Rural Electrification in India:

Economic and Institutional aspects of Renewables

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The paper assesses the demand for rural electricity services and contrasts it with the technology options available for rural electrification. Decentralised Distributed Generation can be economically viable as reflected by case studies reported in literature and analysed in our field study. Project success is driven by economically viable technology choice; however it is largely contingent on organisational leadership and appropriate institutional structures. While individual leadership can compensate for deployment barriers, we argue that a large scale roll out of rural electrification requires an alignment of economic incentives and institutional structures to implement, operate and maintain the scheme. This is demonstrated with the help of seven case studies of projects across north India.

Keywords: Rural Electrification, Distributed Generation, Renewable Energy, India.

JEL Codes: D23, L94, Q42.

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Introduction

We explore the contribution that decentralised and renewable energy technologies can make to rural electricity supply in India. We take a case study approach, looking at seven sites across northern India where renewable energy technologies have been established to provide electrification for rural communities. We supplement our case studies with stakeholder interviews and household surveys, estimating levels of demand for electricity services from willingness and ability to pay. We also assess the overall viability of Distributed Decentralised Generation (DDG) projects by investigating the costs of implementation as well as institutional and organisational barriers to their operation and replication. Renewable energy technologies represent some of the most promising options available for distributed and decentralised electrification.

Demand for reliable electricity services is significant. It represents a key driver behind economic development and raising basic standards of living. This is especially applicable to rural India home to 70% of the nation's population and over 25% of the world's poor. Access to reliable and affordable electricity can help support income-generating activity and allow utilisation of modern appliances and agricultural equipment whilst replacing inefficient and polluting kerosene lighting. Presently only around 55% of households are electrified (MOSPI 2006) leaving over 20 million households without power. The supply of electricity across India currently lacks both quality and quantity with an extensive shortfall in supply, a poor record for outages, high levels of transmission and distribution (T&D) losses and an overall need for extended and improved infrastructure (GoI 2006).

The Indian Government recently outlined an ambitious plan for 100% village level electrification by the end of 2007 and total household electrification by 2012. To achieve this, a major programme of grid extension and strengthening of the rural electricity infrastructure has been initiated under the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) (GoI 2005). However, real benefits for newly connected rural households may be severely restricted unless the ambitious grid expansion plans are accompanied by similarly ambitious distribution reforms and de-politicisation of tariffs. Concerns have been expressed, questioning in particular the long term financial and technical sustainability of the programme (World Bank 2004).

Alternative approaches to rural electrification have been proposed. They typically combine centralised grid connections as distribution franchises and DDG operated at the local level taking advantage of renewable energy technologies. Thus DDG projects, if widely replicated, can ease the burden on both electricity supply shortfalls (by serving rural areas and subsequently feeding back into the grid), and reduce the urgency of costly grid extension. DDG offers the potential for affordable, clean and reliable electricity with minimal losses and effective maintenance and local cost recovery. The recent policy initiative undertaken by the Indian government outlines new avenues for rural electrification through participation of Panchayats (rural bodies), NGOs, self-help groups, cooperatives and franchisees (Ministry of Power 2003).

The use of renewables can avoid fuel transport or grid interconnection to remote areas, harvest frequently good resource potentials and tap into rural communities willingness to pay. The scalability of many renewable technologies allows for a gradual increase of electricity services provided in line with the purchasing power of the communities, and thus avoids the dilemma of past rural electrification projects which first deliver electricity as a free or highly subsidised good and thus subsequently fail to implement effective charging schemes to secure the continuation of power supply.

The experience with the use of renewable energy sources has so far delivered mixed results. Larger scale deployment of renewable energy technologies for rural energy has been prevented and hindered by a range of barriers, even where technologies exhibit economic advantages. Indeed across past programmes and policies, a range of social, political and institutional constraints are often cited as key determinants in the dissemination of modern energy technologies (or lack of) in developing countries (Karekezi 1994; Miller 1998; Duke et al. 2002) and similarly across India (Miller and Hope 2000; Velayudhan 2003; Radulovic 2005). Studies have tended to focus on financing challenges, and in some cases broader institutional, technical and geographical constraints on renewable dissemination. Whilst they point to high ability to pay and willingness to pay amongst rural consumers; credit constraints, lack of technical capacity, lack of awareness and under-developed market distribution all contribute to limited deployment of renewables for rural electricity.

This study outlines a framework to first categorise and assess the economic feasibility by quantifying the energy demand curve and supply options provided by different technologies. While the economics can explain challenges for and failure of some projects, it does not explain why (i) some apparently economically viable projects fail and (ii) economically viable projects are not replicated at large scale. Therefore we analyse the organisational structure of the different DDG projects, to better identify the models that are most suitable for replication and large scale deployment.

Case studies that fail despite economic viability demonstrate the importance of organisational leadership and institutional structures. While individual leadership can compensate for adverse situations, we argue that a large scale rollout of rural electrification requires an alignment of economic incentives and institutional structures to implement operate and maintain the scheme. Successful projects have overcome numerous barriers to deployment and subsequently embedded these 'best practices' into their project implementation. There is great scope for large scale deployment of renewables for rural energy, through replication of these approaches, across India and beyond.

1 Rural Demand for energy services and willingness to pay

The successful deployment of rural electrification is contingent on widespread willingness to pay amongst rural households and energy users. This section shall look at evidence for demand in rural households drawn from surveys and previous studies. Where willingness to pay exists economically viable technologies can succeed even in an environment of cross-subsidy, low bill collection and high non-payment rates.

Rural households spend around 10% of their monthly income on basic fuel and energy services, which are used primarily for cooking and heating activities- Figure 1. Their willingness to pay depends upon income, existing energy mix and costs thereof, availability of electricity, quality of supply and appliance ownership.

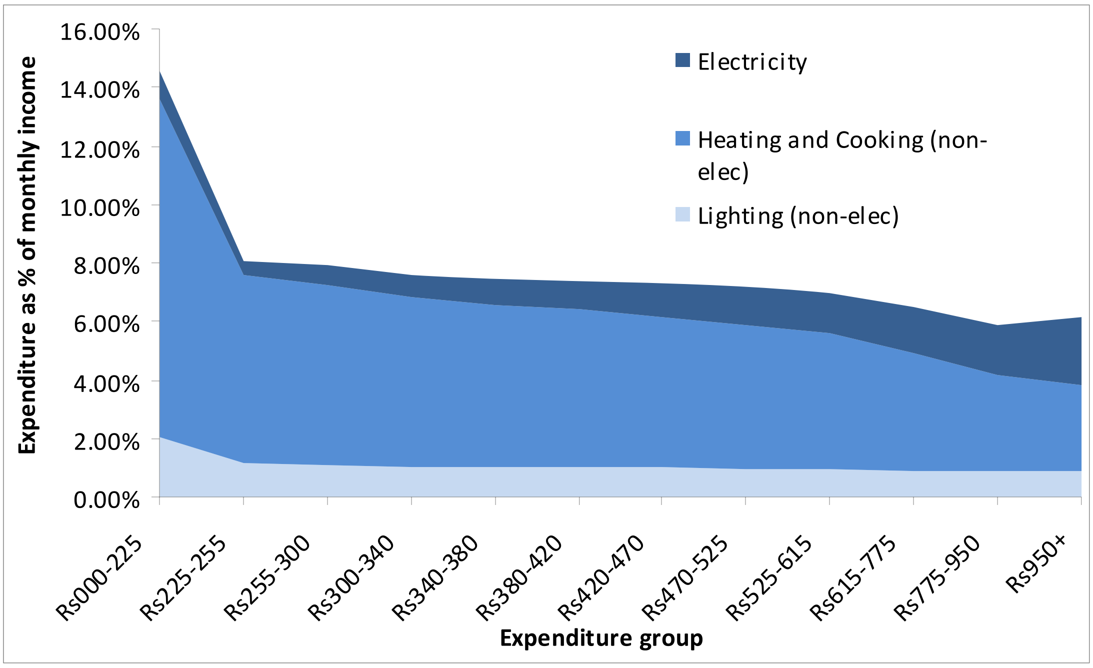

Figure 1 -Rural household spending on energy as % of monthly consumption, by monthly per capita expenditure group- (Adapted from source: (NSSO 2001))

Measuring willingness to pay for electricity poses a challenge; many developing countries, including India, lack the quality and quantity of measured data, hence surveys are frequently used (Choynowski 2002).

1.1 Results from demand survey

Our fieldwork involving 35 rural households across seven locations finds that willingness to pay for electricity ranges between Rs.100 and Rs.120 per month (the equivalent of around Rs7-10/kWh) across socio-economic groups. It should also be noted that previous studies have cautioned against the tendency of rural households to overstate their willingness to pay, or rather, that ability to pay is the binding constraint for poorer rural households. Hence we take a combination of surveyed willingness to pay and revealed preference from monthly tariffs. Figure 2 indicates the range of tariffs paid by households for rural electricity services. By revealed preference we note that they pay a high effective tariff, particularly where fixed monthly rates are charged. In addition, non-tariff electrification options such as Solar Home Systems (SHS) remain expensive in per unit cost terms, despite relatively small upfront costs. Figure 3 depicts household's maximum willingness to pay from survey results. Respondents were asked what monthly fee they would pay for a reliable connection with 5 hours availability. Households are divided into Socio-Economic groups based upon income level and type of abode[4].

