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Viability of husk-based off-grid electricity supply in South Asia

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Abstract

As South Asia is a major producer of rice, this paper analyses the financial viability of rice husk based power generation in South Asia. The paper first presents the business models of Husk Power Systems (HPS) and Decentralised Energy Systems India (DESI), two enterprises that have successfully provided electricity access by generating power using rice husks. It then presents financial analysis of two alternative supply options, namely a small 20kW plant serving some 400 consumers under different demand scenarios, and a 20kW plant serving a rice mill and a rural community of 400 consumers. The paper then explores the viability of a larger 200 kW plant serving a rice mill and a cluster of rural communities. The paper shows that serving low electricity consuming customers alone leads to part capacity utilisation of the electricity generation plant and results in high cost of supply. But the tariff plan based on contracted capacity (Watts) rather than their electric energy use has so far ensured sufficient revenue generation for HPS to sustain its operations. The financial viability improves as some consumers use more electricity but the declining block tariff used to promote such consumption behaviour benefits high consuming customers at the cost of poor consumers. The integration of rice mill demand, particularly during the off-peak period, with a predominant residential peak demand system improves the viability and brings the levelised cost of supply down. Finally, using larger plant sizes to take advantage of economies of scale brings down the cost significantly and can be quite competitive with alternative sources of supply. But the higher investment need and the risks related to monopoly supply of husk from the rice mill, organisational challenges of managing a larger distribution area and plant operation challenges (or risk of failure) can adversely affect the investor interest. Moreover, the regulatory uncertainties in respect of off-grid electrification in general and the coverage of larger geographical areas in particular can hinder business activities in this area.

Keywords: Husk power; financial viability; off-grid electrification.

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1.0 Introduction

Rice is the staple food in many South Asian countries and the region is a major rice producer, contributing about 30% of global rice production (FAO, 2013). Accordingly, rice cultivation and the subsequent processing of rice (i.e. milling) are major economic activities in the rural areas of the region. Rice production process generates considerable amounts of wastes in the form rice straw and rice husks. Although a part of the waste is used as fodder (or in animal food preparation) and in brick kilns, most of it is used as a source of energy, mainly for cooking purposes and for parboiling of rice. However, the conversion efficiency of such applications tends to be very low (below 10% indicated by Kapur et al. 1996) as they rely on primitive systems that burn the residue in simple stoves. Although researchers have considered the potential and commercial viability of improved utilization of the resource for energy purposes, particularly for electricity generation in various contexts (e.g. Kapur et al. 1996, Sookkumnerd et al., 2007 among others), the successful delivery of off-grid electricity by an Indian firm, Husk Power Systems (HPS), has renewed the commercial interest in this waste to electricity conversion. Since its inception in 2007, HPS has installed 80 mini power plants of 20kW to 100 kW size in various Indian villages of Bihar and provided access to electricity to more than 200,000 people. As rice is produced in many parts of South Asia, the lessons from such successful commercial ventures can allow wider application of this waste to electricity technology.

The purpose of this paper is to analyse the business model and techno-economic feasibility of rice husk based electricity generation to understand the basic conditions required for developing a viable husk power business. Moreover, the issue of rice husk-based power in South Asia has not been widely analysed so far. This paper tries to bridge the above gaps. The paper is organized as follows: section 2 presents a review of the HPS business model and DESI Power model; section 3 considers rice-husk based electricity generation for rural applications with and without rice mill demand and checks for the viability of such a system. It then expands the system size to consider the viability of operation at the village cluster (or block) level. Finally some concluding remarks are presented in the last section.

