Solar PV for Rural Electricity–

A Misplaced Emphasis for Mitigating Climate Change

Dr. Hippu Salk Kristle Nathan

National Institute of Advanced Studies
Indian Institute of Science Campus, Bangalore - 560012, INDIA
Phone: +91–80–22185052, +91–8904714396; Fax: +91–80–22185076
Emails: hsknathan@nias.iisc.ernet.in; happyhippu@gmail.com

Abstract

The urban-rural divide in developing economies is a well-known. This inequity is reinforced with unequal distribution of resources and amenities. Energy as a resource and electricity as an amenity are no exception. There exists urban-rural difference in electricity access both in quantity and quality. In this context, this paper evaluates the policy emphasis of solar PV for lighting in rural areas. Do these policies mitigate the rural-urban disparities in electriicty or aggravate it? Is it fair to thrust uncertain, unaffordable systems requiring skilled manpower to rural households and continue to feed urbanites with conventional, convenient and cheaply produced power? Isn't the burden of climate change disproportionately put on rural families? This paper attempts to build a case against the misplaced emphasis of prioritizing solar PV in rural areas by examining the key promotion arguments—'space', 'remote', 'subsidy', and 'climate'. Finally, the study advocates for focusing urban areas under solar PV as rural electrification would benefit because; (i) with more success in urban locations for greater affordability and better maintenance, rural areas can benefit from scale, (ii) reduction of conventional electricity in urban areas and thus, saving electricity for rural consumption, (iii) aligning the climate burden where it ought to be.

1. Introduction

The urban-rural divide in India is a well known symptom. As per the latest Census of India (2011), the share of rural population is 69% and more than two-thirds of the households (68%) are in rural areas. In all socio economic indicators, rural people fall way behind the urban counterparts. As per India Development Report – 2011 (IAMR, 2011), the urban-rural gap in terms of percentage points in literacy, child immunization, and institutional delivery rate are 17, 19, and 37 respectively. In rural areas infant mortality rate (IMR) and under-five mortality rate are, respectively, 1.6 and 1.7 times more compared to the urban counterparts (IAMR, 2011). Inadequate service provision in health, education, roads, sanitation and other infrastructure has lead to lower development in rural areas.

Given the limited resources, it is often the case that cities grow at the cost of rural area; villages feed and water the city population, and provide labor for menial/unskilled work and remain as a 'safe' place for dumping urban wastes. This inequity is reinforced with unequal distribution of resources and amenities. Energy as a resource and electricity as an amenity are no exception to this. Close to 93% urban households use electricity as the main source of lighting through grid, whereas the corresponding figure for rural areas is 55% (Census of India, 2011). [1] This differential is more pronounced when one considers the quality of supply. Considering those who are connected to grid electricity, the observed electricity consumption on an average in rural areas is 96 kWh per person in 2009, which is one-third of the corresponding figure in urban areas, i.e., 288 kWh (MOSPI, 2011).

In this context of rural-urban disparity, this paper evaluates the policy emphasis of renewable energy sources for rural areas, particularly domestic sector and street lights. Do these policies mitigate the rural-urban disparities in energy or instead aggravate it? Is it fair to thrust uncertain, unaffordable systems requiring skilled manpower to rural households and continue to feed urbanites with conventional, convenient and cheaply produced power? Isn't the burden of climate change disproportionately put on rural families?

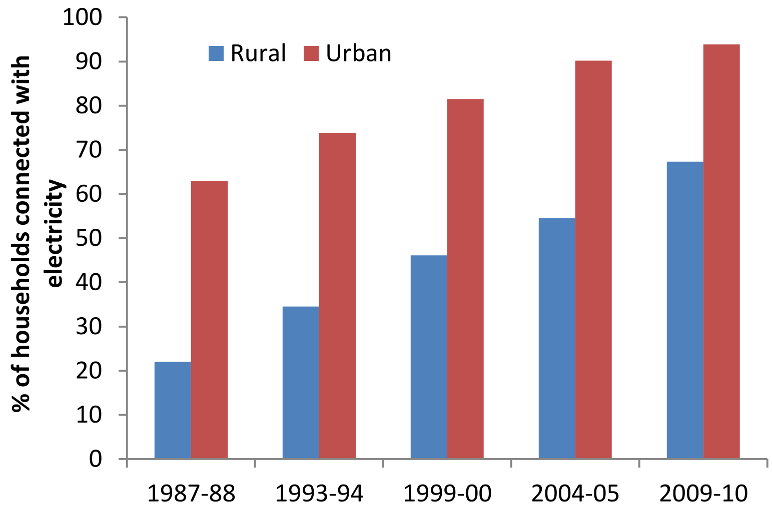
This paper dwells on the above-mentioned questions. First, it looks into the rural-urban electricity disparity for domestic sector both in quantity and quality terms. Then, it asserts how much electricity rural households need and what's their willing to pay. Next it reviews the Government of India's policy priorities with respect to rural-urban distribution of electricity from different energy sources for domestic purpose. Then the paper looks into the causes of failures of renewable systems, and attempts to figure out how much of those can be attributed to the location disadvantage of the systems being installed in rural areas. In the end it makes an appraisal of the policy outcome if urban households are prioritized for renewable system.