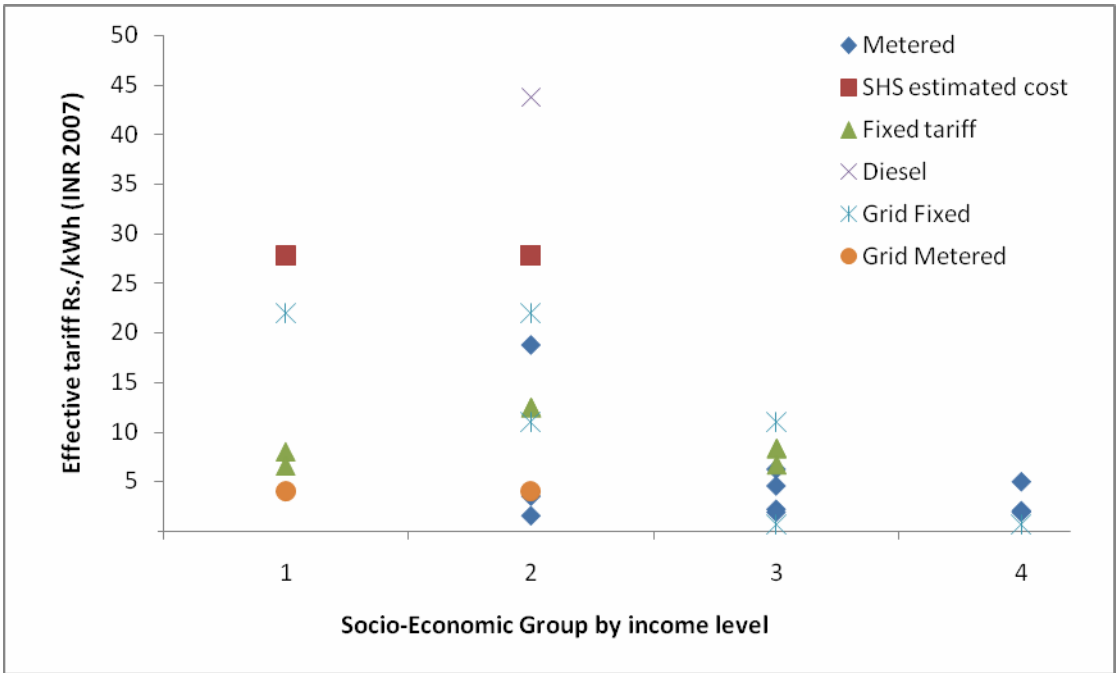

Figure 2 - Effective tariff paid by households (revealed preference) by SEC

Notes: Rural SEC: (R1- more affluent, R4 least). For fixed tariff we assume a daily usage of 5hoursx80W where available and applicable. For fixed rate connections based on more than 3 lighting points, we adjust usage upwards. For 38W SHS we assume daily usage of 4hours at 30W.

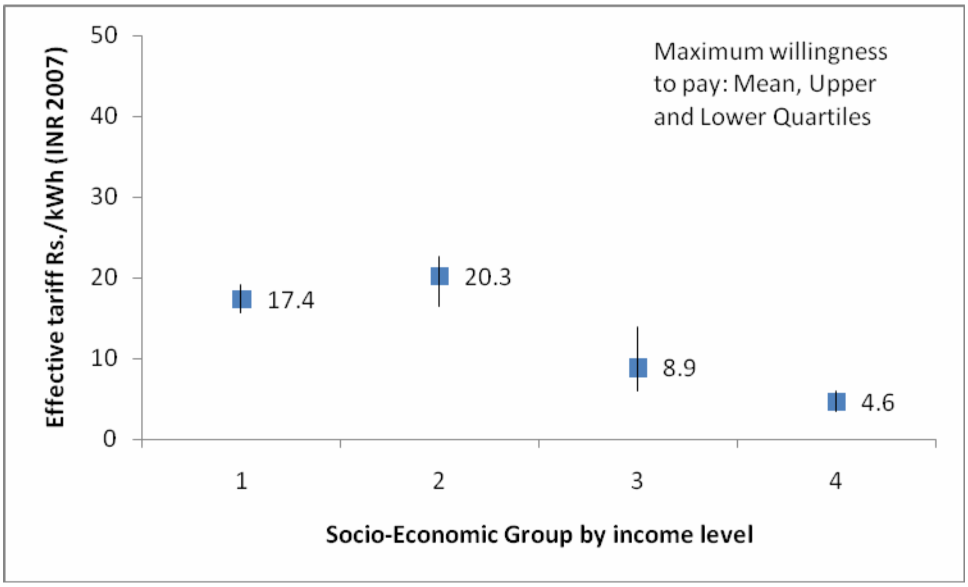

Figure 3 - Maximum willingness to pay, by SEC

Notes: Rural SEC: (R1- more affluent, R4 least). For fixed tariff we assume a daily usage of 5hoursx80W where available and applicable. For fixed rate connections based on more than 3 lighting points, we adjust usage upwards. For 38W SHS we assume daily usage of 4hours at 30W.

[4] We adopt the convention of SEC (Socio-Economic Classification) based on household income and abode type. The ordering of households in our sample by SEC is robust to classification by either education level or income in addition to abode, in both cases. SEC group 1 represents approx- 4% of rural population. group 2: 11%, group 3: 37%, group 4: 48%.

We find that the reported willingness to pay estimates are in line with the revealed expenditure in similar electricity connected households. Indeed where grid connections exist rural households often pay effectively high tariffs, when the costs of connection, fixed charge or monthly minimum charge are included.[5] The willingness to pay survey and additional household level interviews also suggests that the private benefits of lighting alone greatly exceed what households currently pay for electricity, supporting the previous finding that households are likely to pay more than the existing subsidized tariffs (Bose and Shukla 2001; Barnes et al. 2002).

Electricity consumption has high value for rural households and where access exists, willingness to pay is high, even amongst poorer households. Consumers are generally willing to pay significantly more for shorter outages and better quality supply even in grid connected areas. This is confirmed by observations that in remote and off-grid areas consumers are willing to pay a premium for electricity connections, either from diesel generators or for non-conventional connections (Bose and Shukla 2001; Barnes and Sen 2002; Mukhopadhyay 2004). In the Operations Research Group survey of over 5,000 households across 6 states the level of poor households' willingness to pay was estimated at Rs15-20 per kwh, which is about four to five times the typical grid electricity charges[6] (Barnes et al. 2002). This is supported by evidence of thriving markets for private operators of small diesel generators who charge tariffs in a similar range.

Rural communities are able and willing to pay for reliable electricity services. Indeed where good quality electricity connections exist, the positive impact on rural incomes can offset the cost of the electricity supply. If electricity generation and supply is directly tied to income-generation activity, the community's ability to pay for electricity services are further enhanced. As illustrated by our case studies (see Appendix for more details), demand for electricity can become interdependent with effective fuel supply for the power plant, cost recovery through regular tariff payment and high quality power provision.

[5] Rs.5-40 per kWh for 15kwh of monthly use

[6] The Operations Research Group survey (Barnes et al 2002) surveyed over 5,000 household's expenditure on electricity services indicating revealed preference with an upper bound effective tariff of Rs.40/kWh. It should be noted that rural household's willingness to pay is high where tariffs are charged on a fixed basis even where unit consumption is very low. Our fieldwork puts typical consumption between 10-15kWh per month.

2 Rural Electricity Supply Options

Having established the demand for rural electricity supply, we now characterise technologies available to satisfy the demand and their costs. They can be classified in three approaches. First, centralised conventional thermal generation combined with rural grid extension is an approach favoured by the Ministry of Power. Second, small-scale decentralised distributed generation avoids the bureaucratic complexities for rural communities and hence is widely used to supply electricity from diesel generators by local entrepreneurs. Renewable energy supplied in this manner remains a niche application, although several projects by government and other agencies have demonstrated its distinct advantages (Chakrabarti and Chakrabarti 2002; Kishore et al. 2004). Finally, household level technology such as Solar PV can fulfil electricity needs for lighting and other low consumption activities, with minimal unit investment costs and organisational challenges.

We shall address these approaches in turn so as to analyse whether DDG from renewable energy technologies can be economically viable when compared with both grid electrification and diesel generators.

At present in India, non-conventional energy sources (excluding large hydro) represent around 5% of total installed capacity. The untapped resource potential is significantly higher. Many engineering studies consider renewable energy for rural areas on technical feasibility grounds and are complemented by numerous economic calculations of potential and costs for renewable energy used for distributed generation (Ghosh et al. 2002; Kishore et al. 2004; Banerjee 2006; Deshmukh and Bilolikar 2006; Nouni et al. 2007). These studies generally conclude that renewable energy technologies, in particular biomass and small hydro, can be economically viable (under correct conditions) whilst offering both environmental and social sustainability.

Technology	Scale and Ownership	Pros and cons	Cost of supply Rs/kWh
Kerosene Lighting	Households	Affordable and flexible but adverse health effects and poor quality light.	n/a
Grid electrification	State distribution company, Cooperative	Cheap or free, clean (locally), low maintenance. Allows for income generating activities. Costly to supply, high T&D losses, low cost recovery, poor quality, high outages.	3-5
DDG Diesel Generator	Entrepreneur, coop, firm, NGO, gov.	Easy maintenance. Continuous energy services (24hrs). Allows for income generating activity. But high fuel costs and emissions	8-10

Small biomass plant (50-100kw)	Firm, coop, gov agency or NGO	Allows for income generating activities. Base load operation, continuous operation possible. Carbon neutral though noxious emissions in some cases. Limited resource.	6-8
Micro-hydro (50-100kw)	Firm, coop, gov agency or NGO	Long-life, reliability. Allows for income generating activity. Limited resource availability, seasonal variation in supply.	3-7
Wind hybrid*(50-100kw)	Firm, coop, gov agency or NGO	Reduced fuel cost, flexible load. Relatively cost-effective renewable option where strong wind resource. Serious locational problems.	8-10
Biofuel-powered generator (biodiesel, 50-100kw)	Firm, coop, gov agency or NGO	Allows for income generating activities. Base load operation, continuous operation possible. Carbon neutral. Fuel supply issues.	8-15
Solar PV Panels	Households, small businesses	No fuel cost. Self-ownership avoids organisational issues relating to larger power plants. High upfront cost and battery replacement cost.	25+

Table 1 - Technology options for rural electrification

Notes: *We limit our inclusion of to wind hybrid systems; we exclude wind power for rural electrification due to its variable supply and need for battery back-up. When combined in a hybrid unit, with diesel or biomass generation, the viability and potential contribution of wind power is increased.