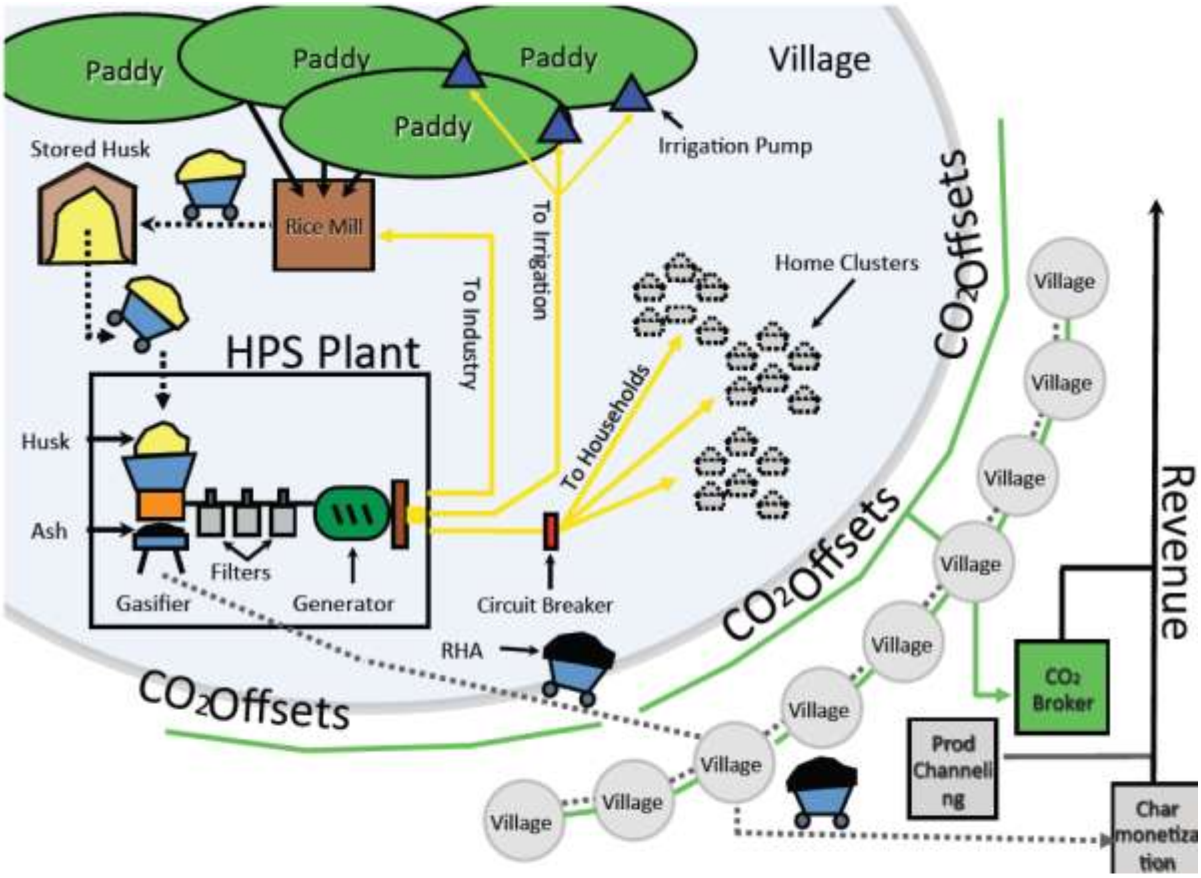
2.0 Husk-based Power Systems

2.1 The HPS model

The Husk Power Systems calls itself a “rural empowerment enterprise” that enables rural development by providing access to electricity while ensuring environment protection, wellbeing of local population and empowerment of local communities. Headquartered in Patna, Bihar, one of the least electrified states in India, the HPS was developed in 2007 by a group of US-educated locals who wanted to combine low cost electricity supply with high quality service to challenge the conventional wisdom that categorises rural electricity supply as a non-viable business. Their search for a viable, small-scale electricity generation option led them to an abundant local resource in the rice-growing region of the country which was hitherto treated as a waste, the husk that can be procured at very low cost for conversion to electricity. However, given the high silica content and silica-cellulose structure of husk, it does not burn easily and causes wear and tear of components coming in contact with it (Kapur et al., 1996). This required customized, proprietary design of gasification technology that can be built and maintained locally without high level technical expertise.

The HPS organized its business synergizing a number of factors that taken together produced the desired outcome (see Fig. 1). The power plant is located in the paddy growing area and more importantly, close to rice mills. In some cases, the company has integrated the rice mill business to ensure business viability (Krithika and Palit, 2013) and to internalize the symbiotic relationship with the power plant. The mill provides a steady supply of husk while the power plant supplies electricity that is reliable and perhaps at a cheaper rate than the alternative sources like diesel generators. The rice mill also provides a base load demand for the power plant and thus helps achieve a better plant utilization rate, which in turn reduces the average cost of supply.

