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The trials and tribulations of the Village Energy Security Programme (VESP) in India

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HIGHLIGHTS

- The Village Energy Security Programme attempted to achieve village energization in rural India.
- The VESP was intended combat poverty, improve health, reduce drudgery, and accomplish other social goals.
- VESP provides important lessons for policymakers launching rural energy programs.

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ABSTRACT

The Indian Ministry of New and Renewable Energy (MNRE) launched the Village Energy Security Programme (VESP) in 2004 but discontinued it during the 12th Five Year Plan, starting in 2012, after a series of unexpected challenges. Planners structured the program so that a village energy committee (VEC) ran a decentralized village program involving biomass gasifiers, straight vegetable oil (SVO) systems, biogas plants, and improved cookstoves. This suite of technologies was intended to produce electricity and thermal energy to meet the "total energy requirements" of rural communities. At the end of January 2011, a total of 79 VESP projects were sanctioned in 9 states and 65 of these projects were fully commissioned, yet more than half were not operational. The MNRE envisaged that the VESP would provide energy services to eradicate poverty, improve health, reduce drudgery, enhance education, raise agricultural productivity, create employment, generate income, and reduce migration. However, VESP projects have had limited success, and the trials and tribulations of the VESP offers important lessons for policymakers launching rural energy programs in India and other developing economies.

1. Introduction

India is an overwhelmingly rural country—approximately 70% of the total population lives in rural areas (Srivastava et al., 2012). For this reason, India's economic and social development is inherently linked to growth in the rural sector. In order to contribute to India's overall development, the rural sector must have access to modern electricity and fuel sources. There is an enormous amount of literature indicating that sustainable and affordable supplies of modern energy are critical to alleviating poverty, improving public health, enhancing education, and generally facilitating economic and societal growth (Chakrabarti and Chakrabarti, 2002; DFID, 2002; ESMAP, 2002; NRECA, 2002; Ghosh et al., 2004; GNESD, 2007; Sovacool, 2012a). Energizing rural India is thus crucial to promoting the country's broader economic and social development.

However, India faces an enormous rural energy poverty challenge, given that many of its citizens lack access to electricity networks and depend on solid fuels for cooking and heating[1]. It has the largest rural population in the world and, as of 2009, 289 million Indians were living without electricity (IEA, 2011b). Despite the government's efforts to improve rural electricity infrastructure for more than a half century, household electrification levels and electricity availability in India are still far below

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[1] While there is no universally agreed and universally adopted definition of energy access, the International Energy Agency has defined modern energy access as a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time to reach the regional average (IEA, 2011a).

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the world average. Further, 836 million people do not have access to modern cooking systems in India and depend on traditional biomass to meet their thermal energy requirements (Rehman et al., 2012). These inefficient stoves demand a great deal of fuelwood, and they also emit dangerous levels of indoor air pollutants inhaled by women and children (Venkataraman et al., 2010). Furthermore, after the discontinuation of the National Programme on Improved Cookstoves (NPIC) in 2002, no alternative program[2] existed until the end of 2009 for pursuing the dissemination of improved biomass cookstoves (Rehman et al., 2012). Some households have expanded their access to LGP stoves, but merely having an LPG connection does not guarantee usage or dependence on the same. For instance, in a classic example of fuel stacking, many Indian households with LPG connections still depend on firewood as their primary cooking fuel, generally due to affordability issues; LPG is then used sparingly for quick cooking (Joon et al., 2009). Energy poverty is further exacerbated in India by the lack of an integrated policy framework, division of the energy sector across multiple agencies, overemphasis on serving urban customers through the national grid rather than rural ones, misdirected subsidy regimes, ineffective implementation, poor governance of the sector, resource constraints and other structural factors (Balachandra, 2011; Krishnaswamy, 2010; Chaurey et al., 2004; Kemmler, 2007).

The prevalence of energy poverty is not only confined to India, it also exists in other major countries throughout Asia and Africa (Bazilian et al., 2012; Sovacool et al., 2012, 2012a, 2012b). For example, in the Asia Pacific overall, 54% of the populations of the Big 5 countries (China, India, Pakistan, Bangladesh and Indonesia) do not have access to modern cooking options. To ensure energy security, which we define as the regular availability of clean, convenient, and affordable modern energy services for basic household lighting and thermal needs[3], India (and other energy deprived countries) must adapt, intensify, and ultimately become more effective in its energy policymaking.

With that goal in mind, this study presents a detailed analysis of the Village Energy Security Programme (“VESP”), a scheme managed by the Ministry of New and Renewable Energy (MNRE) to meet the “total energy requirements” of Indian villages through the use of biomass gasifier systems, straight vegetable oil (SVO) engines, biogas engines and improved biomass and biogas cookstoves. Figs. 1 and 2 depict biogas plants implemented in some of the villages participating in the VESP. The article begins by providing an in-depth view of the energy dilemmas facing rural Indians and their need for modern energy services. Second, it addresses the qualitative and quantitative research methods employed by the authors to compile data on the VESP's performance and gauge the needs of local stakeholders. Third, it explores VESP's project objectives, such as facilitating rural energy access through distributed energy solutions, the specific technologies harnessed and the service delivery model employed for VESP test projects. Fourth, it analyzes both the benefits and barriers facing the VESP and appraises the project's structure, technological performance, financial strategy and convergence with other prevailing development goals. Finally, it presents some conclusions from the VESP scheme to improve the future design of rural energy access implementation efforts in India as well as other developing countries.

Fig. 1. VESP sponsored biogas plant in the village of Sankarghola, Assam.

Fig. 2. VESP sponsored biogas plant in the village of Jawahar, Maharashtra.

We find that programs like the VESP that address these ‘total energy needs’ – electrification and access to modern cooking and productive options – can facilitate economic and social development in village communities throughout India, but only if they are designed and implemented properly. While the MNRE designed the VESP in a novel way, many of the test projects took a long time to implement, and once implemented, less than half of the total test projects were functional. The success of the VESP largely has depended on (1) appropriate institutional mechanisms (2) reliable technologies that suit local requirements (3) successful demonstration projects (4) sound management practices, (5) community awareness programs, (6) the availability of local technical expertise for implementation and service support, and (7) financial subsidies to cover the higher up-front cost of technology. Despite these innovations, the VESP was unable to overcome challenges concerning (1) Low concentration of electricity demand making distribution expensive and difficult, (2) poverty and consequent low demand for electricity, (3) difficulty on the part of users to pay for electricity due to low disposable income in such remote areas,

[2] The National Biomass Cookstoves Initiative (NBCI) was launched in December 2009 to enhance the availability of clean and efficient energy for the energy deficient and poorer sections of the biomass using population.

[3] In the Indian context, the Integrated Energy Policy, Government of India, 2006, defines energy security as ‘we are energy secure when we can supply lifeline energy to all our citizens irrespective of their ability to pay for it as well as meet their effective demand for safe and convenient energy to satisfy their various needs at competitive prices, at all times and with a prescribed confidence level considering shocks and disruptions that can be reasonably expected.