Cost estimates for DDG plant vary between 50kw and 100kw. For smaller sizes costs of Biomass, Wind-Hybrid and Small-hydro increase notably- at smaller scales Diesel and solar PV systems are more appropriate. Lower bound costs typically represent generation costs at moderate plant load factor (50-65%). Upper bound costs typically include some distribution infrastructure and implementation costs (where applicable; Diesel, biomass, small-hydro). Range of costs reflects differing assumptions in the literature with regards fuel cost, discount rate, load factors and implementation costs.

Sources: (Hansen and Bower 2003; Nouni et al. 2005; Banerjee 2006; Nouni et al. 2006; Tongia 2006; Ashok 2007; Nouni et al. 2007)

2.1 Grid Connections

Grid connection remains the most favoured approach to rural electrification for the majority of rural households. Indeed the latest government programme for rural electrification, the RGGVY, focuses in particular on a vast expansion of the existing grid to reach all villages by 2012.Whilst state utilities typically report an average cost of supply at around Rs.3/kWh most studies put the true figure for rural electricity supply significantly higher. Studies suggest that cost of delivery to rural areas can be around three times generation costs (Barnes and Sen 2002). A recent estimate for a Gujarat case study, based on Gujarat Electricity Board data, put the true cost of delivery to rural areas at over Rs.9/kWh (Hansen and Bower 2003).

As the distance from the grid increases, the cost of grid connection rises considerably (Chakrabarti and Chakrabarti 2002; Hansen and Bower 2003; Banerjee 2006; Deshmukh and

Bilolikar 2006; Ashok 2007). It increases costs by roughly Rs1/kWh per kilometre of expansion to individual villages (Chakrabarti and Chakrabarti 2002), see Figure 4.

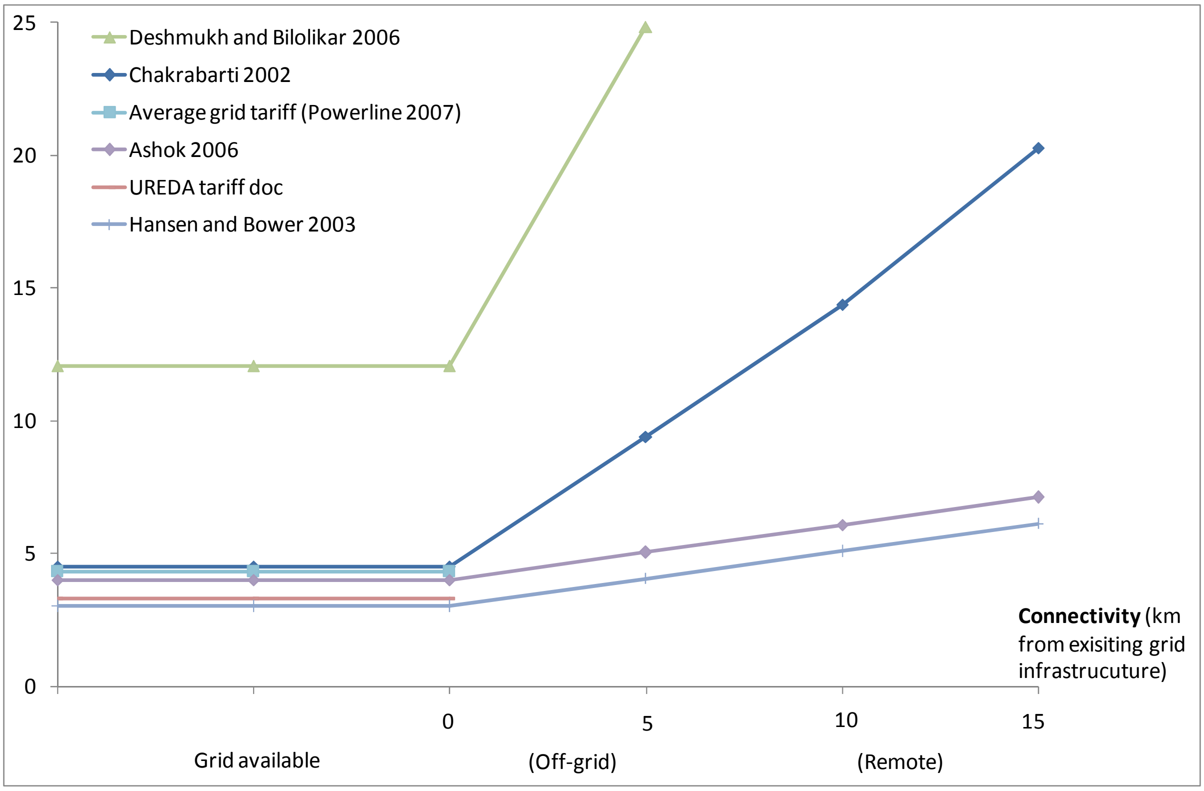

Figure 4 - Cost of grid electrification by distance from existing grid (label cost/km/kWh)
Sources: (Chakrabarti and Chakrabarti 2002; Hansen and Bower 2003; Deshmukh and Bilolikar 2006; UREDA 2006; Ashok 2007; Powerline 2007)

Typically grid tariffs for poor rural households range from Rs.0-10/month for the poorest households[7] and Rs.0-130/month for remaining domestic customers. These charges typically lie well below the cost of supply and are sustained through redistributive policies, tariff cross-subsidies and financial relief to loss-making State electricity boards (SEB). In terms of Rs/kWh, the charge is in the region of Rs.3-5/unit for a typical consumption of 15kWh/month, although even where rural meters exist, they are often not monitored for usage. In per unit cost terms, grid connections often represent the cheapest electrification option for most rural households. Given the government promotion of electricity for water pumping, agricultural tariffs are heavily subsidised with farmers paying around four times less than rural residential customers (Barnes and Sen 2002).

[7] The central government funded Kutir Jyoti programme aims to provide free basic connections for all BPL households. For non-BPL households, grid connections can be effectively free given poor rates of bill collection in many regions.

2.2 Diesel Generators

Diesel gensets have been the most popular choice for commercial and industrial back-up power. For off-grid electrification, particularly where low load factors prevail, diesel generators represent a relatively low cost option for fulfilling basic electricity needs (Banerjee 2006). Past studies have put the typical cost per unit between Rs5/kWh and Rs13/kWh, however when estimated using prevailing fuel prices (Rs35/litre) they lie at the upper end.

At present diesel generators represent the most widespread form of DDG technology, supplying individuals, businesses and operated as mini-grid distribution areas. An estimated 10GW of diesel generator sets are installed, most of which operate at very low load factors.

2.3 Renewable Energy Technologies as DDG

2.3.1 Biomass gasification

The electric power demand in most Indian villages lies between 20kw-100kw and the locally available surplus biomass is often sufficient to meet these power requirements (Bharadwaj and Tongia 2003). Widespread availability of agriculture wastage, fuelwood, animal dung and wasteland make biofuel and biomass based energy appealing, with biomass gasification representing one of the most promising small-scale electricity generating technologies. The use of biomass gasification technology for rural electrification still remains limited, though with large potential across India (Kishore et al. 2004; Ravindranath et al. 2005). Current installed capacity stands at around 350 MW, with small-scale systems representing around 43MW of this, across 1800 systems. The potential for larger scale replication of biomass gasification systems is estimated to be between 20,000 MW (Bharadwaj and Tongia 2003) and 57,000MW[8] (Randrinath and Hall 1995).

Fuel supply plays a crucial role in determining the financial viability and sustainability of biomass gasifier power plants. Competition with food produce makes biomass a potentially contentious fuel supply, precluding the dedicated use of existing farmland for biomass production (Ravindranath et al. 2005). Mismanagement or unforeseen shortages of managed crops can put pressure on forests or common property resources and can threaten the viability of distributed power plants. However, in general rural India has an abundance of wasteland and marginal farmland. Successful projects have helped local communities to effectively

[8]Estimate based on 41,000MW from energy plantations and 16,000MW from crop residues.

utilize energy plantations or common land for the growing of suitable biomass fuel crops. Agricultural residuals can supplement fuel crops for small-scale gasification plants. In addition, in some environments electricity allows for increased irrigation and utilisation of ground water stocks. Where the community can regulate the use of scarce ground water, farmers can grow cash crops and drought sensitive crops instead of low yielding millets.

For small-scale electrification, particularly community loads in rural areas, biomass gasification represent a sustainable and relatively low cost option for fulfilling basic electricity needs. Past studies have put the typical cost per unit between Rs2.5/kWh and Rs7.5/kWh, with cost sensitive to load factor and fuel availability (Tripathi et al. 1997; Banerjee 2006; Nouni et al. 2007). Our fieldwork finds the estimated cost per unit between Rs.6 and Rs.8 for existing biomass plants in rural areas.

2.3.2 Small Hydro

Small run-of-river hydro has enjoyed modest success in many locations across India (Gunaratne 2002; IEA 2002) as a localised, cheap, clean, reliable and minimal-impact electrification option. Currently only 210MW are installed across 267 projects, predominating in the north. Small hydro systems offer significant potential for wider deployment across mountainous rural areas. Across India significant untapped potential would allow for up to 15GW of additional capacity. Prospects for significant expansion of hydro-storage are smaller, and recent growth is stagnating (Tongia 2003).