---

[1] This figure is different, if one considers NSSO (2012) data; the electrification rate for rural and urban areas are 67.3 and 93.9% respectively. Planning Commission (2012, p.132) acknowledges this difference. The possible cause may be NSS asks for electricity consumption, whereas Census asks for prime source of lighting.

2. Rural-Urban Electricity Disparity

Domestic sector is the second largest electricity consuming and it accounts for about one-fourth of total consumption (MoF, 2012). The rural-urban disparity in domestic consumption of electricity is quite evident in both quantitative and qualitative terms. The share of households connected with electricity in rural and urban area is given in Fig. 1. This shows a convergence between rural and urban areas as the gap which was at 41% points in 1987-88, was reduced to 27% in 2009-10.



Data Source: National Sample Survey reports (NSSO, 1997; 2001; 2007; 2012)

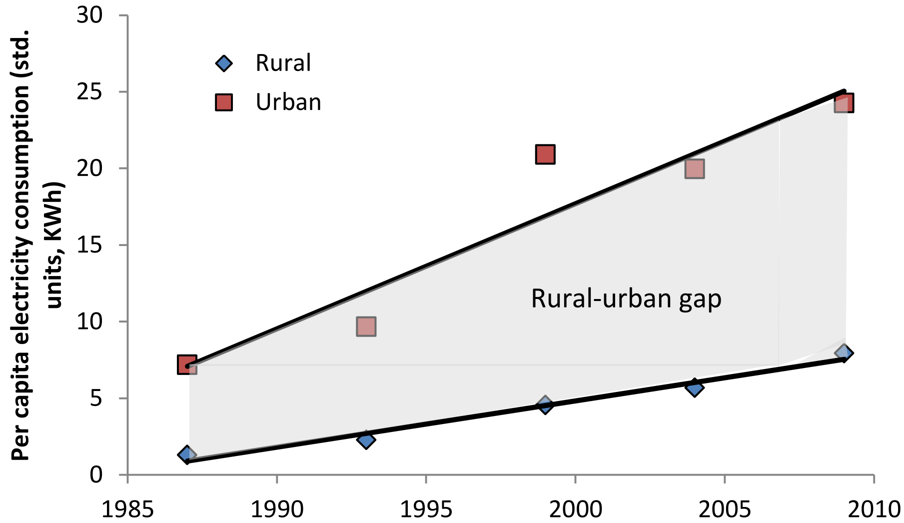
Figure 1. Share of households connected with electricity

Having a connection is important, but it is also important to have adequate electricity. Use of electricity as the prime source of lighting is a more useful indicator in this regard. As per census, between 2001 to 2011, the share of households in rural and urban areas using electricity as the prime source of lighting have changed from 43.5% to 55.3% and 87.6% to 92.7%, respectively. This indicates there is a substantial portion of rural households, though connected to the grid electricity; do not get to use it for basic purpose like lighting on account of lack of availability. As per Planning Commission (2012), availability of electricity supply continues to remain an area of concern, particularly in rural areas, where consumers get supplies for less than eight hours a day in certain states. In most states, supply is restricted to 8-12 hours (Bhushan, 2012). Uncertainty of power supply, frequent load-shedding, and extensive rostering schedule has remained as the characteristics of rural electrification (ESMAP, 2002a; Srivastava and Rehman, 2006).[2]

---

[2] Electricity theft is also another common characteristic of rural electricity. However, certain literatures report electricity theft to be more prevalent in urban than in rural areas (Kemler, 2006; Kemler, 2007).

The per capita consumption of electricity as reported in National Sample Survey reports depicts the rural-urban disparity (see Fig. 2) more vividly.[3] Between 1987 and 2009, the rural-urban gap in per-capita domestic consumption increased from 5.88 units to 16.34 units.



Data Source: National Sample Survey reports (NSSO, 1997; 2001; 2007; 2012)

Figure 2. Rural-urban gap in domestic per capita electricity consumption

The increase in rural-urban gap with increase per capita consumption would mean a contradiction with 'development with equity'. Development in any aspect (here, it is per capita domestic electricity consumption) must simultaneously lead to fall in inequality among different groups in the society (here, rural and urban) (Nathan and Mishra, 2013). In other words, with improvement in per capita electricity consumption, one can expect the gap between rural and urban per capita will decrease. Instead, the gap has increased almost three fold.[4]

3. Electricity Needs in Rural Households and Willingness to Pay

The need for electricity at home, irrespective of its location—rural or urban, cannot be over emphasized. Electricity is recognized as a basic human need and is the key to accelerating economic growth, generation of employment, elimination of poverty, and human development especially in rural areas (WEC, 1999; Modi, 2005; MoP, 2006; Kemmler, 2007). Lighting is highly correlated to productive hours in the household, that is, study hours of children and working hours of adults (Reddy *et al*. 2009; Reddy and Nathan, 2011). The availability of illumination is also advantageous to women in particular (Modi, 2005). Global evidence has

[3] These per capita values, unless otherwise specified, calculated for the connected households, not total population.