Table 1
Research questions asked to evaluate the VESP.

Technological performance	■ How well did the technology perform? ■ What was the capacity utilisation factor? ■ What was the uptime/downtime of the systems? ■ Were the operators provided required training on O&M? ■ Was local servicing infrastructure available or developed? ■ Was the capacity of the systems meeting the local demand? ■ How well did the cookstoves and other technologies implemented under VESP perform?
Institutional performance	■ How effective were local institutions in governing individual projects? ■ Was the role of different local stakeholders clear? ■ What has been the performance of different PIAs in managing projects? ■ Did the PIAs adopt any innovations for better project performance? ■ Were local youth able to operate and maintain the power plant? ■ How was the fuel supply managed and organized? ■ Was the VEC aware of its roles and responsibilities? ■ Were regular records of operations and financial transactions being kept? ■ Was the operator's salary being paid regularly? ■ Was there a system for collecting fees from electricity users? ■ Was the VEC able to get the system repaired when it breaks down? ■ Were local skills available for providing after sales service?
Financial performance	■ What were the costs associated with the project? ■ What was the minimum desired price (MDP[a]) for electricity both from the PIA and user's perspective? ■ What was the amount of electricity being consumed by households per month? ■ What was the cost of such service to households per month? ■ What was their willingness and affordability to pay per month? ■ What was the gap between MDP and the actual payment performance?
Plantation and fuel supply management	■ How were community plantations being managed? ■ Was sufficient fuel supply coming from the biomass plantation? ■ If not, what were sources of biomass fuel, and were they sustainable? ■ Did any other issues arise concerning biomass fuels and oilseeds?
Convergence with other development goals	■ Were any linkages created with productive micro-enterprises? ■ Were VESP projects supplying reliable electricity to the micro-enterprises to fulfil their demand? ■ What was the tariff paid by the micro-enterprise and is it sufficient in achieving viability of the project as well as its own viability

[a] Palit et al. (2011) have detailed out the methodology for estimation of the MDP for electricity.

(4) difficulty in operation and maintenance due to the remoteness of villages, (5) limited technical knowledge of Village Energy Committee (VEC) members, and (6) weak biomass fuel supply chain linkages.

2. Research methods

To assess the performance of VESP, the research team, with the assistance of TERI, primarily collected data from a series of in-depth, semi-structured interviews and focus group discussions. These interviews and discussions involved a number of stakeholders at the federal, provincial, and grassroots level who were associated with the VESP across various project sites (TERI, 2009). The team obtained input from a broad spectrum of key stakeholders, including those representing the government, the Project Implementation Agency (PIA), civil society, and local communities—VEC members and operators and technicians of the system. A purposive sampling strategy was used to select respondents that could represent perspectives from government, the private sector, civil society, and the communities themselves. The team collected secondary information on technology performance through a study of the monitoring data and meeting records (if any) available within VECs and PIAs.

The study covers a total of 50 sanctioned VESP test projects spread across seven states (TERI, 2009). The projects were either commissioned or were at various stages of implementation at the time of assessment. Of these, researchers from TERI made field visits to 16 project sites between September 2008 and June 2009 and gathered secondary information from PIAs at other sites. The team used a combination of tools to collect and analyze information on specific themes, to understand the institutional, operational and technical issues surrounding each project, questions summarized by Table 1.

3. The energy situation in rural India

Households in rural India generally need energy for three purposes: cooking, lighting, and productive uses. The pace of electrification in rural India has been somewhat sporadic and past efforts in terms of both policies and programs have achieved only a marginal success (Modi, 2005; Bhattacharyya, 2006). Though most rural villages-about 93%-have electricity access, the electrification rate among actual households is much lower-about 60% (Palit and Chaurey, 2011). Even where electricity access is available, the quality of supply remains poor because power is often unavailable during the evening hours when people need it the most[4]. Only seven out of 28 states have achieved 100% village

[4] A TERI survey in Uttar Pradesh, the largest state in terms of population in India, indicates that the power shedding varies between 14 and 18 h and electricity in the villages is supplied only during night hours (11 pm to 5 am) and in some cases during daytime with frequent tripping. No electricity is supplied during the peak hours (6–10 pm) in any of the surveyed villages and the voltage dips to as low as 110 V making it difficult to use any appliances when there is electricity during day hours (Palit and Chaurey, 2011).

electrification, and larger states such as Assam, Bihar, Jharkhand, Orissa, Rajasthan, and Uttar Pradesh have lagged behind in terms of their rural electrification efforts. Though Andhra Pradesh and Tamil Nadu have "officially" achieved complete village electrification, a recent field study of TERI indicates that many hamlets and forest fringe villages do not have access to any form of electricity (Palit and Chaurey, 2011).

There is also a geographic and income-based divide in terms of electricity access. Urban areas or upper-income households consume more electricity than do rural areas or lower-income households. (Pachauri, 2007). Even among urban and rural households with comparable incomes, the former consume more electricity. Generally, however, electricity consumption per capita increases with higher levels of income. Low-income groups appear to use electricity mostly for lighting, whereas elevated electricity consumption among upper-income groups can be attributed to appliance and productive use. Further, the rural-urban inequity is significantly greater for modern cooking than for electricity provision. For example, analysis of the recent National Sample Survey (NSSO, 2011) in India indicates a rural-urban electricity access gap of 28 percentage points whereas the rural-urban divide for modern cooking access is much higher at 58 percentage points (NSSO, 2011; TEDDY, 2003, 2011). Other issues related to rural energy are difficulties in accessing finance for poor households for expanding energy access both for lighting and cooking fuels (Rao et al., 2009).

In 2001, the Indian government took a major step towards eradicating energy poverty by creating the Rural Electricity Supply Technology ("REST") mission with the objective of obtaining "power for all by 2012." That same year, the MNRE was tasked with implementing the Remote Village Electrification ("RVE") program. In April 2005, the Indian government intensified its efforts by launching the Rajiv Gandhi Grameen Vidyutikaran Yojana ("RGGVY"), a large-scale program designed to accelerate rural electrification and provide electricity access to all Indian households. Under RGGVY, the government subsidizes grid extension to all but the most remote areas where it is too cost-prohibitive to reach. In terms of the dissemination of cleaner cooking sources, MNRE has been implementing the National Biogas and Manure Management Programme (NBMMP) since 1981–82. Box 1 provides a brief overview of these programs.

However, by 2004, India still had limited experience in implementing programs that involved rural communities in remote locations autonomously produce energy themselves for lighting and cooking. That year, the MNRE (the then Ministry of Non-Conventional Energy Sources) launched the test phase of the VESP to meet a village's total energy requirements using locally available renewable energy sources (MNES, 2004). While the other programs were specific to providing either electricity services or meeting cooking energy needs, VESP was designed to do both. Undoubtedly, the program was ambitious and had set itself an ambitious mandate of meeting a rural community's complete demand for energy services. Appropriately for such a pioneering and unprecedented program, the first phase of VESP was intended as a piloting program to test the concept and capacity of various institutions to deliver energy to remote and inaccessible communities.