Fig. 1: The HPS business model



Source: Pandey (2011)

Moreover, the HPS has exploited other potential income generation opportunities and created a community support system to ensure better integration with the community. The char obtained from burning the husk is used for incense stick making where local women are employed. It is reported by Sevea (2013) that a 32kW plant produces 6t of incense sticks per year. Silica precipitation is sold for mixing with cement. The HPS has registered a Programme of Activities (PoA) under the Clean Development Mechanism[1] for its electrification activity that aims at providing electricity to non-electrified areas through renewable energy sources using biomass gasification, solar PV systems (both AC and DC) and hybrid systems combining solar PV and biomass gasification. It has estimated that 215 Mt of CO2 emissions will be reduced per year. The PoA will remain active for 28 years (until 2040) and will generate an additional stream of revenue support for the plants. The innovative approach towards revenue generation from various products surely helps in improving its financial position.

[1] See http://cdm.unfccc.int/ProgrammeOfActivities/poa_db/3Z2JFO1WYTASQLUB0GE54XM6IDHKN9/view for details.

In addition, the company has been relying on smart technologies to reduce operating costs and potential revenue losses. The distribution mini grid uses smart features for remote monitoring of the system. The company uses smart meters for billing purposes and the bill collectors use hand-held data recorders to keep record of the collection made from door-to-door bill collection rounds. The use of insulated cables hoisted on bamboo poles reduces the potential for electricity theft while reducing the capital investment required for the distribution network.

The company has also developed a system of direct mutual benefits within the local community where its plants are located. Each plant engages 3 to 4 staff – a plant operator, an electrician, a husk loader and a bill collector, who are taken from local youths and trained by the company. Through this employment scheme, about $400 per month is recycled in the local economy. The rice mills supplying husk to the power plant receive about $25 per ton of husk (or about $2500 per year for a 32kW plant). This is an extra source of income for the mills and some of them share this with their customers by offering a reduced fee for milling. Their waste disposal problem is also taken care of in the process. The incense stick making activity mentioned previously also provides earning opportunities to local women. In addition, in some cases, the bill collector also acts a “travelling salesman” who takes orders from the households, procures them in bulk from the nearby town and delivers to the households for a small commission. This ensures an extra income for the bill collector and the households get their goods at wholesale rates. The HPS claims that in the process it returns more to the local community than that it collects through its electricity bills.

As a consequence, the company has been successful in extending its business to create more than 80 plants in 300 villages to provide electricity to more than 200,000 people. The process for installing a new plant is normally initiated on receipt of a request for such a service from a village or the local authority. The HPS requires an initial deposit from the interested villagers to cover up to three months cost of electricity. This is taken in advance and once a suitable number of consumers have expressed interest, the feasibility of a biomass-based plant is undertaken, which essentially identifies a secure source of fuel supply for the plant. The site selection, plays an important role, is thus driven by economic viability of the business. Critics point out that HPS only operates in niche areas where villages had been receiving diesel-based electricity from local entrepreneurs and the relatively rich consumers in those areas were already paying high charges for their electricity. HPS has thus displaced diesel-based generation by offering electricity at a cheaper rate.

The installation process takes about three months and a local team is set up to operate the system on a daily basis. The supply is given for a fixed period of time, normally for 6-7 hours in the evening using a 3 phase 220V system. Consumers willing to gain access have to pay a connection charge and a flat monthly fee (varying between $2 and $2.5) for the basic level of service (2 CFLs and a mobile charging point, called the 30W package). However, customized packages are also available and consumers with a higher level of consumption benefit from a lower unit rate. A typical plant can serve, depending on the size of the village and willing consumers, up to 4 villages with about 400 consumers within a radius of 1.5 kilometers of the plant. Small commercial enterprises are also supplied with electricity but they generally pay a higher flat rate of $4 to $4.5 per month due to higher demand.

The HPS aims to provide electricity to 10 million people in 10,000 villages by installing 3000 plants by 2017[2]. It has successfully managed to secure funds from a variety of sources in the past, including charitable sources and financial institutions. Although the plants initially followed the Build, Own, Operate and Manage (BOOM) model, the HPS is also employing other modes of operation, namely the Build, Own and Maintain (BOM) and Build and Maintain (BM) lately to grow faster. In the BOOM model, the company looks after the entire chain of the business, which in turn requires a dedicated set of staff that needs growing with new plants. The overhead can be high and the company faces the investment challenge. In the BOM model, the business is partly shared with an entrepreneur who makes a small contribution to capital (about 10%). The HPS maintains the plant and gets a rental fee but the operational aspects are taken care of by the entrepreneur. This reduces some of the management tasks for the HPS, and builds a local network of entrepreneurs but the HPS still faces investment challenge. Moreover, verifying the quality of the local entrepreneur is a challenging task and the speed of replication using this approach remains unclear. The company transfers the ownership after a specified period of time, upon recovering the cost of investment. The Build and Maintain model essentially transforms the HPS into a technology supplier where its role is limited to supply of the equipment for a fee and maintaining the plant through a maintenance contract. The supply business is undertaken by a local entrepreneur and the HPS does not get involved in this activity, although the entrepreneur uses the HPS brand for the supply. Thus the business uses the franchisee model in this case and as long as the franchisee is able to finance the investment and is capable of running it effectively, the business can grow. Although this is a proven approach in many other businesses, in the context of rural electricity supply this has not been widely used. This model requires a strong quality control and standardization of the business operation but it is not clear whether or to what extent this has been developed in HPS.