[4] As per the group differential measure suggested in Nathan and Mishra (2013), for an attainment indicator (here, per capita electricity consumption) the difference between rural and urban has increased from 0.14 to 0.43 (assuming minimum and maximum value for per capita domestic electricity consumption to be 0 and 500 KWh/year, respectively).

shown that the availability of illumination in the home and streets increases female literacy and educational attainment; income-generating options, and safety in public places (UNDP, 2001). According to Sen's capability framework (Sen, 1999), energy carriers, particularly electricity can be understood as a commodity or an input factor that expands one's set of capabilities (by providing lighting, motive power and access to mass media and telecommunications, and allowing space cooling and preservation of food), and thus enable his functioning in society (Kemmler, 2007). There is a large set of literature which shows that rural electrification greatly contributes to the welfare growth of rural 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).

In short, rural households need as much energy as urban households. The normative value for minimum level electricity requirement must remain same whether the household is in rural or urban area.[5] Though some estimates give different thresholds, we argue for the same normative value for both rural and urban households for the following reasons. First, the average household size for urban and rural area is about five (rural- 5.01 and urban- 4.80 (Census, 2011)), which essentially mean number of people requiring illumination per household in rural and urban area are same, rather it is a little higher for rural area. Secondly, proportions of houses having different number of dwelling rooms in urban and rural areas are similar (see Table 1).[6] From the data it cannot be claimed that urban areas have significantly higher proportion of multi-room dwellings, hence requiring more electricity. Thirdly, we advocate similar normative consumption pattern in rural and urban areas. We elaborate on this argument further.

It is true that the consumption patterns in rural and urban areas differ in practice and some estimate of normative minimum takes this difference in account. For instance, IEA (2012) estimates of 250 and 500 kWh as minimum consumption levels for rural and urban areas,

[5]However, some estimation gives different threshold for rural and urban area. One instance of such estimation is World Energy Outlook (WEO) analysis where initial threshold level of electricity consumption for rural households is assumed to be 250 kilowatt-hours (kWh) per year and for urban households it is 500 kWh per year considering five people per household for both rural and urban areas.

[6] It is considered that with increase in rooms the electricity requirement will increase with the need for more illumination and electric fans.

Table 1. Households by number of dwelling rooms

No. of dwelling rooms	% of such houses	
	rural area	urban area
No exclusive room	4.3	3.1
One room	39.4	32.1
Two rooms	32.2	30.6
Three rooms	12.7	18.4
Four rooms	6.6	9.3
Five rooms	2.3	3.2
Six rooms and above	2.5	3.3

Source: Census of India (2011)

respectively are based on the assumption that in rural areas, this level of consumption could provide for the use of a floor fan, a mobile telephone and two compact fluorescent light bulbs for about five hours per day, whereas in urban areas, consumption might also include an efficient refrigerator, a second mobile telephone per household and another appliance, such as a small television or a computer. It is debatable to assume that rural households on an average do not need a television or computer as a basic need.[7] If one wishes rural India to catch up with urban counterparts, in education, information and other domains how then one can deny the right of television or computer for the rural households! From social justice point of view, energy services are a right to the individuals; and there have been advocacies to make basic energy services as fundamental rights (Narain, 2010; Practical Action, 2009). Moreover, energy poverty is universally recognized as the bottlenecks in achieving millennium development goals (DFID, 2002; Flavin and Aeck, 2005; UNDP, 2005; World Bank, 2005; WHO, 2006; Practical Action, 2009). Hence, in terms of domestic electricity use normative threshold, rural and urban households must not be distinguished.[8]

