http://www.forumofregulators.gov. in/Data/Reports/CWF%20Off-grid%20final %20 report%20nov %202011_ Latest_ feb2012.pdf

ADB (2010): "Asian Development Bank's Assistance for Rural Electrification in Bhutan: Does Electrification Improve the Quality of Rural Life?", Impact Evaluation Study, Asian Development Bank, Manila.

Balachandra, P (2011): "Dynamics of Rural Energy Access in India: An Assessment", *Energy*, Vol 34, No 14, pp 1944-57.

– (2013): "Rural Energy Needs: It's Beyond Just Energy", Workshop on Solar Photovoltaics for Off-grid Electricity Access in Rural India, Imperial College London in collaboration with Divecha Centre for Climate Change, Indian Institute of Science, Bangalore, 14 January.

Barnes, D F, K B Fitzgerald and H M Peskin (2002): "The Benefits of Rural Electrification in India: Implications for Education, Household Lighting and Irrigation", World Bank, Washington DC.

Bast, E and S Krishnaswamy (2011): "Access to Energy for the Poor: The Clean Energy Option", (Oil Change International, Washington DC).

Bhattacharyya, S C (2006): "Energy Access Problem of the Poor in India: Is Rural Electrification a Remedy?", *Energy Policy*, Vol 34, No 18, pp 3387-97.

Buragohain, T (2012): "Evaluation of Remote Village Electrification Programme in Haryana and Rajasthan", Section 3.3, *International Journal of Environmental Science and Development*, Vol 3, No 4, pp 334-38.

Census of India (2011): "Houses, Household Amenities and Assets: Figures at a Glance", New Delhi.

CEA (2012): "Rural Electrification (as on 30 November 2012)", Central Electricity Authority, http://www.cea.nic.in/reports/monthly/executive_rep/dec12/15.pdf

Chaurey, A and T C Kandpal (2010): "A Techno-economic Comparison of Rural Electrification Based on Solar Home Systems and PV Micro-grids", *Energy Policy*, Vol 38, No 6, pp 3118-29.

Chaurey, A, M Ranganathan and P Mohanty (2004): "Electricity Access for Geographically Disadvantaged Rural Communities: Technology and Policy Insights", *Energy Policy*, Vol 32, No 15, pp 1693-705.

Chokshi, A H (2012): "Nuclear Riddles: TINA and NIMBY", *Current Science*, Vol 102, No 8, pp 1096-98.

CISDL (2002): "The Principle of Common but Differentiated Responsibilities: Origins and Scope", CISDL legal brief, Centre for International Sustainable Development Law (Montreal, Canada).

CSE (2012a): *Going Remote: Re-inventing the Off-grid Solar Revolution for Clean Energy for All*, Centre of Science and Environment, New Delhi.

– (2012b): *Facing the Sun: Policy for Sustainable Grid-connected Solar Energy* (CSE, New Delhi).

– (2012c): "Draft Policy Document of the Jawaharlal Nehru National Solar Mission", Phase II, CSE, New Delhi, http://www. cseindia. org/userfiles/phaseII_offgrid.pdf

Cust, J, A Singh and K Neuhoff (2007): "Rural Electrification in India: Economic and Institutional Aspects of Renewables", Working Paper, EPRG 0730 and CWPE 0763, December.

DfID (2002): "Energy for the Poor: Underpinning the Millennium Development Goals", UK Department for International Development, London.

Ernst and Young (2007): "Models of Rural Electrification", Report to Forum of Indian Regulators, March, http://www.forumofregulators. gov. in/Data/Reports/Final_Foir_Report_5th_March07_Models_of_RE_E&Y%5B1%5D.pdf

ESMAP (2002a): "Energy Strategies for Rural India: Evidence from Six States", ESM 258, Energy Sector Management Assistance Program Program of the UNDP and World Bank, Washington DC.

– (2002b): "Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits", ESMAP Report No 255/02, (World Bank, Washington DC).

Flavin, C and M Aeck (2005): "Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals", Worldwatch Institute, Washington DC.

Gambhir, A, V Toro and M Ganapathy (2012): "Decentralised Renewable Energy (DRE) Micro-grids in India: A Review of Recent Literature", Prayas Report, Prayas Energy Group, Pune, November

Greenpeace (2007): "Hiding Behind the Poor: A Report by Greenpeace on Climate Injustice", Greenpeace, Bangalore.

IAMR (2011): *India Human Development Report 2011: Towards Social Inclusion*, Institute of Applied Manpower Research, Planning Commission and Oxford University of Press.

IEA (2012): "World Energy Outlook: Methodology for Energy Access Analysis", OECD/International Energy Agency, Paris.

IIASA (International Institute for Applied Systems Analysis) (2012): "Global Energy Assessment: Toward a Sustainable Future", OECD/IEA, Paris.

IRADe (2009): "Impact of Solar Energy in Rural Development in India", Integrated Research for

Action and Development Annual Report 2008-09.