While the MNRE discontinued the VESP[5] in 2012 and has not approved any new projects since 2010, several researchers and policy think tanks have argued that decentralized generation using locally available renewable energy sources such as biomass and biogas, available in substantial quantities[6] in India, are key to enhancing lifestyles and achieving social and economic development benchmarks in rural areas (Palit and Chaurey, 2011; Banerjee, 2006; Ghosh et al., 2006; Buragohain et al, 2010). Thus, we believe that our analysis of VESP in the pages to come has value for those wishing to design rural energy programs in the future, not only for India but also for other energy deprived countries and communities.

Box 1–Summary of various energy access programs in India.

Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)

The Government of India launched the RGGVY in April 2005, by merging all other existing schemes of rural electrification, with the goal of electrifying all un-electrified villages/un-electrified hamlets and providing access to electricity to all households in five years and providing 23.4 million free connections to households below the national poverty line. The scheme attempts to address some of the common ailments to rural electrification in a country often characterized by poor networks, lack of maintenance, low load density with high transmission losses, rising costs of delivery and poor quality of power supply. The Ministry of Power provides grants that cover up to 90% of electrification costs, while the remaining 10% is provided through loans from the Rural Electrification Corporation. While 87% of the targeted villages had been energized and 86% of below poverty line households connected to the grid as of December 2011, studies indicate only about 20% of the total un-electrified rural households have established connections to the national electricity grid (Palit and Chaurey, 2011).

Remote Village Electrification (RVE) Program

The RVE program covers un-electrified census villages and hamlets that are not likely to receive grid connectivity. The RVE aims at bringing the benefits of electricity to people living in the most "backward" and "deprived" regions of the country. Similar to the RGGVY, up to 90% of the cost of the projects is provided through a grant with specific technological benchmarks. The RVE program has covered 12,369 villages and hamlets as of December 31, 2011 (MNRE, 2012).

National Biogas and Manure Management Programme (NBMMP)

The NBMMP program is implemented by MNRE and caters mainly to setting up of family size biogas plants to provide fuel for cooking purposes and organic manure to rural households. Other goals include mitigating drudgery of rural women, reducing pressure on forests, and accentuating social benefits. A cumulative total of 4.47million family type biogas plants have been set up in the country as of December 31, 2011 against estimated potential of 12 million plants (MNRE, 2012).

4. Description of VESP

Cognizant of the sheer difficulty of expanding rural energy access in India, the VESP took a more systematic approach to

[5] Currently it is reported that VESP has been discontinued as of 2012 and has been merged with the RVE programme.

[6] Indian Institute of Science Bangalore has also completed a MNRE-sponsored project of creating a biomass atlas of India and results of this indicates that about 249.07 MMTPA of biomass from agri residues and forest and wasteland could be available for power generation with a potential of 33.295 GW (IISc, 2012).

Fig. 3. Biomass gasifier in the village of Dicholi, Maharashtra.

Fig. 4. Biofuel Engine in the village of Jawahar, Maharashtra.

energy security than its predecessors by focusing on energy production systems[7] based on either biomass gasifiers[8] and/or straight vegetable oil[9] ("SVO") shown in Figs. 3 and 4. The VESP also sought to provide clean cooking technologies through the use of improved cookstoves and biogas units. It emphasized using energy for productive purposes (e.g., job creation), and established a dedicated tree plantation and management system as a feedstock for the village's energy needs. It, lastly, prompted VECs to form and develop participatory Village Energy Plans (VEPs). Through the VESP, the MNRE provided a VEC with a one-time grant (up to 90% of the total project cost) to install energy systems capable of meeting the community's energy demand. The community provides at least 10% of an equity contribution with either cash or other contributions such as land and labor. Essentially, the Ministry designed the VESP as a project that would go beyond rural electrification to achieve "village energization."

The cornerstone of the VESP rested on two pillars—community ownership and use of locally available resources. Local communities would plan, implement, and sustain their program with support from external institutions known as the PIA. The VESP thus represents an innovative and pragmatic approach to solving an emerging trilemma of (1) maintaining energy resources, (2) sustaining economic development, and (3) preventing environmental degradation.

The VESP followed a service delivery model whereby the PIA[10], with representatives from the villagers and the local governance body (the *gram panchayat*), formed a VEC. The VEC usually consists of nine to 13 members, selected from the village residents and with representation by the PIA in the committee. The program envisaged 50% representation from women, and there was an elected *Panchayat* member from the village who serves in an *ex-officio* capacity. The PIA set up energy production systems through original equipment manufacturers ("OEM") and handed over the hardware to the VEC for day-to-day operation and management (O&M). Functionally, the VEC acts as custodian of the energy production system and is responsible for the O&M of the systems. The electricity generated from the energy production systems is distributed to the community through a local mini-grid system.

Because standalone and off-grid systems are free of licensing obligations and regulatory oversight, the VEC sets the tariff in consultation with PIA such that it will cover fuel and O&M costs. The VEC is also responsible for procuring the biomass fuel—either on a rotation basis from the project beneficiaries or by purchasing it from the biomass collection agents. Additionally, the VEC creates an energy plantation in the village's forestland or community land to ensure that the system has a sustainable supply of biomass. The VEC collects energy charges from users to meet the operational expenses of the projects, and the VEC manages all project accounts.

Furthermore, under select provisions of the State Panchayati Raj Act, a VEC creates a Village Energy Fund – which is initially supported by beneficiary contributions – to sustain the project's operation and management. Thereafter, a VEC deposits monthly user charges in this account, managed with two signatories nominated by the committee. One of the signatories is the *ex-officio Gram Panchayat* member and the other signatory is the President or Secretary of the VEC. In short, a VEC is responsible for producing the power, distributing the electricity, managing project revenues, and resolving disputes in the event of supply disruptions, a schematic summarized by Fig. 5. The summary of the relationship between the various key stakeholders under the VEC service delivery model is presented in Table 2.

[7] Each village was to be electrified by either a diesel generating set run on straight vegetable oil (non-edible oils such as pongamia or jatropha) of 10–20 kW capacity or biomass gasifier(s) of 10–25 kWe powering a 100% producer gas engine or a biogas engine of capacity 4–10 kW (MNRE, 2008).

[8] Biomass gasification is the process of converting solid biomass fuel into combustible gaseous fuel (called producer gas) through a sequence of complex thermo-chemical reactions. A biomass gasifier power project usually consists of a biomass preparation unit, a biomass gasifier reactor, gas cooling and cleaning system, internal combustion engine suitable for operation with producer gas as main fuel, electric generator, and electricity distribution system (Parikh, 1984).

[9] Straight vegetable oil (SVO) is usually non-edible oil from plant sources that are used as a substitute for diesel as a fuel in diesel engines without any further chemical treatment such as transesterification. When SVO is transesterified then it is converted into biodiesel.