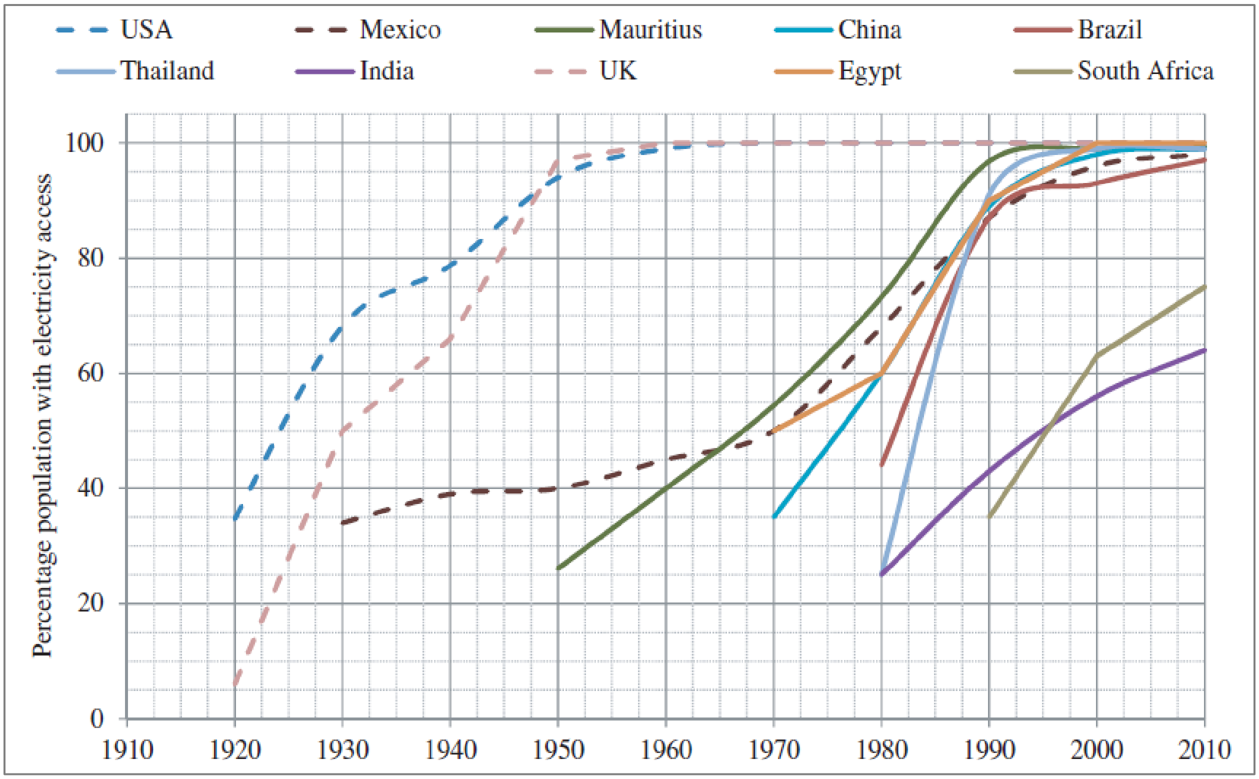
The paying capacity of the rural consumer is lower as compared to the urban consumer (Chaurey *et al*., 2004; Ernst & Young, 2007; Kamalapur and Udaykumar, 2011). However, World Bank studies (ESMAP, 2002; World Bank, 2008a; World Bank, 2010a) show that willingness to pay for electricity in rural areas is high, exceeding the long-run marginal cost of supply. Also, there are evidences from the fields that rural communities are able and willing to pay for reliable electricity services (Barnes *et al*., 2002; Cust *et al*., 2007; World Bank, 2010b).[9] Electricity consumption has high value for rural households and where access exists, willingness to pay is high for shorter outages and better quality supply, even amongst poorer households (Cust *et al*., 2007). In general, people in rural areas appreciate the benefits of electricity and are willing to pay for the same (World Bank, 2008a).

4. Government Policy towards Rural Electrification and Renewable Energy

Though rural electrification has been in the focus of policy makers for the past several decades, there was a continuous neglect at the ground level because of a combination of factors ranging from low tariffs, high cost to serve, poor efficiency levels, and inappropriate organizational frameworks, and state electricity boards' concentration in concentration of efforts in urban areas, metros, and industries (Padmanabhan, 2003; Chaurey *et al*., 2004; Ernst & Young, 2007; Kemmler, 2007). Post Electricity Act of 2003, Government of India made ambitious plan of electrifying all the villages by end of 2007, and all the households ('Power for all') by 2012

[7] As per World Bank (2008b) estimates, the by 2031, the number of TV and refrigerator in rural India will be 162.2 and 100.3 million, respectively; whereas the corresponding figure for urban area will be 133.6 and 101.1 millions.
[8] Sanchez (2010) considers threshold value same for rural and urban; 120 kWh per capita, 600 kWh per household.
[9] There are instances where rural households often pay effectively relatively high tariffs (Cust et al., 2007; Raghu and Reddy; 2012)

(MoP, 2003; Modi, 2005).[10] This goal has been reiterated further in Government's several plan and policy documents.[11] In order to achieve this universalization goal, Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) was launched in 2005 (MoP, 2006; Bhattacharyya, 2006; Cust *et al.*, 2007). Now, since it is already 2013, these goals are missed. In terms of village electrification, as on 31.11.2012, 94.1% villages are connected to the grid (CEA, 2012).[12] Also, with only 55.3% rural households using electricity for lighting (Census of India, 2011), the household electrification target has been missed miserably.



Source: IIASA (2012)

Figure 3. Household electrification progress in selected countries

In the latest Global Energy Assessment (GEA) report, IIASA (2012) has given the historical progress of access to electrification for some selected countries (see Fig, 3). This shows how

[10] A village is deemed to be electrified if basic electricity infrastructure is provided in the inhabited locality, electricity is provided to the public places and 10% households are provided with connection (MoP, 2006). The indicator of village electrification was not traditionally not on the percentage of households or population with access to electricity but merely extension of electricity lines to a particular area, because energisation of irrigation pump-sets was for a long time the principal aim of rural electrification (Bhattacharyya, 2006; Kemmler, 2007).