[2] This is indicated in the company website and in the Programme of Activities Design Document available from the UNFCCC website.

Thus, a rapid replication of activities which is necessary for achieving the company target of electrifying 10 million people by 2017 depends to a large extent how the above business models work. This expansion demands significant energy resources, financial resources, management capabilities, skilled local staff, and commensurate manufacturing capabilities. It is not clear whether the company can ensure all the success factors to ensure a rapid growth. It is reported that the husk price has significantly increased since its plants have started operation. Moreover, the niche areas for its operation where consumers can afford high tariffs may be difficult to find in the future, which can limit the growth prospect. In addition, the plant size will range between 5 kW and 250 kW[3], which fails to exploit the economies of scale and scope and affects the business prospects. Clearly, the replication issue requires further investigation.

2.2 DESI Power

The Decentralised Energy Systems India Private Limited (DESI Power)[4] is a not-for-profit company registered in Delhi and was promoted by Development Alternatives and DASAG Seuzach, a Swiss renewable energy company[5] in 1996. Its aim is to provide affordable and clean decentralized energy to rural communities for rural development by offering an integrated solution. To achieve this objective, DESI Power builds and operates decentralized power plants, creates rural service infrastructure through mini/micro grids, engages with the local community for establishing partnership models and organization structures for community-based management of the services, and provides training for capacity building in rural areas for micro-enterprise and business development. It integrates two core activities, namely rural electricity supply through renewable energy sources and rural development through rural enterprising through the following arrangements:

1) DESI Power Kosi (DPK) for generation and supply of electricity to village consumers;

2) DESI Power Gramudyog (DPG) for village level businesses and enterprises;

3) DESI Mantra for training and capacity building; and

4) Joint Ventures and partnerships for energy service and village enterprises.

[3] Mentioned in the PoA DD indicated above.
[4] This section is based on the following sources: company website at http://www.desipower.com/; company profile at http://www.desipower.com/downloads/DESI-Power-Company-Profile.pdf; and IFMR (2010).
[5] They acquired the licence for the gasifier technology developed by the Indian Institute of Science, Bangalore.

Like HPS, DESI Power has also relied on biomass gasification systems for rural electricity supply and the first plant was set up in 1996 in a village in Madhya Pradesh. It has set up 16 power plants in total by 2012. These power plants have installed capacities ranging between 11 kW and 120 kW, and use biogas and dual fuel systems. Unlike HPS, most of these plants are used for captive or own energy use purposes by small industries that would otherwise rely on diesel generators for their electricity supply to complement unreliable grid supply. Typically, in such cases it acts as a rural power generator and enters into a power purchase agreement with the buyers' organization (which could be an individual entity, a co-operative society or an association of buyers). The company also enters into biomass purchase agreements with local suppliers (who can be villager groups or commercial suppliers). It also assists in the development of micro-enterprises, often linked to agriculture.

However, beyond this niche area of operation, DESI Power has also installed four mini-grid systems to supply electricity to households, micro-enterprises and mobile phone towers. In order to achieve cost effective operation, an anchor demand (like the mobile phone towers) is generally included in the system that offers the base load and increases the financial security for the operation. Until 2012, 10 mobile phone towers have been connected to its existing power plants and it plans to expand this to another 20 towers in two years. Moreover, the emphasis is on generating as much electricity as possible through the inclusion of micro-enterprises. This reduces the average cost of supply that in turn enhances viability of the micro-enterprises. This inter-dependence is exploited to ensure affordable power as well as rural economic development.

In contrast to HPS, which relies on temporary networks, DESI Power has installed underground cables to connect consumers. Although underground cabling is less prone to theft and is more secure, it is a costlier option for the company. DESI Power also offers a range of bill collection options – daily for small households and micro-enterprises and monthly for bigger industrial/ institutional consumers. Although this appears to be working for them at the moment, the daily collection of revenue is a labour intensive, costly option. Moreover, it follows the Build-Operate-Transfer model of operation wherein it hands over the plant to the local community or village groups after a period of operation.