The investment costs for small rural and remote hydro power projects in India vary between Rs. 124,310–Rs. 233,335 per kW. This includes the cost of power evacuation and distribution system (Nouni et al. 2005). At a discount rate of 12%, the energy delivery costs rang from Rs.3/kWh up to around Rs.9/kWh, dependent on the plant load factors. Seasonal variation in water flow and under utilization of the produced electricity can threaten the viability of hydro plants. Our fieldwork at two sites in Uttaranchal puts the estimated cost per kWh between Rs.3 and Rs.7, with differences caused by utilisation factor, local resource availability and seasonal variation.

2.3.3 Wind Hybrid

Wind power represents one of the most widespread and commercially viable renewable energy generation technologies, gaining significant levels of deployment across both the developing and industrialised world. Most of the wind energy deployment is grid connected. Due to supply variations it is less suited to off-grid stand alone generation. However, when considered part of a hybrid system, alongside diesel, biomass or solar generation, wind turbines can be economically appealing. Decreasing capital costs as well as government incentives strengthen the viability of wind-hybrid systems. However difficulties in siting of turbines, combined with often undocumented local wind-speed variations, make effective deployment time and information intensive, reducing its suitability even in hybrid-configuration for small-scale applications.

Wind-hybrid systems are currently in limited operation at a handful of DDG sites across India. Whilst the wind resource is generally poor in many parts of India, Hansen and Bower estimate a potential for around 45GW across 13 states (Hansen and Bower 2003).

They show wind-hybrid systems to be viable for decentralised generation where average wind speeds exceed 4.75m/s. The cost estimates are highly sensitive to scale, load factor, wind resource and choice of back-up/supplementing generation. Diesel and increasingly biomass gasification technology are chosen to supplement wind power, with per kWh cost estimates ranging from between Rs.7/kWh and Rs.10/kWh; our fieldwork puts the estimated cost per unit around Rs8/kWh.

2.3.4 Solar Photovoltaic

The Indian climatic conditions are highly suited to solar photovoltaic (PV) technology; India enjoys between 250-300 sunny days per year, translating to between 4-7kwh/m^2 (compared to an average of 2.7kwh/m^2 in UK and Germany). With capital costs of between $3,000/kw and $6,000/kw (Hansen and Bower 2003)[9], solar PV and thermal technologies are very expensive, making them only suitable for small highly dispersed loads or for remote locations. Solar Home Systems (SHS) and small solar panel systems have been used in such niche applications especially in projects that requiring small loads of 20-100W. SHS do not have sufficient capacity to serve small rural industries and groups of villages with 50-100kw demand profiles. However, SHS and solar lanterns have been successful in southern India and are becoming more widely available in northern parts. The Ministry of New and Renewable Energy (MNRE) under its PV programme has distributed around 610,000 systems, totalling around 20MW of capacity. This includes solar lanterns, home lighting systems, street lighting systems, water pumping systems, and an aggregate capacity of about 1.2 MW of stand-alone power plants.

[9] http://129.3.20.41/eps/othr/papers/0401/0401001.pdf

For community scale solar power plants, Chakrabarti and Chakrabarti (2002) put the cost of delivering electricity for Indian conditions at Sagar Island (Sunderbans, West Bengal) to be between Rs. 26-34/kWh[10]. Similarly, energy delivered from solar lanterns and SHS is estimated to typically lie between Rs.20/kwh and Rs.30/kWh. Our fieldwork puts the estimated cost per unit between Rs.14/kWh and Rs.25/kWh.

2.4 Comparison of the economic characteristics of different electricity supply options

Renewables struggle to compete in generation cost terms at subsidized tariff rates for grid electrification (Banerjee 2006; Nouni et al. 2007). However, where full cost of energy delivery is taken into account for serving rural areas with grid power, renewables are often cost competitive. As noted previously, the cost of grid extension increases the cost of electricity supply by approximately Rs1/kWh/km.. Banerjee (2006) and Deshmukh and Bilokar (2006) find that biomass gasification technologies are the least-cost electrification option (versus diesel or grid extension) at a distance from the existing grid- potentially as little as 3km.

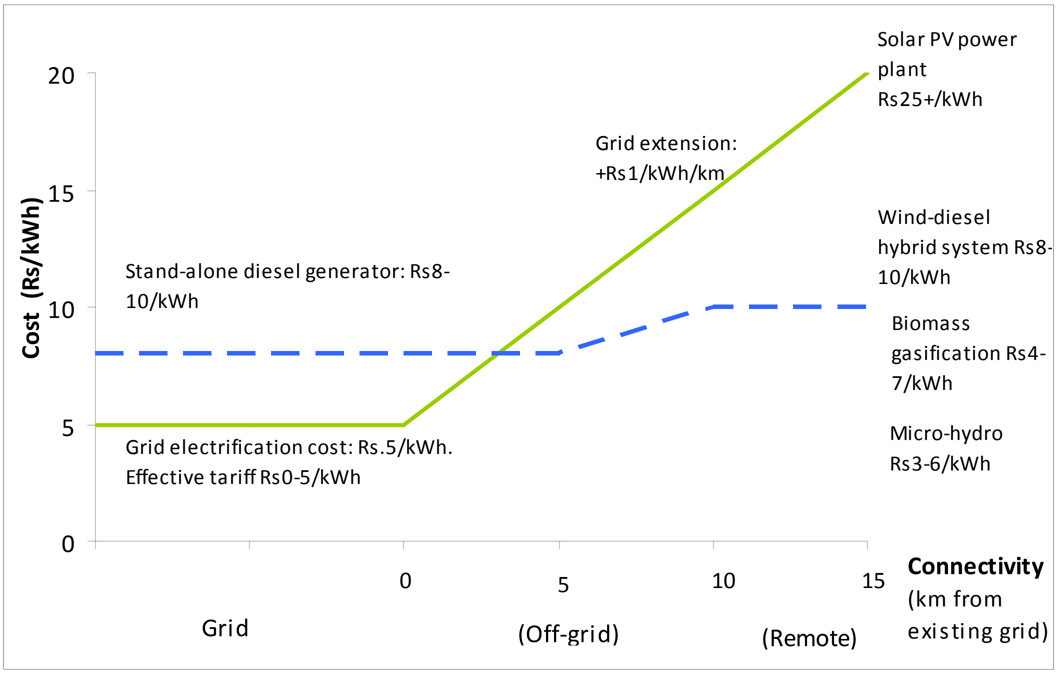

Figure 5 - Cost comparison of renewable and conventional electrification technologies

[10] For an estimated annual output of 1750 kWh from a SPV power plant of 1 kW_p capacity

Figure 6 depicts the approximate economic viability curve of non-conventional electrification options, taking into account the cost of conventional electricity supply options. Where technologies lie below this curve, they are capable of delivering cheaper electricity (in cost Rs/kWh terms) than conventional rural electrification options (grid extension or diesel generators). The curve takes into account basic costs of supply from the grid plus costs of grid extension and T&D losses calculated by various studies. As we are interested in the comparative costs of electrification options, we do not represent the increased willingness to pay for reliable electricity supplies, nor the price of energy delivered, hence we exclude the effect of grid tariff cross-subsidies.

2.4.1 Costs as a function of load factor/usage

Whilst distance from the existing grid is a key determinant of DDG technology competitiveness, their comparative strengths depend critically on the load factor. Several studies have estimated the levelised cost of energy from different biomass plants (Tripathi et al. 1997; Ghosh et al. 2002; Kishore et al. 2004; Banerjee 2006; Deshmukh and Bilolikar 2006; Nouni et al. 2007). The load factor proves to be decisive for making biomass gasification technology attractive. When compared to diesel generation, biomass costs are favourable at higher load factors, whereas diesel is preferred for load factors of roughly 0.35 or less, although cost estimates can vary. Our own case studies support the finding that high plant load factor (PLF) is critical to viability of renewable DDG and as such we argue ownership structures and management that ensures maximization of PLF is desirable. Similarly for micro-hydro power, capacity utilisation levels are important factors in determining per unit cost and lifetime viability with PLF exceeding 30% registering positive NPV according to Nouni (2005).

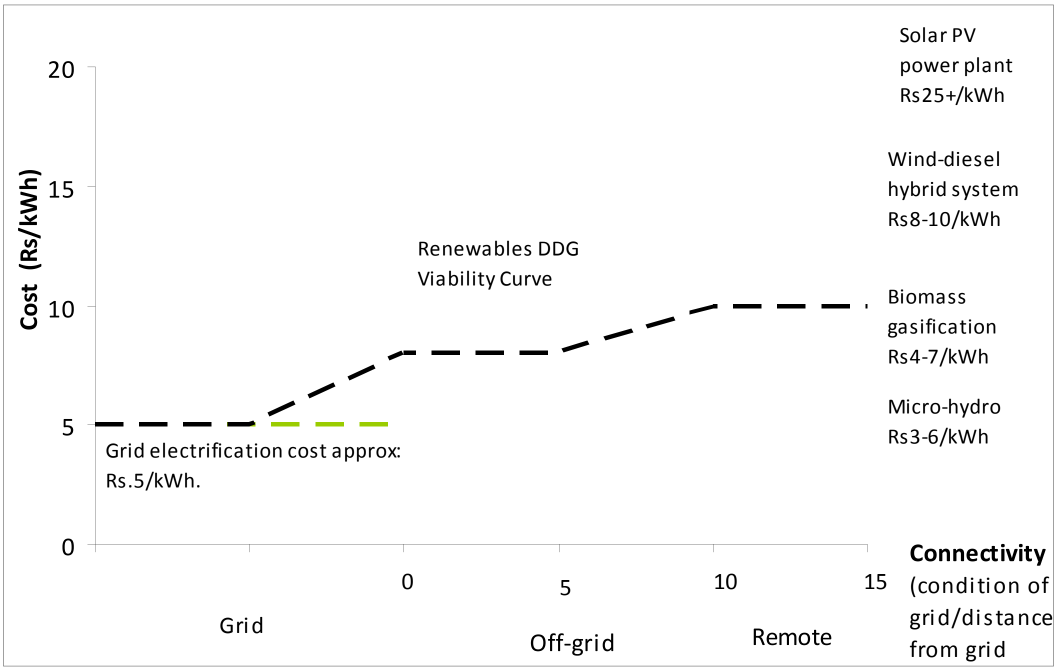

Figure 6 - Viability of decentralised energy technologies based on Rs/kWh levelised cost compared to conventional electrification alternatives

Under the current subsidy regime, grid extension is fully subsidised to all but the most remote areas (RGGVY 2006). The criteria upon which SEBs identify these 'remote' villages is largely based on physical constraints such as hard-to-reach locations, rather than an optimization of the economically appropriate mix between grid and off-grid solutions. In these 'notified' regions it is the responsibility of the MNRE's state nodal agencies to implement renewable energy projects in order to meet central government targets. Investment costs for renewable energy electrification is subsidised at 90% of benchmark costs.