Infraline (2004): "Report on Electricity for All", http://www.infraline. com/ power/Important Report/RepElectAll.aspx

Jhirad, D and H Sharma (2011): "Smart Power for Environmentally-sound Economic Development: An Agenda for Action", Rockefeller Foundation, New York.

Kamalapur, G D and R Y Udayakumar (2012): "Rural Electrification in the Changing Paradigm of Power Sector Reforms in India", *International Journal of Electrical and Computer Engineering,* Vol 2, No 2, pp 147-54.

Kemmler, A (2006): "Regional Disparities in Electrification of India: Do Geographic Factors Matter?", CEPE Working Paper No 51, Centre for Energy Polices and Economics, Swiss Federal Institute of Technology, Zürich.

– (2007): "Factors Influencing Household Access to Electricity in India", *Energy for Sustainable Development*, Vol XI, No 4, December.

Kumar, A, P Mohanty, D Palit and A Chaurey (2009): "Approach for Standardization of Off-grid Electrification Projects", *Renewable and Sustainable Energy Reviews*, Vol 13, No 8, pp 1946-56.

Martins, J (2005): "The Impact Use of Energy Sources on the Quality of Life of Poor Communities", *Social Indicators Research*, Vol 72, No 3, pp 373-402.

Mitavachan, H and J Srinivasan (2012): "Is Land Really a Constraint for the Utilisation of Solar Energy in India?", *Current Science*, Vol 103, No 2, pp 163-68.

MNRE (2004): "Remote Village Electrification Programme", Chapter 6, Annual Report 2003-04, Ministry of New and Renewable Energy, Government of India.

– (2005): "Remote Village Electrification Programme", Chapter 4, Annual Report 2004-05, Ministry of New and Renewable Energy, Government of India.

– (2006): "Remote Village Electrification Programme", Chapter 4, Annual Report 2005-06, Ministry of New and Renewable Energy, Government of India.

– (2010): *Building Solar India*, Guidelines for Off-grid Decentralised Solar Applications and Rooftop and Other Solar Power Plants, Ministry of New and Renewable Energy, Government of India.

– (2012): "Renewable Energy for Rural Applications", Chapter 3, Annual Report 2011-12, Ministry of New and Renewable Energy, Government of India.

– (2013): "Renewable Energy for Rural Applications", Chapter 5, Annual Report 2012-13, Ministry of New and Renewable Energy, Government of India.

Modi, V (2005): "Improving Electricity Services in Rural India", CGSD Working Paper No 30, Center on Globalisation and Sustainable Development, December.

MoF (2012): "Statistical Appendix", *Economic Survey 2011-12,* Ministry of Finance, Government of India, http://indiabudget. nic.in/es2011-12/estat1.pdf

MoP (2003): "Discussion Paper on Rural Electrification Policies", Ministry of Power, November.

– (2006): "Rural Electrification Policy", Ministry of Power, Gazette of India, http://powermin. nic.in/whats_new/pdf/RE%20Policy.pdf

– (2013): "Continuation of Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in 12th and 13th Plan", Office Memorandum, F No 44/10/2011-RE, Ministry of Power, Government of India, 2 Sepember, http://powermin. nic.in/whats_ new/pdf/ Continuation_ RGGVY_12th&13th_ Plan_Sept2013.pdf

MOSPI (2011): "Key Indicators of Household Consumer Expenditure in India, 2009-10", National Statistical Organisation, National Sample Survey Office, Ministry of Statistics and Programme Implementation, Government of India, July.

Narain, S (2010): "See the Light", *Business Standard*, 30 July, New Delhi.

Nathan, H S K and S Mishra (2013): "Group Differential for Attainment and Failure", *Journal of International Development*, DOI: 10.1002/jid. 2898.

Nouni, M R, S C Mullick and T C Kandpal (2008): "Providing Electricity Access to Remote Areas in India: An Approach Towards Identifying Potential Areas for Decentralised Electricity Supply", *Renewable and Sustainable Energy Reviews*, Vol 12, No 5, pp 1187-220.

NSSO (1997): "Consumption of Some Important Commodities in India, 1993-94", NSSO 50th Round, Ministry of Statistics and Programme Implementation, Government of India.

– (2001): "Consumption of Some Important Commodities in India, 1999-2000", National Sample Survey Organisation, 55th Round, Ministry of Statistics and Programme Implementation, Government of India.

– (2007): "Household Consumption of Various Goods and Services in India, 2004-05", NSS 61st Round, NSSO, Ministry of Statistics and Programme Implementation, Government of India.

– (2012): "Household Consumption of Various Goods and Services in India, 2009-10", NSS 66th Round, NSSO, Ministry of Statistics and Programme Implementation, Government of India.

Padmanabhan, S (2003): "Rural Electrification: Time for Corporate Sector to Repay Debt", *Business Line*, 1 August.

Palit, D and A Chaurey (2011): "Off-grid Rural Electrification Experiences from South Asia: Status and Best Practices", *Energy for Sustainable Development*, Vol 15, No 3, pp 266-76.

