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Evaluation of Indian rural solar electrification: A case study in Chhattisgarh

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ABSTRACT

Despite the considerable efforts spent on village electrification schemes in India, there is a general lack of evaluation of impacts, successes and of failures. A case study in Chhattisgarh state in India has been carried out to assess what effect village electrification through solar power has had for the beneficiaries and whether technical and maintenance factors provide for the desired results set by Indian rural electrification policy. Consequences for the beneficiaries have been investigated through a field survey conducted in eleven villages with 158 respondents, maintenance factors have been investigated through interviews with engineers and operators, and technical factors through analysis of electricity output from micro-grids.

In villages where the systems had been installed in the past two years, children studied on average 41 min more in the evenings, more than twice as much as before electrification. Dinner cooking commenced on average 36 min later, a sign of higher flexibility of time use and thus of women's empowerment. Furthermore, the median household monthly kerosene use decreased by 2 l, or 67%, but commercial productive activities were found to be limited.

75% of the 69 micro-grid power plants evaluated were found to have too little output to supply for the stated 6 h of daily light per household, and the capacity installed per household decreased with village size. Plant capacity factors were found to vary greatly, most likely an effect of poor installation and/or inferior components. A tendency to replace energy-saving lights with incandescent lights requiring more power per lumen was found, leading to a decrease in obtainable light output.

Introduction

Of the 1.3 billion people who live without access to electricity, 400 million people live in India (IEA, 2011). In the rural areas of India, 67% of the households had access to electricity in 2010, in contrast to 94% of the urban households (NSSO, 2012). Of the 69% of the population living in rural areas, 69% are literate in contrast to 85% in urban areas. There is also a large gender disparity; in rural areas 79% of the men but only 59% of the women are literate (Census of India, 2011). Even though improvements have been substantial since the previous census in 2001, there is still large potential for rural electrification to improve living conditions, especially for remote areas.

The causal relationship between electricity use and economic growth in developing countries has not been established (Welle-Strand et al., 2012), but electricity access has long been argued to be a necessary albeit not sufficient condition to trigger rural development (Bhattacharyya and Jana, 2009; Kirubi et al., 2009). Complimentary infrastructure is required for the users to be able to put the electricity to productive uses (Cook, 2011), and subsidies have shown to be required for electricity to reach the poor (Cook, 2011; World Bank, 2008).

There are many potential benefits from electrification stipulated in the literature, of which some, for instance improved cooking technologies, are not viable in this context. Fuel-wood reliance changes little in the rural and poor context even with access to grid electricity, as the more electricity demanding applications such as heating and cooking are less expensively done with wood (Bhattacharyya, 2006; Madubansi and Shackleton, 2007).

Pumping stations can decrease the amount of time spent on water collection as well as provide cleaner water and thus health benefits, and irrigation systems can increase yield (OECD/IEA, 2010). The burden of water collection is most heavily shouldered by girls and women (United Nations, 2010), and thus gender inequalities could be reduced. Availability of power of quantities sufficient for driving machinery and power tools has been found to also increase productivity and revenue (Kirubi et al., 2009), and school electrification has been found to improve study results (Gustavsson, 2007). Electricity supports the functioning of health care centres (OECD/IEA, 2010) and has been found to increase worker presence in health clinics and schools (World Bank, 2008, p.58).

Solar photovoltaic power at present technology and cost does hardly provide enough electricity for cooking or machinery, but is nevertheless a promising potential solution for the electrification of

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rural areas for several reasons. Decentralized power generation may be the only viable option for remote and environmentally protected areas, and many poverty stricken areas experience intense solar radiation. The sun is deeply rooted in many religions and the comprehensibility of the source tends to lead to a larger acceptability of the technology (García and Bartolomé, 2010).

There are relatively large potential benefits also from a limited amount of electricity. Electric lighting can replace kerosene, providing less polluting light of on average 500 times higher efficacy (lumens/W) (Mahapatra et al., 2009). Better light improves the ability to keep hygiene and thereby health, and further leads to a larger flexibility of time use as it makes it easier and more efficient to do household tasks, which in turn may provide opportunities for health clinic visits (Porcaro, 2005), study after dark, and commercial productive activities. Streetlights increase the safety especially for women, allowing for night school and community activity attendance (OECD/IEA, 2010). Electricity of relatively small quantities can also provide for radio, TV and mobile phone use, which connect the villages to the outside world and can increase awareness and education levels about diseases, which have been found to empower women (Panjwani, 2005).

Under the Indian Remote Village Electrification (RVE) programme, two types of de-centralised solar photovoltaic systems are installed: Solar Home Systems (SHS) and micro-grids (MNRE, 2011). An SHS is a single-household PV-module charging a 12 V battery, supplying basic DC appliances. The output is generally enough to power compact fluorescent lights (CFL) or LED lights, or a 12 V TV, radio or fan for a few hours per day. A micro-grid consists of a small power plant and a power distribution network. A solar power plant has an array of PV modules charging a battery bank connected to a Power Conditioning Unit (PCU), which contains an inverter, charge controllers, etc., and converts DC from the batteries to the 220 V, 50 Hz AC which is supplied to the power distribution network. Both types of systems usually have an autonomy of one to two days to cover for cloudy days (Chaurey and Kandpal, 2010b).