Figure 6 illustrates that for off-grid applications, small-hydro and biomass gasification represent the potentially lowest costs options compared to diesel generator or grid extension. Whilst solar PV and wind hybrid systems incur higher capital costs, their minimal fuel costs make them attractive where hydro or biomass resource availability is limited. The viability of renewable energy technology, relative to conventional rural electrification options increase with rising distance from the existing grid.

Most notably at the rural level, small hydro and biomass gasifier projects, compare favourably with the full costs of grid supply and grid extension. The limited number of successful projects reflects the significant challenges that exist beyond cost competitiveness of DDG renewable energy technologies.

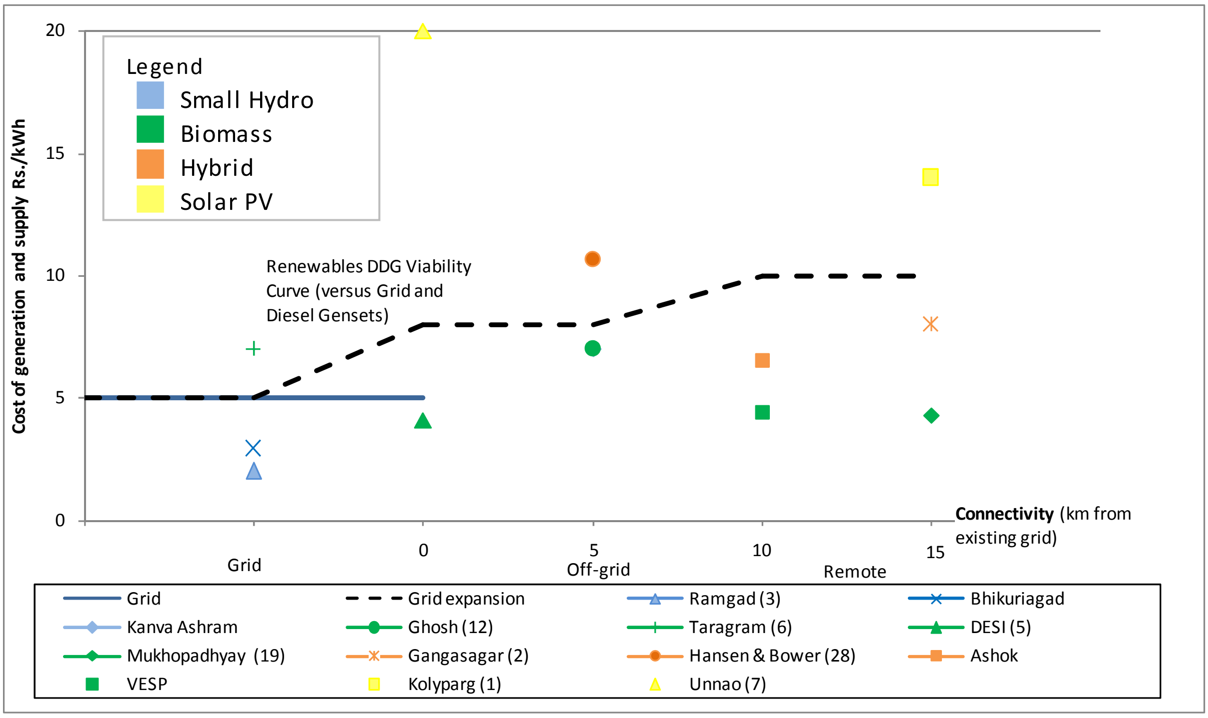

Figure 7 - Cost per kWh (Rs.) from various renewable energy projects
Sources: (Fieldwork, (Chakrabarti and Chakrabarti 2002; Hansen and Bower 2003; Ghosh et al. 2004; Mukhopadhyay 2004; UREDA 2006; Ashok 2007)

3 Barriers: Initial, Organisational, and Structural

Even where demand exists and economically viable DDG options exist based on renewable energy, projects failed and success of pilot projects was rarely replicated. This section identifies and categorises the relevant barriers.

Existing literature has explores technological, financial and broader institutional barriers to small scale renewable technology dissemination. It has less often focused on the role of organisational structures that determine ownership, management, local participation and conflict with the prevailing regulatory environment.

We assess which organisational structure is better suitable to overcome different types of barriers. The analysis is based on seven detailed case studies, reports from further 10 examples of Indian DDG project.

We divide the barriers encountered into: initial barriers, organisational barriers and structural barriers.

The majority of the projects surveyed represent pilot or early implementation initiatives and as such encountered a range of challenges we might characterise as **initial barriers**. These barriers, although significant and potentially critical, represent problems that can be overcome by organisational learning, capacity building or simply by redesign of subsequent project strategies.

Organisational barriers are often problems that have been overcome in early projects, but learning alone will not eliminate them. By the nature of project implementation, first movers may possess the right combination of individuals, organisational capacity and other leadership traits that mitigate the effect of the potential challenges. Subsequent large scale replication, whilst continuing to face these same challenges, has to be able to succeed even without exceptionally strong local leadership and find organisational structures that are less dependent on exceptional individuals to take local or regional leadership.

Structural barriers take the form of those challenges faced by projects that arise from fundamental problems in the regulatory and institutional environment. Examples include unfavourable licensing constraints or problematic tax and subsidy regimes. These barriers will likely continue to pose a threat to project replication unless concrete steps are taken to reduce or remove them through various regulatory or policy actions.

In Table 2, we highlight the strategies deployed by different projects to address a variety of barriers. These barriers are generally overcome in the projects assessed, with strong leadership of individuals that allows for ad hoc solutions. This does however require that any replication has access to experts with experience and similar leadership, thus limiting the scope for large scale replication. However some examples of good practice emerge. The shaded boxes represent a first-best situation, whereby barriers would be tackled through structural or organisational adjustments allowing replication of successful projects and less reliance on ad hoc solutions using individual leadership.

Solutions/ Barriers	**Leadership strategies**	**Organisational approaches**	**Structural changes**	**Not applicable**
Initial Barriers				

• Project risks	5, 6, 9, 17	8		1,2,3,4, 7,10
• Technology choice	1, 2, 3,4,5,6		8	7, 10
• Site selection	1,2,3,4, 5, 6,9, 10			7, 8
Organisational barriers				
• Local partners	1, 2, 3*, 4, 17, 10	5*, 6, 9		7, 8
• Adequate load factor	1,2, 3,4, 17	5, 6*		7, 8, 9, 10
• Training and technical support	7, 17, 10	5*, 6, 9		
• Fuel supply	17	5*, 6		1,2,3,4,7, 8,9, 10
• Organisational capacity	5,6, 10	8, 9		1,2,3,4,7, 17
Structural/Institutional barriers				
• Regulatory	5,6	1,2,3,4,8, 17	10	7,9
• Legislative (distribution licensing)	5,6	1,2,4, 17	3*	7, 8,9, 10
• Cost barriers	6	5, 9, 10	8	1,2,3,4,7, 17
• Viability/ cost recovery		5, 7,8, 9, 10		17

Table 2 - Barriers and strategies for successful DDG projects

Notes: *indicates examples of good practice in overcoming this specific barrier. See discussion for more details.

3.1 Initial Barriers faced

The most significant initial barrier is the appropriate technology choice. Where organisations have had limited experience with project implementation, or are using new technologies, equipment failures, resource availability problems or other critical technology issues may threaten the longer-term sustainability of the project. Few implementing organisations have yet demonstrated effective methods for handling technology risk, short of simply avoiding locations that are not suitable for their favoured technology. Where state nodal agencies of MNRE have been charged with remote rural electrification, they typically revert to solar lanterns The experience of independent organisations such as DESI Power suggests that a learning process is often involved in finding the correct strategies for technology choice and implementation. The ongoing success of Bahabari (case study #5) and the addition 100 Empower village projects come after a decade of experimentation and pilot phase initiatives. Future replication can build on experience gained during past mistakes and successful practice that has emerged in response.

In addition, establishing village power plants is associated with significant financial and organisational risks. Unproven technology, unpredictable local conditions and uncertainty about the capacity of the organisation to deliver, all contribute to the risk of failure. Such project risks can be managed effectively by replicating successful approaches and learning from failures. Increasingly organisations are moving beyond pilot phase programmes with effective strategies in place. For initial projects, financing can represent the single largest barrier to entry. High capital costs of DDG projects exclude many smaller NGOs from considering such initiatives and government subsidies are often hard to access. Where financing is available, it is sometimes restrictive. One example is the Village Energy Security Programme which has subsidies available for biomass gasifiers. Outside organisations have been invited to participate in implementation on condition that they utilise 75kw units.