[11] Eleventh Plan (2002-07) document mentioned 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; which need to be implemented within the stipulated time in order to make power available at affordable cost to all by 2012 (Planning Commission, 2007). Rural Electrification Policy (MoP, 2006) also reiterated the goal to provide access to electricity to all households by year 2009 and provide minimum lifeline consumption of 1 unit per household per day as a merit good by year 2012.

[12] Note that the universal village electrification target was due in 2007.

India lags behind other developing countries like China, Mexico, Brazil or Thailand. India's electrification progress, which is slower compared to many developing and emerging economies, if continues at the same pace the country would achieve power for all, by 2051 (see, Fig. 4).[13,14]

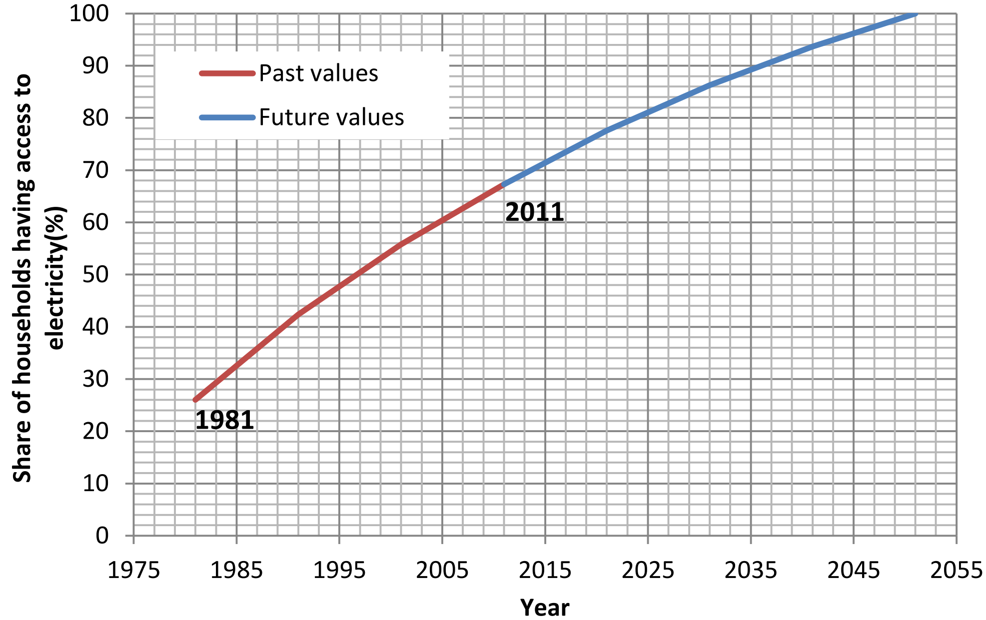


Figure 4. India's household electrification estimation

The slow pace of household electrification in India can be attributed to both supply and demand side reasons. From supply point of view, there is not enough electricity available to cater to the needs of rural households. Excessive shortfall has led to severe power-cuts and uncertainty, which have traditionally dampened the electricity demand in rural areas (Planning Commission, 1982; Srivastava and Rehman, 2006). Kemmler (2007) has shown electrification is better extended by improving supply quality rather than subsidising consumption by a non-cost-effective tariff. Households are discouraged to use electricity by the frequent outages, whereas the approach of facilitating electricity access for the poor by offering initial electricity units at a reduced tariff shows little success (Kemmler, 2007). Urban areas do not suffer from this limitation.[15]

---

[13] Forecast is obtained through using AR (Auto Regression). Data on electrification in 1981, 1991, 2001 and 2011 are taken from Census figures (Reddy, 2002; Infraline, 2004; Census of India, 2011). The intermediate values are interpolated using same compound annual compound 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

[14] For expanding access to electricity Twelfth Plan has re-emphasized the criticality of village electrification and connection of rural households to electric supply under RGGVY (Planning Commission, 2012).

[15] For residential consumption there are slabs, i.e., lower consumption are charged low tariff per unit, whereas higher consumption are charged higher per unit tariff. However, if consumers are connected with more or less

Now let us turn to government policy related to generation of electricity using renewable for rural areas. One can consider dividing the rural areas into two categories (i) remote and (ii) non-remote.[16] For remote villages, where it is be difficult to service through the conventional power grid in the near future, renewable options must be prioritized with necessary subsidies (Plannig Commisison, 1997; 2002).[17] The remote village electrification (RVE) program Ministry of new and renewable energy (MNRE) is on the roll since October, 2003 for this purpose, and as per the latest MNRE (2012) report, about 30% of the total remote villages are so far electrified.[18]

Barring this remote villages, the large majority of villages which are non-remote and grid-electrifiable (of which about 95% of the villages are already grid connected) also gets the priority in renewable energy applications. The first and foremost thrust areas in renewable energy as identified in the Eleventh Plan (Planning Commission, 2011) is to meet basic energy needs in the rural areas through locally available renewable energy resources. Though 'renewable energy for urban, industrial, and commercial applications' also forms the part of renewable energy program of Eleventh Plan (2007-12), expenditures on this program was less than one-sixth of the expenses made for rural applications (Planning Commission, 2012).[19]