[10] While the VESP guideline (MNRE, 2008) says that the VESP test projects were to be undertaken by the *Panchayats* duly facilitated by implementing agencies such as DRDAs, forestry departments, NGOs, entrepreneurs, franchises, corporate entities, co-operatives and state renewable energy development agencies (SREDA), in most cases the test projects were sanctioned to forestry departments (34 test projects), NGOs (27) and SREDAs (14) out of the total 79 test projects across 10 states.

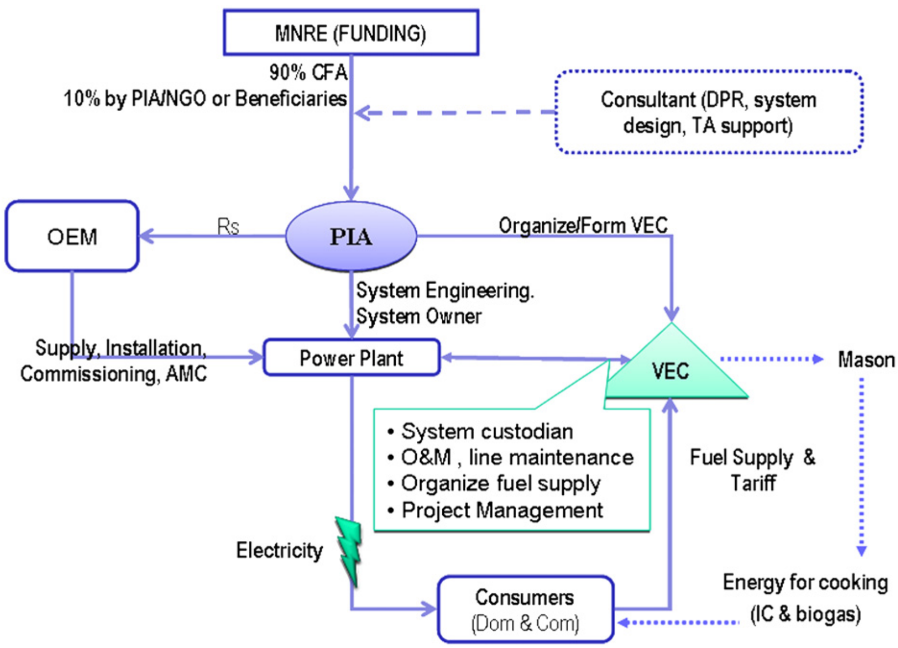

Fig. 5. The Village Energy Committee Model.
Source: TERI, 2009.

Table 2
Summary of transactions between key entities in the VEC model.
Source: TERI, 2009.

S. no.	Entities	Offers	To	Expects in return	Instrument
1	Beneficiaries	Fuel	VEC	Payment for fuel supply	–
2	VEC	Electricity	Beneficiaries	Payment for electricity	Negotiated tariff
3	Beneficiaries	Payment	VEC	Reliable Electricity	Connection Agreement
4	OEM	Annual Maintenance Contract	VEC	Payment	AMC agreement

5. Results and discussion

Statistics released by MNRE (2012) report that a total of 79 VESP test projects have been sanctioned as of December 31, 2011. These projects have covered un-electrified remote villages/hamlets that are not likely to be electrified through conventional grid extension in the immediate future. Of the total, 65 projects have been commissioned in 9 states and the others are at various stages of implementation or have not been declared commissioned. In all, about 700 kW of electricity generation equipment was installed during the VESP, 90% of these based on biomass gasification technology (The World Bank, 2011). Further, about 4100 households were given improved cook-stoves and 1330 m^3 of biogas capacity was created. However, the VESP has suffered serious setbacks. Less than half (42%) of the 50 projects surveyed by our research team were fully or partially operational, and the rest were either non-functional (26%) or had not even been commissioned (32%) at the time of assessment (figures shown in Table 3). The following two subsections explain what happened—first by depicting some of the achievements of the VESP, and then by detailing the challenges that prevented it from reaching all of its goals.

Table 3
Status of VESP projects surveyed.
Source: TERI (2009), Palit (2011).

Region	No. of projects	No. of commissioned projects	No. of functional test project
Assam	14	–	–
Chhattisgarh	6	6	3
Gujarat	2	2	–
Madhya Pradesh	10	9	4
Maharashtra	5	5	5
Orissa	9	9	7
West Bengal	4	3	2
Total	**50**	**34**	**21**

5.1. Best practices from the VESP

The VESP test projects, sanctioned in remote rural areas, are inhabited predominantly by a “base of the pyramid” population with low incomes and lack of knowledge and capacity concerning energy services. Notwithstanding these challenges, our assessment has observed limited but visible benefits arising from the VESP.

5.1.1. Institutional performance

We found that the VESP projects emerged as a vehicle to motivate the community – especially unemployed youths – to develop their engineering, mechanical, and managerial skills. Local youth enhanced their ability to operate and install energy production systems in almost all surveyed test projects. In some projects, diesel engine mechanics, operating in different neighborhoods, augmented their expertise and entered into an annual maintenance contract (AMC) with the VEC and PIA to provide the technical support for post-installation maintenance. Selected PIAs pursued innovative strategies to build the technical capacity and competency of the operators, which bolstered their confidence to run the system continuously and thereby improve overall performance. This also helped to build confidence among communities, facilitating a willingness to pay for regular and reliable electricity.

Additionally, in some projects NGOs were effective in building the technical capacity and competency of system operators. For instance, TERI implemented projects in Jambupani and Dawania village in Madhya Pradesh and conducted month-long training sessions during pre-installation, during installation and commissioning, and for the first six months following commissioning. TERI also entered into an AMC with a local diesel engine mechanic in both of these villages who provides the necessary support to the operators on an on-call basis. This ensured that the system was operational for more than 20 days per month on average.

5.1.2. Technological performance

For some projects, we found project run-time to be satisfactory, indicating that the technologies disseminated under those programs were robust (Palit, 2011). Runtime was as high as 70% in some well-performing projects. Further, VESP also provided a good platform for various technology designers and manufacturers to test new technologies. For example, TERI-New Delhi, Indian Institute of Science- Bangalore, and Ankur Scientific Energy Technologies-Baroda had an extensive opportunity to field test the small capacity gasifier systems that they designed, which allowed them to further customize their technologies for rural markets.

Some villages also found innovative uses for the biogas technology. In Mokyachapara village in Maharashtra, the community operated six floating drum biogas plants (with six cubic meters of capacity each) on a communal basis. They designed each of the biogas plants to supply cooking fuel to five to six households. Further, de-oiled cakes obtained as byproduct from the oil expeller are also used as feed material for the biogas plant and are mixed along with cow dung to obtain higher gas yield. In Kumhedin Village in Madhya Pradesh, 14 domestic-sized biogas plants (each two cubic meters of capacity) are in operation. Each biogas plant serves one family, and cow dung is used as the feed material. In addition to using biogas as a cleaner cooking option, the beneficiaries also use the sludge as manure for growing vegetables that are then sold in the nearby block town to earn additional income. Lastly, AC lighting systems have been connected to some of the biogas plants and beneficiaries such as those in Fig. 6 enjoy illumination from biogas.