3.2 Organisational Barriers

As highlighted in section 3, plant load factor plays a critical role in determining economic viability of DDG technologies. The load factor is largely dependent on organisational approaches to distribution and supply ensuring adequate load and where relevant bio-fuel supply for the system. Where organisational approaches lack the incentive to increase or maximise load, by adding additional customers, the viability of the project may be threatened. Where measures are taken to help communities increase load through income generating activity or acquiring modern appliances, the project may succeed with increased benefit for local people. Cooperatives and self-help groups may be suitable local bodies to work in partnership with implementing agents to ensure engagement by local households and businesses, whilst also highlighting the opportunities created by a reliable electricity supply.

Local cooperatives, NGOs, Village Energy Committees and Panchayats can help ensure the reliable collection of bills and timely repairs and maintenance. Whereas past programmes implemented by outside organisations without such local participation often saw subsequent disuse and petty disputes emerging, the increasingly community oriented approach to ownership and management has helped circumvent these issues. The Ramgad (3) case study demonstrates how effective community cooperation can help establish reliable bill collection, thus ensuring the long term viability of the project (see Appendix for more details). Local individuals or groups are well positioned to conduct routine maintenance and operation, whilst local ownership helps ensure the incentives to use the generation capacity efficiently.

Typically government projects are able to avoid the regulatory challenges that can constrain non-government organisations; however such top-down approaches can incur organisational and participatory challenges of their own, with regards localised management and community participation. Limited organisational capacity to engage with local people combined with retained ownership that offers few incentives for cooperation of local people can contribute to both under-utilisation and disuse of power plants (1 & 2). Although government projects do not face the same hard budget constraints as other projects, low plant load factor threatens long term viability of such projects. Working alongside a local NGO, Panchayat, cooperative or self help group can help establish sufficient demand for power to thus ensure sufficient PLF for viable plant operation (4 and 5). The Orcha case study (6) demonstrates how small scale rural industry can be utilised to ensure day long demand for electricity.

Adequate technical support is essential to ensure long term viability of DDG projects. This can be located at distance, such as the nearest town or city; however successful projects, such as at Bahabari in Bihar (5), have demonstrated the effectiveness and sustainability of training of local people to operate, service and repair power systems. It reduces the dependence on outside expertise and allows independent projects who can pass on training and experience for other DDG plants. This is turn can facilitate more rapid project replication with minimal ongoing outside support. Such scaling up can be further enhanced through clustering of projects, providing some second tier support in nearby towns.

Reliable resource availability or fuel supply can be critical for success of DDG projects. Local knowledge of seasonal variation or farming patterns can be utilised to identify future problems. For biomass gasification, successful projects, such as in Bahabari, Bihar (5), have demonstrated effective energy plantations utilising village waste land. The addition of a cash crop into the community can also help offset the risk associated with other food crops for market, providing a stable price for gasifier fuels such as Daicha, Ipomoea, rice husk and other crop residuals. Establishing effective fuel supply or drawing up fuels supply agreements with the local community requires leadership or experience. Successful projects have demonstrated how reliable fuel supply can be ensured however lessons must be learnt from previous mistakes. Caution should be exercised with regards proximity of neighbouring biomass projects and upward pressure on food crop prices, both of which can be avoided with utilisation of waste land and dedicated plantations.

Organisational barriers can prove as severe as those initial barriers encountered by projects. Where DDG systems fail to implement effective management and participation structures, otherwise economically attractive projects can fail. Such barriers can and are being overcome. They typically require organisational leadership in the first instance, but lessons from previous experiences can be internalised to form best practice approaches in subsequent replications.

3.3 Structural Barriers

Whilst pilot projects have demonstrated the potential contribution from DDG renewable technologies, large scale deployment is limited by numerous structural barriers. Tax, subsidy and regulatory regimes can be used to accelerate effective rural electrification; however their effect at present remains a constraining one. State actors retain a monopoly on generous central subsidies, whilst non-state actors struggle to secure financing. Credit constraints exist under a risk-averse commercial banking sector and are reinforced by a lack of demonstrated medium term successes that could build confidence and capacity for lending. Whilst several international support mechanisms such as the UNFCC Clean Development Mechanism have begun to support small-scale non-governmental projects, the transactions costs associated with applications make individual submissions prohibitive. Those organisations with the capacity to bundle many small projects together (such as the DESI EmPower 100 projects totalling 5.15MW, CDM Ref# 00001187) are beginning to experience success in this area.

The prevailing Indian approach to rural electrification remains highly centralised and a target-driven supply push strategy; this can impede the contribution from non-governmental groups, local bodies and the private sector. Where support does exist, incentives and financial grants are often misused or misdirected hindering implementing organisations or constraining technology choice[11]. Subsidies that are currently tied to implementation rather than project performance have resulted in limited viability and sustainability of many projects.

[11] The most recent example is perhaps the Village Energy Security Programme. MNRE financing has been made available to electrify remote villages using biomass gasification; whilst MNRE took bids from non-government organisations such as DESI Power, their inflexible stipulation regarding the scale of generation unit (75kw) prevented DESI from applying- they consider this scale inadequate for sustainable operation (Sharan, 2007, personal communication)

Many programmes report restricted access to commercial credit or short repayment periods on commercial loans. These conditions have limited the ability for organisations to replicate the successes of subsidised government initiatives. Despite this, the market for renewable energy technologies is well-established in India, although largely oriented toward non-rural applications.

Whilst government reports have recognised the potential role for DDG in meeting India's electrification challenges, their recommendations (Gokak Committee 2003) and even policy provisions (Electricity Act 2003) have failed to see changes at the state level. There continue to exist severe regulatory barriers to rural generation and distribution; existing legislation lacks clarity and open to alternative interpretation and rent-seeking with significant bureaucratic delays and barriers (corruption, coop licensing).

Although the Electricity Act of 2003 provides for licence-free generation in rural areas, the situation is ambiguous in off-grid locations, making it hard for independent power producers (IPP) to distribute electricity legally. In response to these legislative restrictions on their distribution permissions, implementing organisations have adopted a variety of approaches. DESI Power (5) has been forced to adopt a single-buyer model for distribution. Under this approach distribution is conducted by the cooperative amongst its members and buys all power itself from the power plant; for household electrification DESI have to operate through an agent who is a cooperative member and cannot supply directly to non-members[12]. Currently the process for obtaining permission to act as an IPP is sufficiently lengthy and bureaucratic to dissuade DESI from seeking full distribution licences. Licence-exemption is possible for remote 'notified' areas, but these remain largely the domain of MNRE and its state nodal agencies, where state agencies implement projects, obtaining permissions is typically straightforward (e.g. 1 and 2)[13].

[12] Household electrification takes place indirectly through the battery charging enterprise and the proposed sale of per bulb based lighting service on a mini-grid operated by a cooperative entrepreneur.

[13] Rural electrification policy states that under conditions laid down in combination with the Electricity Act 2003, those areas that have been notified as rural for purposes for Section 14 of the E-Act (grant of licence conditions), stand-alone systems shall be permitted to operate licence free. Indeed, under point 8.5 of the Rural Electrification Policy, a "person exempted under the eighth proviso to Section 14 from licensing would be free from the licensing obligations". As stated in Section 13[13] (referring to person's exempted from Section 14) of the E-Act, in accordance with the national policy on rural electrification, local authorities, Panchayats, users' associations , cooperative societies, NGOs and franchises, shall be exempted from licensing. As stated in the rural electrification policy, such licence exemption is extended to stand-alone systems, provided they conform to necessary stipulated safety and technical standards (section 8.5).

Few states have acted on this federal legislation making the position of rural IPPs ambiguous with regards distribution permissions. State electricity board's (SEB) determination to protect rural distribution areas (even where the grid does not yet exist) has prevented outside organisations from proceeding with household electrification from DDG. The Planning Commission 'Integrated Energy Policy' report recommended that all states move to reduce these barriers to rural distributed generation and supply (GoI 2006). However such recommendations are not new (Gokak Committee 2003) and progress in this area has been slow.

Regulatory issues create a critical constraint on effective replication of DDG renewable energy projects; this is highlighted by the Renewable Energy and Energy Efficiency Partnership (REEEP) initiative prizes for renewable energy. Their prize giving programme receives a disproportionate number of applications for regulatory assistance rather than financial support, echoing the concerns within implementation organisations (Vipradas 2007). This reflects the difficulties experienced widely across India- whilst financing may be challenging, it often remains a secondary barrier to projects. Opening up rural distribution in the manner laid down by the Electricity Act 2003 and the subsequent National Electricity Policy, would go some way to alleviating these constraints and allowing for innovative approaches to rural electrification. Concerns persist however with regards the political will for SEBs with distribution monopolies to grant small IPPs the right to wheel power (Hansen and Bower 2003).

Structural barriers are perhaps the largest and most problematic of barriers faced by DDG projects. The scale of the challenges exceeds the capacity of most organisations to bring about any change. Reforms at the structural level seem to be required.

4 Organisational experiences from case studies: Ownership, Participation and Governance.

Organisational approaches, including ownership, governance, management incentives and community participation represent features that both lie within the control of implementation organisations and frequently determine outcomes of implementation projects. Our case studies reflect the wider experiences of early implementation experiences; those projects that can align incentives between the implementing agency, plant operators and end-users, can be economically viable whilst delivering quality electricity to the community.

Indeed, past experience suggests that at the local level, project challenges are often organisational or institutional rather than economic. Willingness to pay exists in rural communities; however effective delivery of electricity often requires generation equipment on a scale that exceeds the community's ability to pay upfront. This in turn is determined less by technological constraints, but rather strategic decisions made by implementing organisations.

We characterise the typical approaches to rural DDG using renewables for four organisational approaches. Whilst these four do not exhaust observable models, they draw out the important distinctions with regards management incentives and level of community ownership and participation; features our paper considers critical to successful replication of projects. As shown in Figure 8 the models differ in their approach to ownership, generation, distribution and community participation. We discuss their details with regard to our seven case studies (for more details see Appendix). Table 3 highlights the typical effects of the differing organisational models with regards barriers to project success and replication.