The emphasis of renewable energy for rural applications also comes from climate perspective. As per Planning Commission (2011) for climate change concerns, Renewable energy sources—solar, wind, small hydro, and bio-power—have an important role to play in supplementing conventional power generation and meeting basic energy needs, especially in rural and remote areas. This brings to the question that how far it is justified to emphasize on supply of electricity to rural (non-remote) areas through renewable, in order to achieve climate objective. Shifting the climate burden to rural areas is the opposite thesis of 'common but differential responsibility',[20] which developing countries argue in international fora when the question of sharing the climate burden among countries is in question. Hence, the principle of inter-country equity can be extended to intra-country equity, where urban households need to take the prime responsibility of

uninterrupted power supply, and they have the ability and willingness to pay, consumption is not a constraint. However, for rural areas supply is limited.

[16] Remote villages are those which are unelectrified census villages and unelectrified hamlets in electrified census villages, where electrification is not feasible or not cost effective and these villages are not covered under RGGVY (MNRE, 2012).

[17] For remote villages with dispersed households conventional grid becomes highly uneconomical (Nouni *et al*., 2008; Valencia and Caspary, 2008; World Bank, 2010a)

[18] However, the target at the launch of the program was to electrify all the remote census villages in the country by 2007.

[19] The expenses during Eleventh Plan on Renewable Energy for Urban, Industrial and Commercial Applications was 147.28 crores, whereas the corresponding figure for rural applications was at 910.95 crores (Planning Commission, 2012).

[20] 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).

saving climate through use of renewable energy and reduction of use of conventional fuel.[21] If the upper and the middle class do not manage to check their CO_2 emissions, they will not only contribute to global warming, but will also deny hundreds of millions of poor Indians access to development (Greenpeace, 2007).

5. Causes of Failure of Decentralized Renewable Systems

In rural areas, small energy generation systems, installed to provide electricity to small villages or communities, frequently last a few months before being abandoned (Practical Action, 2009). We highlight some of the important causes of these failures below.

Cost factor or un-affordability: Planning Commission (2002) recognizes an important limitation on the extent to which one can shift to renewables is the high unit cost at present, compared with other conventional sources. As the system becomes smaller, the cost of electricity production per unit will be 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).[22] Now, the question comes while we continue to serve the urbanites with cheap electricity, how far it is rationale to prioritize the expensive system for people who cannot afford the same when left to themselves. Even if the installation is provided almost free, the finances for operation and maintenance might turn out to be higher than the paying capacity of villagers. Affordability is an important consideration in realizing energy access. Energy poverty, indicated by the lack of access to modern energy services, is a direct outcome of income poverty (Balchandra, 2011). Most of the mini-grid projects suffer from financial un-viability results in closure of these projects after few months of operation (Palit *et al*., 2011).

Want of skill: The service life of small decentralized energy systems is critically dependant on proper maintenance, which requires technically trained personnel (Ramamurthy and Kumar, 2012). Lack of such skills leads to frequent stoppages of such systems in rural areas. 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 only energy consumers or customers, rural households are treated as energy producers and scientists and engineers (Balchandra, 2013).

Lack of supply chain: The maintenance of renewable energy systems suffer due to lack supply chain of components and spare parts to rural locations. For instance, an evaluation report by

[21] A similar argument was made by Greenpeace (2007) report entitled 'hiding behind poor' that while India has a right to demand a 'common but differentiated' responsibility at an international level, there is the urgent need for intra-national common but differentiated responsibility too. Developed nations need to cut their CO_2 emissions not only to prevent climate change but also to give space to the developing world to catch up, without pushing the global temperatures over the tipping point. The same is true within India.

[22] The cost figures are calculated for 35Wp and 70Wp models of SHS and the microgrid figures correspond to a village having 100 households within 1km grid network (Chaurey and Kandpal, 2010). For details of calculations see, the original paper.

IRADe (2009) of RVE scheme in state of Rajasthan shows 37% of SHSs are not working, and in 80% of the cases the level of distilled water was below the prescribed limit. The access and follow-up difficulties for renewable technologies in rural areas have been highlighted in different studies (Valencia and Caspary, 2008). The closure of these projects not only makes the villages de-electrified, but also renders these projects, set up with capital subsidy from the Government, as dead infrastructure (Palit and Chaurey, 2011).

Natural damage: The safety and security of renewable energy system is difficult to maintain in rural areas. There are instances of theft of solar panels and batteries and these incidents are on rise (Global Advisors, 2012). The occasional solar panel is also damaged due to incidents involving monkeys, peacocks, and even rats eating the wires (Singh, 2009).