5.1.3. Plantations & fuel supply management

Indeed, some VESP project sites had fuel supplies sufficient to meet their energy needs. In Mankadiatala and Champapadar villages in Orissa, where the Forest Department is implementing VESP projects, scientific species selection and plantation management practices have resulted in optimal survival rates of about 50 to 60%. The community has planted Simaruba, Bakain, Eucalyptus, Mahaneem and Acacia species, which grow well in the region. The community was fully involved in pit digging, nursery raising, sapling planting, and weeding, and the Forestry Department planted 1400 to 1500 plants per hectare as a block plantation.

In Mokhyachapara, true to the spirit of VESP's multi-stakeholder approach, the Pragati Pratishthan (the PIA for this project) approached local plantation experts from the region to get their guidance. Initially, the farmers from the village were motivated to plant jatropha and, through meeting and discussing the issue, creating awareness about the plants benefit. Proper plantation

Fig. 6. Biomass gasifier based lighting in a VESP beneficiary household in the Village of Kumedhin, Madhya Pradesh.

methods and post-plantation maintenance (such as weeding, gap filling etc.) ensured that about 80% of the plants remained in healthy condition.

In most of the test projects, fuel supply was based on each household bringing in a certain quantity of biomass from the community forests and contributing to the power plant every week. During our field visits, we observed that the fuel supply was well streamlined in villages such as Dicholi, Karrodoba, Bhalupani and Mahishakeda. In Dicholi and Bhalupani, each household contributes about 30 to 40 kg of fuelwood on a monthly basis. This is collected from the fallen wood found in surrounding forest areas and within the existing plantations of the village. In Karrodoba, villagers contribute biomass from 'kitchen surpluses,' that is savings achieved because of the use of improved cookstoves implemented under VESP. Electricity payments are also linked with biomass contribution, with non-contributing households required to pay amounts equivalent to what they pay for biomass fuel.

5.1.4. Financial performance

Data collected from our field research suggests that consumers' willingness to pay for electricity (Rs/month/household) ranged from Rs 30 to Rs 133 (with an average of Rs 82). However, the actual tariff that consumers paid for four hours of daily supply ranged from Rs 30 and Rs 60 per month per household, depending on the socioeconomic conditions of the village (Palit, 2011). This payment is usually equivalent to the replacement cost of kerosene. Communities generally pay the set tariff wherever the systems are in regular operation (around 20 days or more in a month), with about 50–70% paying their tariffs on time. We found that revenue management was comparatively better where villagers have greater income opportunities—either existing income generation activities such as operating a flour mill, or activities introduced after electrification under VESP, such as honey extraction and *sal* leaf stitching, which we mention below.

5.1.5. Convergence with development programs

The potential for income generation activities exists in almost all VESP communities.[11] The only reason that these activities have

[11] Our financial analysis indicates that the MDP (Minimum Desired Price of Electricity) for a 10-kWe biomass gasifier system 'without any subsidy' is Rs 16.26 kW h at a capacity utilization factor (CUF) of 33%. Considering a capital

not been exploited is because of improper or nonexistent guidance from the VECs. Active involvement of the *gram panchayat* (the lead representative in VEC) tended to help in developing the required synergy between village development funds and VESP funding for initial project costs and operational expenses. For instance, test projects at Dicholi, Bhalupani, and Karrudoba villages swap use of funds from local *panchayat*, state government and local forest offices, respectively, either as a capital contribution towards the project or for establishing income generation activities. For example, the local *panchayat* contributed to complete a power distribution line in Dicholi, while the forest department in Karrudoba installed an open well for water supply to the gasifier plant.

One case study is most illustrative. Bhalupani is a small tribal village in Mayurbhanj district of Orissa. Sambandh, an NGO, implemented a VESP test project in the village with 44 households. Income generation activities promoted under a watershed project were integrated with the VESP. Accordingly, eight *donapatta* machines having a total load of 2 kW were provided in connection with the gasifier power plant. In addition, a honey-processing unit (6 kW) powered by a gasifier plant managed by the Women's Federation of the Balupani Gram Panchayat was also set up in the village, with support from the Integrated Tribal Development Agency from the Government of Orissa.

The *donapatta* systems are operated by self-help groups, and promoted by Sambandh. These commercial units produce cup-plates from *sal* leaves and operate for about four hours daily in the evening for 10–15 days a month. The Women's Federation pays Rs 60 per day for electricity when the *donapatta* unit is operational. This *donapatta* unit *sal* stitching produces net income of about Rs 57 per month. Without that revenue, the VEC would incur a loss of about Rs 500 every month. In addition, the Women's Federation makes payments of Rs 300 per month for about half of the year for using electricity for a honey-processing unit, which contributes further to the financial viability of the project.

5.2. Challenges facing the VESP

While we observed positive developments in some of the VESP projects visited, at the same time many others, if not most, experienced debilitating challenges.

5.2.1. Institutional performance

Many projects faced sustainability challenges because of the dispersed nature of electricity demand in the villages; low economic activity (implying lower electricity demand); lower ability to pay of consumers (in the absence of cash income opportunities); difficulty in operation and maintenance; the VECs having limited technical knowledge; and, most importantly, weak biomass fuel supply chains. Any combination of the above factors led to very low CUFs of between seven to 10% in some villages, corresponding to a higher unit cost of energy production in those locations. Further, a lack of clarity about the roles and responsibilities among the different stakeholders (PIAs, state renewable energy development agencies, and VECs) contributed to delays. The absence of group activities in many villages created a regulatory vacuum, especially where the VECs seldom met to review projects.

In many areas, the VECs were not adequately trained and empowered to manage decentralized projects effectively, especially in locations where state forestry departments executed projects. The assumption in these communities was that VESP projects would be similar to any other government-supported projects, meaning that the government would take charge of the implementation process. While the VESP guidelines require at least 50% female membership in the VEC, we found that women's participation was almost absent or minimal in most projects. Additionally, inordinate delays[12] in installation and commissioning of electricity generating systems severely impacted the mobilization of beneficiary communities.

5.2.2. Technological performance

Performance analysis of some of the better-run projects such as Karudoba (West Bengal), Bhalupani (Orissa), and Jambupani (Madhya Pradesh) indicates substantial variation in operational days and electricity generation over the course of several months. While there may be non-technical reasons for this variation such as low load or fuel supply issues, technological issues contributed as well. Indeed, inadequate management was found to be one of the most critical determinants of poor project performance. However, technical reasons for system non-operation have more to do with poor technical knowledge by the operators than with the technology per se. Still, the implication is that problems of operational knowledge were not overcome at the grass root level. As a result, Fig. 7 shows how for some months gasifier systems were operating for less than five days and Fig. 8 reveals that electricity generation was as low as 50 kW h.