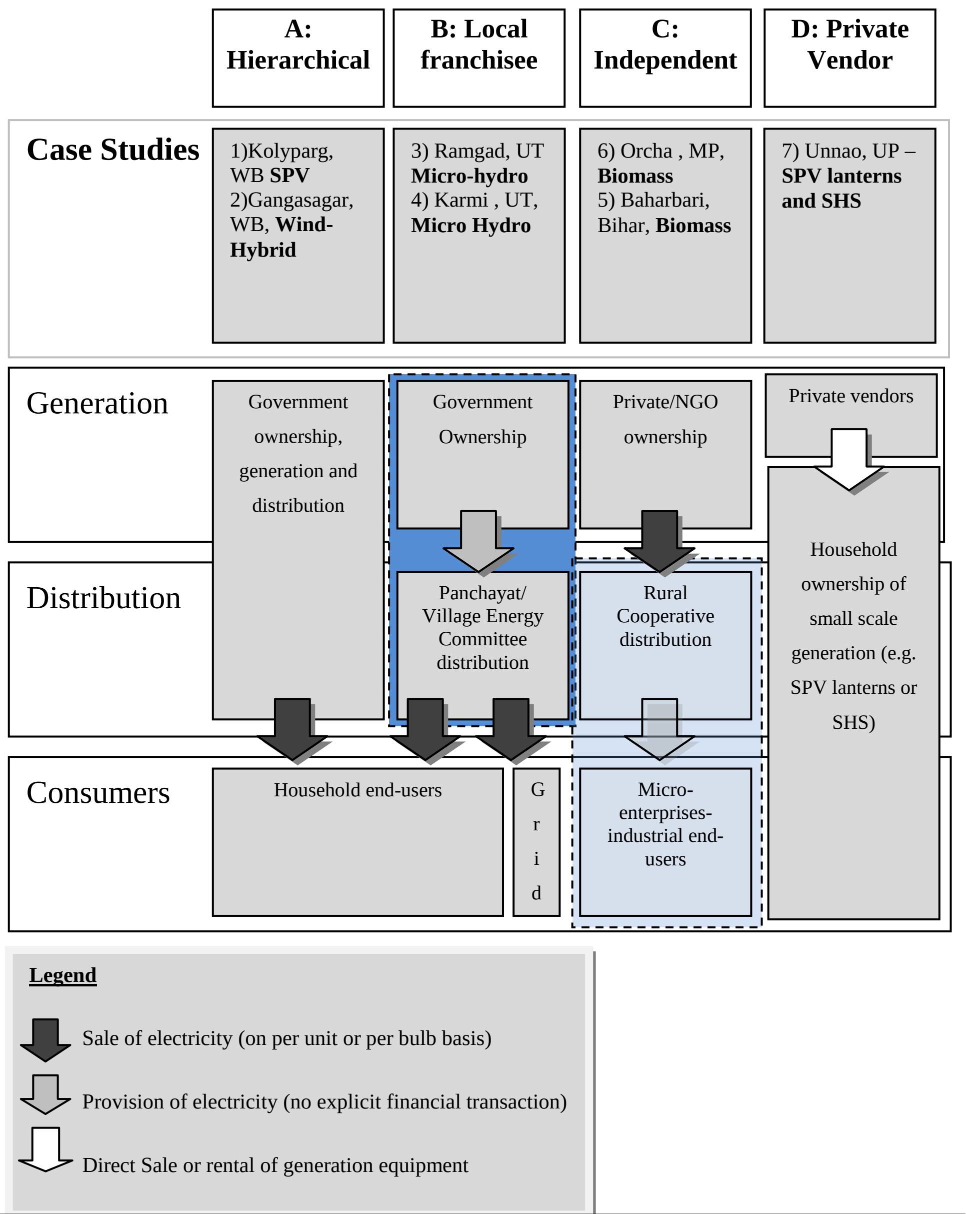

Figure 8 - Organisational models for rural electricity services from renewables

Successful implementation of our case study projects can be better understood by the organisational model it broadly conforms to. Four of the projects surveyed were government funded, initiated and owned (A and B). Under 'A', a hierarchical approach to implementation, (1 Kolyparg and 2 Gangasagar) the project was operated by local cooperative and panchayat members employed on behalf of the state government agency. Project risks were borne by state and central government bodies, whilst implementation costs and ongoing expenses were backed by government finances. Sustainability was not contingent on effective revenue collection and consequently this soft budget constraint did not incentivise efficient utilisation of the generation asset.

Organisational Model B (3 Ramgad and 4 Karmi) the operation, maintenance and distribution responsibilities were decentralised into the hands of a local village energy committee (VEC), with support from the state government. Here franchisee-type control by the community meant better capacity utilisation combined with effective leadership and technical support at the government level. This avoided some of the technical and training problems encountered by local or independent groups acting alone. However, where projects were overseen by external government agents, even where they participated in local cooperative management the efficient operation of the system was reduced. Where VECs or other local groups had decision making power over metering, distribution expansion, additional connections and tariff charges, projects have often been successful (Gokak Committee 2003). Introduction of metering in particular has ensured better voltage stability and higher user satisfaction, whilst also allowing most households to reduce their bills.

The independent or locally owned and operates approach (Model C) encompasses initiatives increasingly observed in the private and non-governmental sector. An implementing agency or partnership of external actors engages with the local community through a cooperative, self-help group or Panchayat committee. They build and operate a decentralised electricity system. In the case of Bahabari (5) and Taragram (6), the power plant is operated by local persons employed by the implementing organisation (DESI Power). Ownership is divided between the implementing agency and the cooperative. Bill collection, connecting new customers and determining plant operation is carried out by the local cooperative. This model is often limited to commercial and industrial consumers rather than households, given regulatory restrictions in state-controlled distribution areas. Cooperative managed projects with autonomy from external actors display incentive to ‘load growth’. As local groups are more responsive to community distribution needs it can ensure more rapid growth in connection than with comparable government run projects (Gokak Committee 2003). In addition where the implementing agency has some investment in the project (financial or some ongoing involvement), it may have correct incentives for providing maintenance, ongoing technical assistance and even future capital expenditure or expansion. This contrasts with supply-push or target-driven approaches that may exist under alternative configurations.

Model D is based upon the vendor approach to rural dissemination of renewable and other energy technologies. This approach is typically the domain of the private sector or non-government actors, though in India we observe state government participation. Under this organisational model, the vendor typically provides individual scale technologies, such as solar lanterns or solar water pumps, to individual households or small businesses; hence there is no subsequent generation and distribution system; our Unnao case study (7) is characteristic of this approach. This approach avoids the need to generation and distribution licences, hence avoiding the regulatory challenges faced by DDG power-plants. Instead this approach is often limited to partial electrification solutions and can incur high upfront costs borne by the individual end-user.

Model #	A	B	C	D
Structure /Issues	Hierarchical (Government)	Franchisee (Gov and local)	Independent (NGO, private and local)	Vendor-End-user relationship
Organisational				
Incentive to forge effective local partnerships	N	Y	Y	N
Incentive to grid extension	N	Maybe	Y	N
Incentive to customer-base expansion/ maximise PLF	N	Y	Y	Y
Incentive to introduce metering	N	Y	Y	n/a
Incentive to ensure adequate technical support	Maybe	Y	Y	N
Incentive for effective fuel supply arrangements	Maybe	Y	Y	N
Structural				
Able to gain access to licensing/ exemption preference	Y	Y	N	n/a
Able to gain access to central government subsidy	Y	Y	N	N*

Table 3 – Characteristics of different organisational models and their approach to barriers faced

Note: *excluding government Askay Urja shops.

5 Conclusions

Rural electricity access in India is currently inadequate for needs of the rural population, and there is observed and revealed willingness to pay for better electricity supply. The Indian government is pursuing large scale initiatives towards greater access mainly through grid expansion.

The prospects for rural electricity needs to be met by conventional approaches may be limited. Indeed from an economic perspective, non-conventional forms of rural electrification may least-cost, particularly where villages are some distance from the existing grid. Our paper argues that renewable energy DDG projects, if widely replicated, can ease the burden on both electricity supply shortfalls (by serving rural areas and subsequently feeding back into the grid), and reduce the urgency of costly grid extension. In addition, by securing high bill payment rates, locally operated projects can ensure better cost recovery than equivalent grid distribution.

These solutions have however been constrained in India by a combination of state-controlled electricity, a culture of non-payment, subsidised conventional energy sources and distorted support for renewable energy technology programmes. Thus DDG renewable energy projects or otherwise innovative approaches to rural electrification can often find themselves 'crowded out'. In addition we find that the regulatory environment imposes constraints, in particular licence restrictions on rural electricity generation and distribution.

Looking across a range of case studies in literature and fieldwork, we find that leadership and organisational approach to project management and ownership can mitigate some barriers to success. Where projects see local participation in project ownership or franchisee roles, the incentives for efficient use of the system are better assigned. Partnerships between local groups and outside agents can overcome technical and financing constraints whilst meeting the localised needs of a community.

While individual leadership can compensate for adverse situations, we argue that a large scale rollout of rural electrification requires an alignment of economic incentives and institutional structures to implement, operate, and maintain the project. The correct combination of financial support mechanisms and adjustments in the regulatory framework could allow innovative approaches to rural electrification to thrive alongside the centralised grid expansion approach.

6 Appendix: Case Studies

In order to better understand what determines project success, we take a more detailed assessment of seven case studies. These sites were visited between January and March 2007. Interviews with stakeholders and members of the local community as well as surveys of end-users were conducted.