6. The Way Out

Focusing urban areas under decentralized renewable generation can be a way out. The urban focus would help rural electrification strategy in the following ways: (i) lead to more success in renewable applications because of greater affordability and better maintenance in urban locations, and therefore, rural areas can benefit from the scale, (ii) reduce conventional electricity in urban areas and thus, save the same for rural areas, (iii) align the climate burden where it ought to be. For instance, in case of solar decentralized system, the priority can be put in the following order (Figure 5).

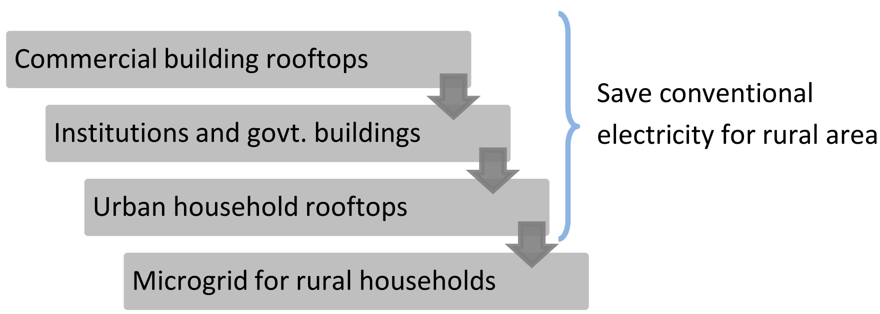


Figure 5 The priority in solar decentralized systems

Build arguments

7. Concluding Remarks

This paper returns to the rural-urban debate purely because electrification rates vary dramatically between rural and urban area. For instance, two-thirds of the urban poor are grid connected, whereas three-fourths of rural poor are not connected (Modi, 2005).

Incomplete

References

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

Balachandra, P. (2011) "Dynamics of rural energy access in India: An assessment", *Energy*, Vol. 34, No. 14, pp.1944–1957.

Balachandra, P. (2013) "Rural energy needs – it's beyond just energy", Workshop on "Solar photovoltaics for off-grid electricity access in rural India", organized by Imperial College London in collaboration with Divecha Centre for Climate Change, Indian Institute of Science, Bangalore, 14th Jan.

Barnes, D.F., Fitzgerald, K.B., and Peskin, H.M. (2002) The Benefits of Rural Electrification in India: Implications for Education, Household Lighting, and Irrigation, World Bank, 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. 3387–3397.

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

CEA (Central Electricity Authority) (2012) Rural Electrification (as on 30-11-2012), < http://www.cea.nic.in/reports/monthly/executive_rep/dec12/15.pdf > (last accessed Feb 06, 2013)

Chaurey, A. and Kandpal, T.C. (2010), 'A techno-economic comparison of rural electrification based on solar home systems and PV microgrids', *Energy Policy*, Vol. 38, No. 6, pp. 3118–3129.

Chaurey, A., Ranganathan M., and Mohanty, P. (2004), 'Electricity access for geographically disadvantaged rural communities—technology and policy insights', *Energy Policy*, Vol. 32, No. 15, pp. 1693–1705.

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

Cust, J., Singh A., and Neuhoff K. (2007) "Rural Electrification in India: Economic and Institutional aspects of Renewables", Working Paper, EPRG 0730 & CWPE 0763, Decemeber. < http://www.eprg.group.cam.ac.uk/wp-content/uploads/2008/11/eprg0730.pdf> (last accessed Feb 06, 2013)

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

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

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

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

Global Advisors (2012) Energy, Monthly News Letter, Sep 30. < http://www.globaladvisors.in/pdf/2012/energy-september-2012.pdf> (last accessed Feb 12, 2013)

Greenpeace (2007) Hiding behind the Poor, A report by Greenpeace on Climate Injustice, Greanpeace, Bangalore.

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

Infraline (2004) Report on Electricity for All. < http://www.infraline.com/power/ImportantReport/RepElectAll.aspx> (last accessed Feb 06, 2013)

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

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

Kemler A. (2006) "Regional disparities in electrification of India – do geographic factors matter?", CEPE Working Paper No. 51, Center for Energy Polices and Economics, Swiss Federal Institute of Technology, Zürich

Kemler A. (2007) "Factors influencing household access to electricity in India", *Energy for Sustainable*

Development, Vol. XI, No. 4, December.

Martins, Johan. 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.

MNRE (2012) "Renewable Energy for Rural Applications", Ch. 3, Annual Report 2011-12, Ministry of New and Renewable Energy, Gov. of India, Available at: http://mnre.gov.in/file-manager/annual-report/2011-2012/EN/index.htm (accessed on 20th Oct, 2012).

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

MoF (Ministry of Finance) (2012) Statistical Appendix, Economic Survey 2011-12, MoF, Government of India. < http://indiabudget.nic.in/es2011-12/estat1.pdf> (last accessed Feb 03, 2013)

MoP (Ministry of Power) (2006) Discussion Paper on Rural Electrification Policies, November.

MoP (Ministry of Power) (2006) Rural Electrification Policy, Ministry of Power, The Gazette of India. Available at < http://powermin.nic.in/whats_new/pdf/RE%20Policy.pdf> (last accessed Feb 03, 2013)

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

Narain, S. (2010) See the light, Business Standard, New Delhi, Jul 30.