Palit, D, R Malhotra and A Kumar (2011): "Sustainable Model for Financial Viability of Decentralised Biomass Gasifier Based Power Projects", *Energy Policy*, Vol 39, No 9, pp 4893-901.

Planning Commission (1982): "Evaluation of Rural Electrification Programme", Vol 1 (Growth and Coverage), Government of India.

– (1997): "Ninth Five-Year Plan, 1997-2002", Energy, Planning Commission, Government of India.

– (2002): "Tenth Five-Year Plan, 2002-07", Energy, Ch 7.3, Sectoral Polices and Programmes, Planning Commission, Government of India.

– (2006): "Integrated Energy Policy Report of the Expert Committee", Planning Commission, Government of India.

– (2007): "Eleventh Five-Year Plan, 2002-07", Agriculture, Rural Development, Industry, Services, and Physical Infrastructure, Vol III, Chapter 10, Energy, Planning Commission, Government of India.

– (2011): "Mid-term Appraisal, Eleventh Five-Year Plan, 2002-07", Energy, Chapter 15, Planning Commission, Government of India.

– (2012): "Twelfth Five-Year Plan, 2007-12", Economic Sectors, Vol II, Chapter 14, Energy, Planning Commission, Government of India.

Practical Action (2009): *Energy Poverty: The Hidden Energy Crisis* (London: Practical Action Publishing).

Raghu, K and M T Reddy (2012): "Favouring the Rich: Domestic Electricity Tariff in Andhra Pradesh", *Economic & Political Weekly*, Vol 47, No 33.

Ramamurthy, V S and S Kumar (2012): "Pedal Power as the 21st Century Charkha", *Mainstream*, Vol L1, No 1, pp 69-70.

Reddy, R (2002): "National Human Development", *Macroscan*, 29 April, http://www.macroscan.org/ cur/apr02/cur290402national_human_development.htm

Reddy, B S, P Balachandra and H S K Nathan (2009): "Universalisation of Access to Modern Energy Services in Indian Households: Economic and Policy Analysis", *Energy Policy*, Vol 37, No 11, pp 4645-57.

Reddy, B S and H S K Nathan (2011): "Emerging Energy Insecurity: The Indian Dimension" in *India Development Report 2011*, Chapter 14, pp 135-50 (New Delhi: Oxford University Press).

RGNIYD (2010): National Youth Development and National Youth Development Index, Rajiv Gandhi National Institute of Youth Development.

Sanchez, T (2010): *The Hidden Energy Crisis: How Policies Are Failing the World's Poor* (London: Practical Action Publishing).

Selco (2013): "Financing for Off-grid Solar Home Lighting Systems: A Guide to Financing Procedures with Regional Rural Banks and Other Institutions", Selco Incubation Centre, Bangalore.

Sen, A K (1997): "Human Capital and Human Capability", *World Development*, Vol 25, No 12, pp 1959-61.

Singh, K (2009): "In India's Sea of Darkness: An Unsustainable Island of Decentralised Energy Production", *Consilience*, No 1, Field note.

Srivastava, L and I H Rehman (2006): "Energy for Sustainable Development in India: Linkages and Strategic Direction", *Energy Policy*, Vol 34, No 5, pp 643-54.

Sukhatme, S P (2011): "Meeting India's Future Needs of Electricity through Renewable Energy Sources", *Current Science*, Vol 101, No 5, pp 624-30.

Toman, M and B Jemelkova (2003): "Energy and Economic Development: An Assessment of the State of Knowledge", *Energy Journal*, Vol 24, No 4, pp 93-112.

UNDP (2001): "Generating Opportunities, Case Studies on Energy and Women", UNDP Sustainable Energy, United Nations Development Program, New York.

– (2005): "Energising the Millennium Development Goals: A Guide to Energy's Role in Reducing Poverty", UNDP, New York.

Valencia, A and G Caspary (2008): "Barriers to Successful Implementation of Renewables-based Rural Electrification", Briefing Paper, 7/2008, German Development Institute.

WHO (2006): "Household Energy and the Millennium Development Goals", *Fuel for Life*: *Household Energy and Health*, World Health Organisation, http://www.who.int/entity/indoorair/ publications/ fuelforlife.pdf

WEC (1999): "The Challenge of Rural Energy Poverty in Developing Countries", World Energy Council and Food and Agricultural Organisation of the United Nations, London.

World Bank (2005): "Energy Services for the Millennium Development Goals", http://www. undp.org/energy/docs2/MP_Energy.pdf

– (2008a): "The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits", Independent Evaluation Group (IEG) Impact Evaluation, World Bank, Washington DC.

– (2008b): "Residential Consumption of Electricity in India, Documentation of Data and Methodology", Draft, Background Paper, India: Strategies for Low Carbon Growth, World Bank, July.

– (2010a): "Addressing the Electricity Access Gap", Background Paper for the World Bank Group Energy Sector Strategy, World Bank, June.

– (2010b): "Empowering Rural India: Expanding Electricity Access by Mobilising Local Resources", South Asia Energy Unit, Sustainable Development Department, World Bank.