Case Study	Technology	Connection type	Hours service	Average household bill	Cost of Supply (Rs./kWh)	Effective tariff (Rs./kWh)	Connections	PLF
1. Kolyparg	Solar	Fixed	5-6	100	14	8-10	200 (of possible 500)	c.20%
2. Ganga Sagar	Wind-diesel hybrid	Fixed	5-6	120	8	6-7	680 (800 soon)	
3. Ramgad	Small-hydro	Metered	24	34	3.08	2	372	60%
4. Karmi	Small-hydro	Fixed	24	55	7	5	225	15-50%
5. Bahabari	Biomass gasification	Metered/Co operative	24	-	5-6	7.5	6 micro-enterprises	c.50%
6. Taragram	Biomass gasification	Metered/Co operative	24	-	8-14	6	8 micro-enterprises	c.40%
7. Hasanganj, Unnao	Solar PV	Individual	Up to 4	-	-	-	Households and small businesses	-

Table 4 - Case study details

As we saw in Figure 7 the economic viability of each of the case studies can be viewed by the relative degree of connectedness to the grid. Projects such as the Kolyparg Solar PV (1) power plant and Ganga Sagar Wind-Diesel Hybrid (2) fall above area of project viability. Whilst these projects are able to operate effectively, serving over 200 and 680 households respectively, they both received 100% government capital subsidy for construction. Subsequent tariff collection revenue is used to cover ongoing maintenance and operation costs only. Other renewable technologies, as well as diesel generators would represent less costly alternatives; however these technologies were chosen as pilot projects for demonstration.

In contrast Uttaranchal government projects such as the Ramgad (3) and Karmi (4) small-hydro power plants represent relatively cost-effective technology choices. Although they both received substantial government grants (100% and 90% of total capital costs respectively), their generation costs of Rs.3.08/kWh and around Rs.7/kWh compare favourably with other off-grid electrification options. Combined with effective bill collection and sufficient demand, these projects could be commercially viable. According to the director of UREDA, Arun Tyagi, local participation in these projects has been crucial. Indeed he argues that "without ownership- at least partial ownership- then the community has insufficient incentive to cooperate" (Tyagi, 2007, interview). Indeed, UREDA now stipulate that the community must arrange for both free land provision and the establishment of the Village Energy Committee, as pre-requisites for any state support.

The turnaround of Ramgad from a failing project to a key revenue earner to both the VEC and UREDA was determined by two key innovations. The introduction of metered billing transformed the power supply; where it had previously been overused in peak periods, leading to poor voltage quality and dissatisfaction amongst customers, now it is carefully controlled by users, allowing an additional wave of household connections taking advantage of the new surplus capacity[14]. In addition, the community and UREDA negotiated a buyback arrangement with the Uttaranchal Electricity Regulatory Commission, whereby they could connect the plant to the encroaching grid network (now only several km from Ramgad). During periods of low local demand, the plant can sell back to the grid at a rate of Rs.1.64 per kWh, deriving additional revenue for both the VEC and UREDA (25% and 75% respectively). This provision has now been extended for other projects in the state following the success of the Ramgad example.

The success of the Ramgad project in delivery affordable and quality power to households has prompted neighboring villages to call for replication of the project elsewhere. The neighboring communities have now negotiated disconnection for the grid (where power was significantly less expensive) to establish their own VEC-managed micro-hydro system. Here the local community will take advantage of the natural water resource to deliver reliable energy to households- willingness to pay for such power is demonstrably high.

The Karmi project, although unable to connect to g rid for export of power, has had its own successes. As a result of access to electricity, the village and its hamlets have witnessed a major transformation. Television for entertainment / information, drinking water pumping, domestic, street and community lighting, etc. have now become possible. A UNDP initiative is now assisting the VEC to extend the mini-grid to supply income-generating activities. In addition the support will help establish a computer centre for the surrounding communities and in turn ensure day-long demand for the power.The biomass projects of Bahabari (5) and Taragram (6) represent viable (or close to viable) commercialised models of rural

[14] The meters were paid for by households (except BPL where cost was subsidized). The average internal rate of return was about 12%, representing an average bill reduction of Rs15 per month.

electrification. The low fuel costs of biomass, combined with strong local participation, help ensure a reliable fuel supply and effective operation and maintenance. By ensuring local enterprises will utilise the generated power, these projects help ensure the plant load factor is sufficiently high to make the project sustainable. The positive consequence of this is that income generating activities become an integral part of replication of this model of supply. Both biomass projects have followed from a series of pilot projects where lessons were learnt regarding organisational approaches, technological issues and economic sustainability. Setting up a village power plant imposes significant financial and organisational risks. Unproven technology, unpredictable local conditions and uncertainty about the capacity of the organisation to deliver, all contribute to the risk of failure in early implementation projects. Prior to Taragram, DESI experienced failure; notably in Karnataka a plant failed where it was overly dependant on a single power customer in the form of a small scale risk husking factory[15]. Also in Orissa a biomass power plant hoped to replace unreliable grid connected water pumps for farmers in the region, but instead found itself competing with heavily subsidised though privately operated distribution[16]. Both these examples taught DESI the importance of full prior assessment of fuel supply, local conditions and potential demand. In addition it emphasised the need for getting the demand side right, as well as the supply side. DESI's emphasis on multiple micro-enterprises reflects this need for risk mitigation and assurances of high PLF for financial sustainability. These lessons are passed on for subsequent DESI projects, but can also be picked up by other organisations; these lessons have been embedded in the Project Feasibility Report Package commissioned in each village prior to implementation, and DESI MANTRA, which equips project operators and managers with skills and cautionary lessons acquired from past implementation.

Although fuel supply has constrained and undermined previous biomass projects, in Bahabari DESI were able to overcome these challenges. The power plant has created a market for rice husk, a farming by-product and Daicha, an abundant and fast growing weed, commonly found across most of India. Whilst previously the crop was grown only as a nitrogen-fixer, a household fuel and around fields to protect jute crops from cattle, now, with the crop commanding a stable price, many farmers are able to diversify into this crop as an extra source of income. This is especially relevant given the price uncertainty surrounding the

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[15] A seven year drought affecting the entire region soon crippled the factory and hence the power plant, pushing the PLF too low to be economically sustainable.
[16] Orissa electricity sector reforms saw a sudden improvement in distribution under a private franchise, whilst heavy tariff subsidies persisted; DESI soon found itself unable to compete.

regions other major cash crop, jute. There is now enough Daicha grown locally to provide around 50% of the plants fuel requirements[17]. Biomass fuel management proved to be one of the critical issues and challenges of making this project a success.

The private vendors covered in the Unnao case study (7), provide individual scale Solar PV technology as either lanterns or solar home systems. Whilst exhibiting high per unit costs, these technologies are commercially viable and popular amongst more affluent households. The scale of this technology means it avoids any of the operation and distribution complications of community scale power. Individuals with sufficient ability to pay can purchase this technology and operate it with minimal prior knowledge. Technical support is often costly and located at distance from end-users. Our fieldwork observed disuse of equipment due to lack of technical support and maintenance. Solar systems have been purchased to complement unreliable grid connections, or in place of grid supply. In the village of Chandouli Khurd, Hasanganj, although officially grid connected, access to power had been severed by theft of the lines for sale as scrap metal. Although financing support is provided by the state for SPV systems (as in case study 8), bureaucratic and lengthy subsidy delivery mechanism has limited its uptake. Private vendors are successfully filling the gap and also benefiting from poor perceptions of government support mechanisms.

Detailed Case Studies

	Location	Technology	Implementing Org.	Source
1	Kolyparg, Sunderbans, West Bengal-	110kw Solar PV power plant	WBREDA	Fieldwork
2	Ganga Sagar, Sunderbans, West Bengal	500kw Wind-diesel hybrid system	WBREDA	Fieldwork
3	Ramgad, Nainital, Uttaranchal	50kw small-hydro	UREDA	Fieldwork
4	Karmi, Bageshwar, Uttaranchal	50kw small hydro	UREDA/UNDP	Fieldwork and (Nouni et al. 2005)
5	Bahabari, Bihar	50kw biomass gasifier	DESI Power	Fieldwork
6	Orcha, Madhya	biomass gasifier	Taragram/ DESI	Fieldwork

[17] The Daicha sells for Rs.35/kg although must be dried afterwards, leaving only around 40% usable for gasification. The final cost of the fuel is around Rs.1.2-1.5/kg. The remaining 50% is sourced from risk husk briquettes, Ipomia another local weed, commercially available hardwood, and some hand-collected jungle hardwood. Maize core can also be used, creating a new income stream for corn farmers from a previously valueless part of the crop.

7	Pradesh Hasanganj dist., Unnao , Uttar Pradesh	Solar Lanterns and SHS	Power Private vendor: Hi-Tech	Fieldwork
Supplementary Case Studies				
8	NEDA Askay Urja	Solar lanterns and SHS	Government vendor	(NEDA 2007)
9	S3idf	Solar Lanterns and SHS	S3idf	(Personal communication, 2007)
10	Punjab water pumping	Solar Water Pumps	AuroRe	(Personal communication 2007) and (Radulovic 2005)
11	Gosaba (VESP)	Biomass gasifier	(VESP pilot)	(Ghosh et al. 2004),(MNRE 2006)
12	Tumkur (BERI) (VESP)	Biomass gasifier	(VESP pilot)	(MNRE 2006)
13	Odanthurai Panchayat, Tamil Nadu (VESP)	Biomass gasifier	(VESP pilot)	(MNRE 2006)
14	Deodhara, Orissa(VESP)	Biomass gasifier	(VESP pilot)	(MNRE 2006)
15	Korba, Chattishgarh(VESP)	Biomass gasifier	(VESP pilot)	(MNRE 2006)
16	Karnataka	Biomass gasifier	IISc Bangalore	(Ravindranath 2004)
17	Chottomollakhali Island	Biomass gasifier	WBREDA	(Mukhopadhyay 2004)

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