Inadequate post-installation maintenance networks (for example, the limited number of spare parts suppliers) contributed further to long lead times for fault rectification. Inadequate rural maintenance networks also tended to increase after-sales service costs and thereby threaten operational viability. Because of the remoteness of many projects, many found it difficult not only to attract suppliers but also to establish reliable after-sales service locally.

During field visits and interactions with PIAs and the community, the team also found great demand for irrigation pump sets ($\sim$5 to 10 HP Capacity), indicating that village needs could not be met by the installed low-capacity systems currently promoted by the VESP. On the other hand, in extremely remote areas, existing capacity was found to be underutilized. We found this underutilization largely the result of domestic load consuming only about one-third of installed capacity in the absence of any productive load. Some of the specific challenges with proper technology utilization included:

- DC motors used in the cooling and cleaning train of many of the gasifier systems not receiving required maintenance;
- Missing safety paper filters on many units. These paper filters can help lower dust intake, reduce maintenance, and increase the engine life of gasifier units;
- Malfunctioning battery charger systems in some of the sub-projects. The batteries were not recharged during operation

(*footnote continued*)
subsidy of 90% (available under VESP, RVE and DDG projects) and 10% contribution by the community or PIA, the MDP for 10-kWe and 25 kWe systems are Rs 5.60 kW h and Rs 4.29 kW h respectively at a CUF of 33% (Palit et al., 2011). However, based on the field assessment of the VESP test projects, we found that most of the units have been operating at a CUF of only 7%. The real challenge, therefore, is to set a domestic tariff consistent with the willingness to pay (i.e., somewhere around Rs 40–80 per household per month). The financial analysis for a typical VESP project indicates that introduction of a variable tariff of about Rs 10 kW h for productive load and Rs 50 to Rs 60 for domestic load (at a collection efficiency of at least 70%) will make VESP projects financially sustainable. See Palit et al. (2011) for more details.

[12] In the states of Assam and West Bengal, the majority of test projects overseen by the state forestry departments between 2005 and 2006 took more than four years to commission when they were supposed to take six to eight months.

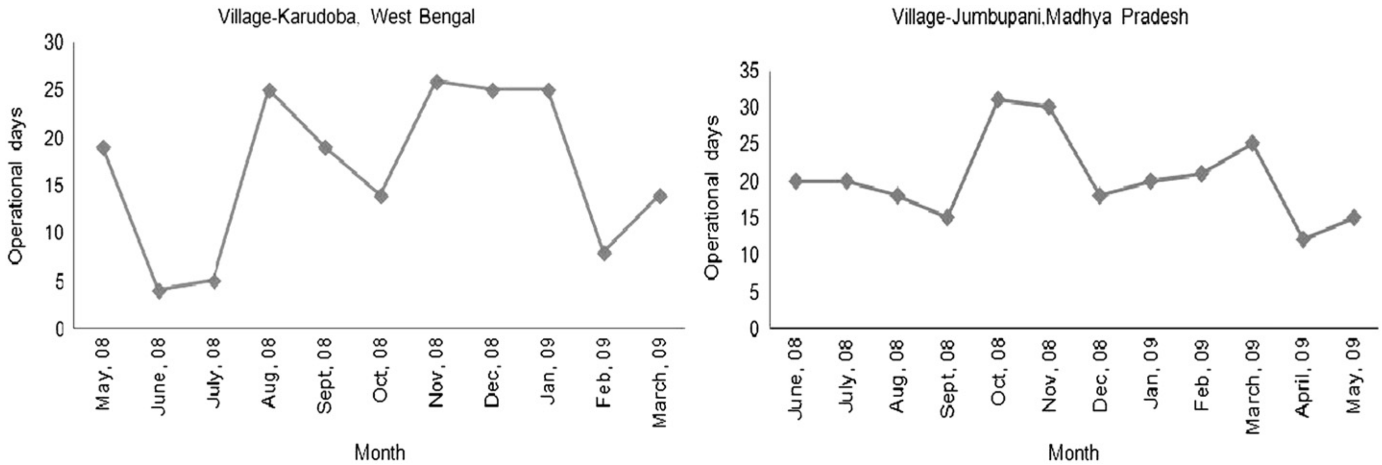

Fig. 7. Days of operation of gasifier systems in Karudoba and Jambupani.

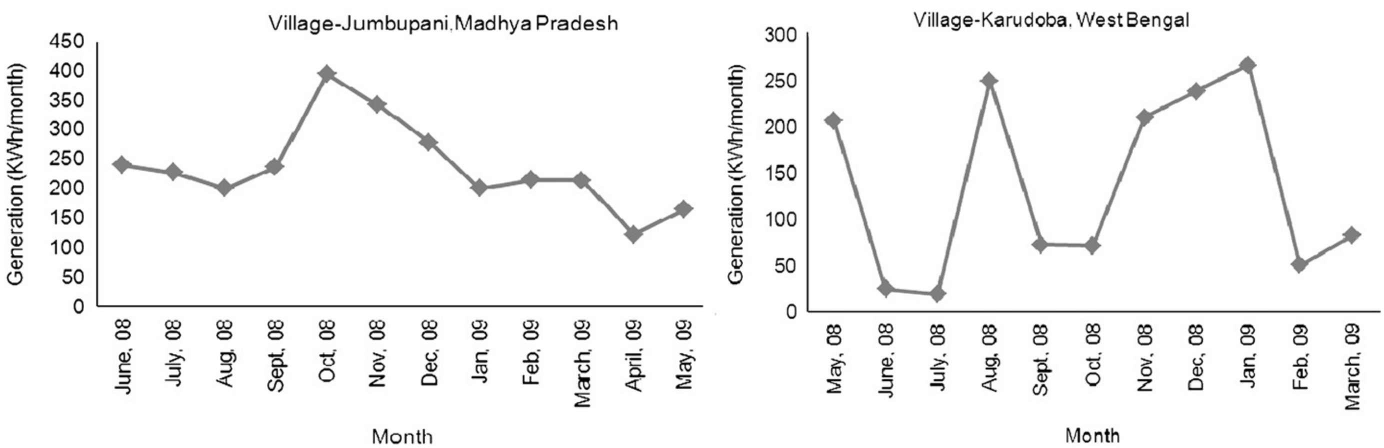

Fig. 8. Electricity generation from gasifier systems in Karudoba and Jambupani.

and had to be discharged after 15 to 18 h, rendering gasifier systems non-operational. The batteries therefore had to be taken to the nearest town for recharging which took some effort and contributed to substantial net downtime;

- Improperly built tanks to supply clean water for cooling and cleaning. Most units have only one chamber in the water tank instead of two as called for in the design. Consequently, dirty water containing tar is re-circulated for cleaning gas. This results in inadequate cleaning, higher engine maintenance, and increased difficulty in operating the system;
- Unfiltered operation. In many SVO systems, oil is directly fed to the engine without passing through a filter. This can lead to long-term engine damage and reduce the operational life of the system.