There are advantages and drawbacks with both types of systems. Due to the centralised nature, micro-grids ease maintenance compared to SHSs. Unmetered electricity consumption can however lead to the usage of more electricity than agreed, resulting in faster degradation of the batteries (Ulsrud et al., 2011), whereas SHSs are owned and operated by the households and thus households cannot use more than their share of electricity. The batteries have been found to be the weakest part in both micro-grid (Ulsrud et al., 2011) and SHS systems (Laufer and Schäfer, 2011). SHS systems require DC appliances which are not readily available, but for micro-grids there is a risk for inefficient appliances from the market being used (Chaurey and Kandpal, 2010b). Micro-grid systems can also be inflexible to demand increases (Ulsrud et al., 2011). Chaurey and Kandpal (2010b) have showed that a village with a total of 18 W load during 4 h daily per household requires *at least* 180 densely situated households for a micro-grid to be more economical than SHS over the life-time.

While there is literature on rural electrification in South-Asia and on the individual country level (Palit and Chaurey, 2011), despite considerable efforts put into village electrification schemes, there is a general lack of evaluation of success and of failures on the village-level. Recently, a project in Sri Lanka (Laufer and Schäfer, 2011) and different aspects on the village-level in the Sundarbans in India have been assessed (Ulsrud et al., 2011; Winther, 2012). However, to date, no on-site or bottom-up study of the effects for the end-users under the Indian rural electrification programme has been published. Neither views of and changes for the users nor electricity supply to households MoP/UNDP (2010) have been assessed, feedback which is crucial for improving the programme and reducing poverty. Thus, this study attempts to contribute to fill part of that gap through a case study on remote village electrification in Chhattisgarh. The overall aim of the study is to evaluate both the benefits that have actually been provided by the electrification schemes and to assess possible weaknesses in the schemes. This is broken down into the two following questions:

(a) What effect has remote village electrification in Chhattisgarh had for the beneficiaries?
(b) Do technical and maintenance factors provide for the desired objectives set by Indian policy and CREDA?

Method

The study has two main focuses, with separate methodologies. The effect for the beneficiaries has been investigated through a survey conducted in remote villages electrified by CREDA. Maintenance factors have been investigated through interviews with the director and executive engineers within the CREDA head office in Raipur and within the regional offices in Bilaspur and Jagdalpur, as well as with operators in the villages. Technical factors have been investigated through output performance reports from the micro-grid power plants.

No suitable framework for assessment was found, and therefore a set of evaluation factors was chosen after a literature review on the subject, mainly focusing on changes for women. A survey was developed with questions regarding general household information, energy use, appliances used, habits, productive uses, own perceptions of benefits, and household economy. For general planning and design of the survey, Glewwe (2005), and for time allocation questions, Harvey and Taylor (2000) were found useful. The initial survey was tested with a pilot study, during which questions were simplified and adapted to suit the realities found and to improve the understanding and translation as well as render surveying more effective. Changes in habits were sought but no prior data were available, and thus the respondents were asked about daily habits prior to electrification and at the time of surveying. No watches were seen in the villages, but sunrise and sunset fluctuations are relatively small over the year in Chhattisgarh, so that the answers have been judged to be sufficiently accurate.

The surveys were initially conducted with one researcher and one translator, but with growing experience some of the translators could also conduct surveys alone. Since the study focus is on the benefits of women in particular, women of the households were generally surveyed. However, this was often with an entourage of other family members who most of the time helped to convey answers or provided a better understanding for both parties. With growing experience, the survey interview time could be halved from an hour initially to around half an hour in the end.

Surveys were conducted in the Bilaspur and Bastar areas of Chhattisgarh, India, in villages 2 to 3 h by Jeep into the jungles from the main cities Bilaspur and Jagdalpur. The villages were chosen through recommendation from CREDA in the cases of Sarsoha, Babutola, Shantipur and Dhudwadongri in the Bilaspur district, and Tiriya, Mardaya and Nagalsar in the Jagdalpur district. Criteria when choosing plants were age of plants, an equal mix of SHS and micro-grid villages, and villages where the systems worked well and where they did not. As no villages where there had been problems were found through the recommendation of CREDA, the other four villages were independently found with the explicit intent to find villages where there were problems. In total, 11 villages were visited and $N = 158$ women were surveyed in March 2011. In parallel to this, qualitative interviews were conducted with key people in villages, namely technicians, operators, village chiefs, Village Electricity Committee (VEC) members, teachers and medical staff.

Villages with SHSs were largely inaccessible to the authors, due to their location in remote areas affected by Maoist guerillas (Naxalites). Hence, villages that had older SHSs could not be examined. A limit of two years since installation was therefore set for the comparison