Nouni M.R., Mullick S.C., and Kandpal T.C. (2008) "Providing electricity access to remote areas in India: An approach towards identifying potential areas for decentralized electricity supply", *Renewable and Sustainable Energy Reviews*, Vol. 12, No. 5, pp. 1187–1220

NSSO (National Sample Survey Organization) (1997) Consumption of some important commodities in India, 1993-94, NSSO 50th Round, Ministry of Statistics and Programme Implementation, Government of India.

NSSO (National Sample Survey Organization) (2001) Consumption of some important commodities in India, 1999-2000, NSSO 55th Round, Ministry of Statistics and Programme Implementation, Government of India.

NSSO (National Sample Survey Organization) (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.

NSSO (National Sample Survey Organization) (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*, Aug 01. <http://www.thehindubusinessline.in/2003/08/01/stories/2003080100101100.htm> (last accessed Feb 06, 2013)

Palit, D., Malhotra, R. and Kumar, A. (2011) Sustainable model for financial viability of decentralized biomass gasifier based power projects. *Energy Policy*, Vol. 39, No. 9, pp. 4893–4901.

Palit, D. and Chaurey, A. (2011) Off-grid rural electrification experiences from South Asia: Status and best practices. *Energy for Sustainable Development*, Vol. 15, No. 3, pp. 266–276.

Planning Commission (1982) Evaluation of Rural Electrification Programme Vol. 1 (Growth and Coverage), Govt. of India. <http://planningcommission.nic.in/reports/peoreport/cmpdmpeo/volume2/eorep.pdf> (last accessed Feb 06, 2013)

Planning Commission (1997), Ninth Five-Year Plan, 1997-2002, Energy, Planning Commission, Govt. of India.

Planning Commission (2002) Tennth Five-Year Plan, 2002-07, Energy, Chapter 7.3, Sectoral Polices and Programme, Planning Commission, Govt. of India.

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

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

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

Practical Action (2009) Energy poverty: The hidden energy crisis, Practical Action Publishing, London.

Raghu, K and Reddy, M. T. (2012), 'Favouring the Rich Domestic Electricity Tariff in Andhra Pradesh', *Economic & Political Weekly*, Vol. XLVII, No. 33, Aug 18.

Ramamurthy, V. S. and Kumar, S. (2012), 'Pedal Power as the 21st Century Charkha', *Mainstream*, Vol. L1, No. 1. < http://www.mainstreamweekly.net/article3929.html> (last accessed Feb 06, 2013)

Reddy, R. (2002), 'National Human Development', *Macroscan*, April 29. < http://www.macroscan.org/cur/apr02/cur290402national_human_development.htm> (last accessed Feb 06, 2013)

Reddy, B. S., Balachandra, P., and Nathan H. S. K. (2009), 'Universalization of Access to Modern Energy Services in Indian Households—Economic and Policy Analysis', *Energy Policy*, Vol. 37, No. 11, pp. 4645–4657.

Reddy, B. S. and Nathan H. S. K. (2011), 'Emerging Energy insecurity— the Indian Dimension', In *India Development Report 2011*, Chapter 14, pp. 135–150, Oxford University Press, New Delhi.

Sanchez, T. (2010) *The Hidden Energy Crisis: How policies are failing the world's poor*, Practical Action Publishing, London.

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

Srivastava, L. and Rehman, I.H. (2006) "Energy for sustainable development in India: Linkages and strategic direction", *Energy Policy*, Vol. 34, No. 5, pp.643–654.

Toman, M. and Jemelkova, B., 2003. "Energy and economic development: an assessment of the state of knowledge", *The Energy Journal*, Vol. 24, No. 4, pp. 93–112.

UNDP (United Nations Development Program) (2001), Generating opportunities, Case studies on energy and women, UNDP Sustainable Energy, UNDP, New York.

UNDP (United Nations Development Program) (2005) Energizing the Millennium Development Goals- A Guide to Energy's Role in Reducing Poverty, UNDP, New York.

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

WHO (World Health Organization) (2006) Household energy and the Millennium Development Goals, *Fuel for life*: *Household energy and health*, < http://www.who.int/entity/indoorair/publications/fuelforlife.pdf> (last accessed Feb 03, 2013).

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

World Bank (2005), Energy services for the Millennium Development Goals. <http://www.undp.org/energy/docs2/MP_Energy.pdf > (last accessed Feb 06, 2013)

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

World Bank (2008b) residential consumption of electricity in India, Documentation of data and methodology. Draft, Background Paper, India: Strategies for Low Carbon Growth. The World Bank, July.

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

World Bank (2010b) Empowering Rural India: Expanding Electricity Access by Mobilizing Local Resources. South Asia Energy Unit, Sustainable Development Department, The World Bank. <http://online.wsj.com/public/resources/documents/WorldBankreport0215.pdf> (last accessed Feb 06, 2013)