5.2.3. Plantations & fuel supply management

Lack of adequate supply of biomass was another key constraint; not necessarily because it was not available but because of unorganized supply. In this regard, fuel supply chains for both biomass and oilseeds were found to be erratic in majority of the villages as villagers often did not receive monetary benefits for contributing a share of the total biomass, resulting in a "severe disinterest" in the VESP after the initial months. In the case of SVO based projects specifically, the oilseeds collected from forests yielded better prices in the local market than those sold for electricity generation. As such, villagers were more inclined to sell the oil seeds for cash income instead of contributing to energy production.

5.2.4. Financial performance

In most of the test projects, revenue management was virtually absent. Because systems were down for most of the time, communities were reluctant to pay for service. Poor revenue flow diminished interest in maintaining system operations, creating a vicious cycle. Operator costs (varying between Rs 500 to Rs 1500 per month) also became significant since low lighting loads and the absence of productive loads diminished demand. Normal maintenance costs added to total expenditures, often overwhelming revenues that could be generated through user payments. Because the VECs did not levy any penalties for non-payments, they had no reason to keep any revenue-related records tracking project income and expenses.

5.2.5. Convergence with development programs

Inadequate capacity building and support to the VEC and system operators was a final key factor negatively impacting VESP projects. While the operators of the energy production system in the test projects were offered training, many did not become competent in maintenance and operation.

For instance, in a majority of VESP subprojects, ICSs and biogas plants were either non-functional or were not given adequate importance, even though these technologies were critical to the VESP concept. Communities were not inclined to use biogas and

ICSs because they were used to cooking on wood and were reluctant to change their cooking practices. For most villages, dung availability was low because cattle were not stall-fed in most of the projects, and, moreover, plenty of fuelwood was available at zero cash outlay. These obstacles ultimately meant that the VESP was not harmonized with other prevailing state and national development concerns and, thus, users and village leaders focused on other tasks and programs.

At a deeper level, lack of awareness and gender bias may have impeded the acceptance of biogas and ICS devices. State-led biogas programs in the 1980s and 1990s, for instance, contributed to increases in the local prices of materials, cement, wages, accessories, and even food; some village leaders therefore came to see biogas technologies as curses rather than blessings. Furthermore, the VESP may not have adequately targeted gender and educational issues, despite its intent to incorporate women. One recent assessment reported a lack a "critical awareness" among male village leaders concerning the problems associated with cooking, since most of that work is done by women. As a result, men can lose interest in technologies and systems to be predominately utilized by women (Myles, 2010).

6. Lessons learned and conclusions

Planners conceived of the VESP as a holistic way of energy services delivery based on the premise that biomass based technologies can be reliable, decentralized operations can be viable, and local communities can autonomously plan and manage projects with support from PIAs. The main strength of the VESP lied in its goal of "providing total energy security to achieve sustainable development" to remote areas through utilization of locally available renewable bio-energy resources and the direct empowerment of local communities. Despite its innovative approach, however, the VESP did not achieve its desired goals due to a mesh of discrete failures and unintentional weaknesses including lack of clarity between various stakeholders, unreliable fuel supply, and poor after sales service and maintenance. With this in mind, we present three main conclusions for energy development practitioners and policymakers based on the VESP experience.

First, some renewable energy technologies require clusters, or certain economies of scale and scope, to work properly. One cannot promote biogas or gasifier systems the same as solar home systems or improved cookstoves, and in the particular case of the VESP, its community-scale ambitions did not always match the realities of local fuel supply. Depending on the proximity of the habitations, the merit of setting up a local mini-grid and a central power plant of higher capacity might have been beneficial over smaller capacity systems. Further, renewable energy technologies and affiliated infrastructures also need to be compatible for future grid synchronization to ensure that communities can still rely on them when the grid reaches the village and or if they become connected to the grid. In addition, appropriate standards for design and performance can help minimize downtime and enhance the ability for villages to achieve the best overall lifecycle costs with their systems. This serves as an enduring reminder that development and energy practitioners should remain flexible about the sizes, capacities, and configurations of the technology they intend to deploy, and maintain strict quality specifications for the systems they select.

For example, our analysis of the VESP implies that biomass and biogas technologies only work properly if (1) there is sufficient feed material for sustained generation; (2) waste disposal is coordinated and assured; (3) spare parts and machinery for the plant and equipment are readily available; (4) reliable after-sales service is available at the locations where projects are planned; (5) individuals are properly trained for operation and maintenance of the system; and (6) applicable laws and regulations allow and support the project. Most projects under the VESP met few of these conditions, and villages struggled to maintain a steady supply of fuel and a reliable source of energy services.

Second, energy users – in this case villagers and VECs – do not effortlessly know how to manage energy systems without extensive capacity building. VESP projects were implemented on the premise that the community (through the VEC) or the local *panchayat* own the project and assume overall responsibility for management and operations. Yet our analysis strongly suggest that most were not properly trained on how to use, service, and maintain the gasifiers, biogas and vegetable oil systems. Moreover, we found that in many cases those that were trained were unable to grasp a proper understanding of the technology because of lack of exposure and familiarity. Further, biomass fuel suppliers also showed reluctance to develop a post installation service network because of a low volume of activity, creating a negative feedback loop that severely impacted project performance.

This finding has somewhat profound implications for other development projects, as it suggests that decentralizing and democratizing energy planning at the scale of villages is not a panacea, and presents its own type of obstacles. It also implies that alternative service delivery models are urgently needed, perhaps those involving energy service companies (ESCOS), cooperatives, and build, own, operate and manage (BOOM) or build, operate, transfer schemes. Under these models, energy service providers could play the role of stand-alone power producer, distributor and supplier of electricity and manage revenue through payment collections from electricity users and VECs who would retain their ability to act as regulator and set tariffs, and to resolve disputes and grievances. However, appropriate regulatory frameworks may have to be developed for these different models to find widespread adoption (Palit et al., 2011).

Third, we observe that maximizing the load of rural energy systems becomes a crucial factor for ensuring financial viability. As we detailed in this study, capacity utilization factors are perhaps the strongest determinant of whether a VESP test project "failed" or "succeeded." This lesson means that operational sustainability goes hand in hand with high capacity factors and either efficient systems of revenue collection, or finding ways to couple energy services with additional productive uses. Further, we note that the load factor is also dependent on organizational approaches to distribution and supply. Wherever organizational approaches lack the incentive to increase or maximize load, the viability of projects become a challenge. Wherever measures are taken to help communities increase load through income generating activities or acquiring modern appliances, the chances of project viability increase. This finding underscores how the provision of energy services to rural areas must be linked with the creation of livelihood opportunities and adequate capacity building.

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References

Balachandra, P., 2011. Modern energy access to all in rural India: an integrated implementation strategy. Energy Polciy 39, 7803–7814.
Banerjee, R., 2006. Comparison of options for distributed generation. Energy Policy 34, 101–111.
Bazilian, M., Nussbaumer, P., Singer, C.E., Brew-Hammond, A., Modi, V., Sovacool, B.K., Ramana, V., Aqrawi, P.K., 2012. Improving access to modern energy services: insights from case studies. Electricity Journal 25 (1), 93–114.
Bhattacharyya, S.C., 2006. Energy access problem of the poor in India: is rural electrification a remedy? Energy Policy 34, 3387–3397.
Buragohain, B., Mahanta, P., Moholkar, V.S., 2010. Biomass gasification for decentralized power generation: the Indian perspective. Renewable and Sustainable Energy Reviews 14, 73–92.
Chakrabarti, S., Chakrabarti, S., 2002. Rural electrification programme with solar energy in remote region—a case study in an island. Energy Policy 30, 33–42.
Chaurey, A., Ranganathan, M., Mohanty, P., 2004. Electricity access for geographically disadvantaged rural communities—technology and policy insights. Energy Policy. 32, 1693–1705.
DFID, 2002. Energy for the Poor: Underpinning the Millennium Dev Goals. Department for International Development, London.
ESMAP, 2002. Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits. Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) Report. The World Bank, Washington, DC.
Ghosh, D., Sagar, A., Kishore, V.V.N., 2006. Scaling up biomass gasifier use: an application-specific approach. Energy Policy 34, 1566–1582.
Ghosh, S., Das, T.K., Jash, T., 2004. Sustainability of decentralized woodfuel-based power plant: an experience in India. Energy 29, 155–166.
GNESD, 2007. Reaching the Millennium Development Goals and Beyond: Access to Modern Forms of Energy as a Prerequisite. Global Network on Energy for Sustainable Development, Denmark.
IEA, 2011a. Energy for all: Financing Access for the Poor, International Energy Agency, Paris.
IEA, 2011b. World Energy Outlook 2011. International Energy Agency, Paris.
IISc, 2012. Biomass Atlas of India. CGPL: Indian Institute of Science, Bangalore (〈http://cgpl.iisc.ernet.in〉).
Joon, V., Chandra, A., Bhattacharya, M., 2009. Household energy consumption pattern and socio-cultural dimensions associated with it: a case study of rural Haryana, India. Biomass and Bioenergy 33, 1509–1512.
Kemmler, A., 2007. Factors influencing household access to electricity in India. Energy for Sustainable Development Volume XI No (4), 13–20.
Krishnaswamy, S., 2010. Shifting of Goal Posts—Rural Electrification in India: A progress Report. Vasudha Foundation, New Delhi.
MNES, 2004. Test Projects on Village Energy Security; Guidelines for Planning, Implementation and Funding of the Test Projects. Ministry of Non-Conventional Energy Sources, Government of India, New Delhi.
MNRE, 2008. Implementation of Village Energy Security Test Projects during 2008–2009 and 2009–2010. Ministry of New and Renewable Energy Sources, Government of India, New Delhi.
MNRE, 2012. Renewable Energy for Rural Applications. Annual Report 2011–2012, Ministry of New and Renewable Energy, Government of India, New Delhi.
Modi, V. 2005. Improving Electricity Services in Rural India. 〈http://www.me.columbia.edu/fac-bios/modi/resources/RuralEnergy_India.pdf〉.
Myles, R., 2010. Development, promotion, dissemination, and diffusion of household biogas technology in rural India. In: Koyla, Abramsky (Ed.), Sparking a Worldwide Energy Revolution: Social Struggles in the Transition to a Post-Petrol World. AK Press, Oakland, pp. 277–291.
NRECA, 2002. Economic and Social Impact Evaluation Study of the Bangladesh Rural Electrification Program. NRECA International Ltd, Dhaka, Bangladesh.
NSSO 2011. NSS 66st round (July 2009–June 2010), (Uniform and Mixed Reference Period, Unit Level Data, Household Consumer Expenditure Round). Data on CD, National Sample Survey Organization, Ministry of Statistics and Programme Implementation, Government of India.
Pachauri S. 2007. Global development and energy inequality options; 〈http://www.iiasa.ac.at/Admin/INF/OPT/Winter07/opt-07wint.pdf〉; Last accessed on November 20, 2011.
Parikh, P. 1984. State of the Art Report on Gasification of Biomass. Report Submitted to Department of Nonconventional Energy Sources. Delhi: Government of India.
Palit, D. 2011. Performance assessment of biomass gasifier based power generation systems implemented under Village Energy Security Program in India. In: Proceedings of the International Conference Advances in Energy Research. December 9–11, 2011. Mumbai: Indian Institute of Bombay.
Palit, D., Malhotra, R., Kumar, A., 2011. Sustainable model for financial viability of decentralized biomass gasifier based power projects. Energy Policy 39, 4893–4901.
Palit, D., Chaurey, A., 2011. Off-grid rural electrification experiences from South Asia: status and best practices. Energy for Sustainable Development 15, 266–276.
Rao, P.S.C., Miller, J.B., Wang, Y.D., Byrne, J.B., 2009. Energy-microfinance intervention for below poverty line households in India. Energy Policy 37, 1694–1712.
Rehman, I.H., Kar, A., Banerjee, M., Kumar, P., Shardul, M., Mohanty, J., Hossain, I., 2012. Understanding the political economy and key drivers of energy access in addressing national energy access priorities and policies. Energy Policy 47, 27–37.
Srivastava, L., Goswami, A., Diljun, G.M., Chaudhury, S., 2012. Energy access: revelations from energy consumption patterns in rural India. Energy Policy 47 (2012), 11–20.
Sovacool, B.K., Cooper, C., Bazilian, M., Johnson, K., Zoppo, D., Clarke, S., Eidsness, J., Crafton, M., Velumail, T., Raza, H.A., 2012. What moves and works: broadening the consideration of energy poverty. Energy Policy 42, 715–719.
Sovacool, B.K., 2012a. The political economy of energy poverty: a review of key challenges. Energy for Sustainable Development 16 (3), 272–282.
Sovacool, B.K., 2012b. Deploying off-grid technology to eradicate energy poverty. Science 338 (5), 47–48, October.
TERI, 2009. Impact & Adequacy Assessment Report. National Contract for Economics & Financing, Monitoring & Evaluation Frameworks and Policy & Institutional Issues. The Energy and Resources Institute, New Delhi.
TEDDY, 2003. TERI Energy Data Directory and Yearbook. TERI Press, New Delhi, India.
TEDDY, 2011. TERI Energy Data Directory and Yearbook. TERI Press, New Delhi, India.
The World Bank, 2011. India: Biomass for Sustainable Development: Lessons for Decentralized Energy Delivery. The World Bank, India Country Management Unit, New Delhi.
Venkataraman, C., Sagar, A.D., Habib, G., Lam, N., Smith, K.R., 2010. The Indian National Initiative for Advanced Biomass Cookstoves: the benefits of clean combustion. Energy for Sustainable Development 14, 63–72.