DESI Power follows a pricing policy that mimics the charges imposed by diesel-based electricity suppliers. Normally, for a light point of 60W a fixed rate of 5 rupees per day is charged while micro-enterprises pay a fixed fee for the service. For example, one hour of irrigation water supply from a 5HP pump is charged at 60 rupees (IFMR, 2010).

To take advantage of carbon credits, DESI Power has registered a small-scale project with the CDM Board for establishing 100 biomass gasifier-based decentralized, power plants in the District of Araria in Bihar state (India). The plants will be of 50 kW capacity with the exception of a few 100 kW plants. In total, 5.15 MW of capacity was expected to be installed by 2012 which will reduce about 360 kilo tonnes of CO2 emission over the first ten years of the project[6]. However, it appears that only a few plants have been set up so far, thereby significantly underachieving in terms of emissions reduction and capacity addition targets. Although the company expansion plan maintains that it aims to achieve its 100 village target in 3 to 5 years, and would establish 5 pilot plants in 2013, the outlook remains uncertain.

Apparently, the investment challenge is the most important barrier faced by DESI Power. It estimates that a 100 kW gasifier plant (running on pure biogas) costs $80,000 while the micro-enterprise development requires another $73,000. The cost for a 50 kW plant is indicated as $45,000. The investment requirement for a 20x5 HP diesel generator is just $10,000. This capital cost difference affects the electricity generation cost particularly at low plant utilization factors[7]. In addition, the village co-operatives or associations have limited borrowing capacity and do not have the required deposit or bank guarantees for availing any debt finance. Similarly, in the absence of a bankable agreement with the co-operatives or the buyers, the company cannot finance its projects. This constraint appears to be having a significant effect on the business expansion of the company. In addition, the technical capacity to deliver plants and human capacity to operate and maintain them are also constrained.

3.0 Business case of power generation from husk

The proprietary nature of information does not allow us to analyse the economic and financial dimensions of the rice-husk based power business accurately. Instead, we present a set of cases based on available information and realistic assumptions about electricity generation from husk. The analysis is presented for a plant size of 20 kW for different levels of electricity demand and alternative capital structures. It is then extended to include electricity supply to the rice mill and to explore the possibility of supplying to a wider geographical area using bigger plants.

[6] For details, see the CDM PDD https://cdm.unfccc.int/filestorage/0/B/G/0BGM0Q8ZJQQXFMD2YOWWDGIYOD7CS0/PDD%20revised.pdf?t=dU98bW4zbTYzfDCbexG61m04_xsFtcH5Oply

[7] CDM PDD indicated in footnote 7.

3.1 Providing access to electricity with a 20 kW plant

We assume that a plant generally serves about 400 households, most of whom may be consuming a minimum amount of electricity for lighting and mobile phone charging. We consider alternative scenarios of demand as indicated in Table 1 below.

Table 1: Alternative demand scenarios

Description	***Scenario 1***	***Scenario 2***	***Scenario 3***
Total number of households serviced	400	400	400
% of HH using basic 30W service	100%	90%	85%
% of HH using a medium level of 75W	0%	10%	10%
% of HH using high demand of 250W	0%	0%	5%
Number of commercial units	20	30	30
Demand by commercial units	75W	75W	75W
Hours of service	6	6	6
Days of operation	365	365	365
Electricity demand (kWh per year)	28,908	34,164	43,800
Required Plant utilization (for a 20kW plant)	16.5%	19.5%	25%
Plant loading (for 6 hours of operation)	66%	78%	100%

It can be noticed from Table 1 that in scenario 1, when all 400 households use the basic level of electricity and if there are 20 small commercial units serviced at 75W per unit, the demand can be met by a 20 kW system but the plant runs at part load (66% of its full capacity). In the second scenario where 90% of the households use the basic level of demand, the rest 10% use a moderate level of electricity at 75W per household, and 30 commercial units are considered instead of 20 units, the demand increases marginally but a 20kW plant still can service the load at 78% loading. The third scenario modifies the residential load slightly to ensure a 100% loading of the plant. However, as the plant runs for a fixed period of 6 hours, its overall capacity utilization does not exceed 25%. This is relatively low for a power generating plant.

For the financial analysis of the 20kW generator plant, the following assumptions are made:

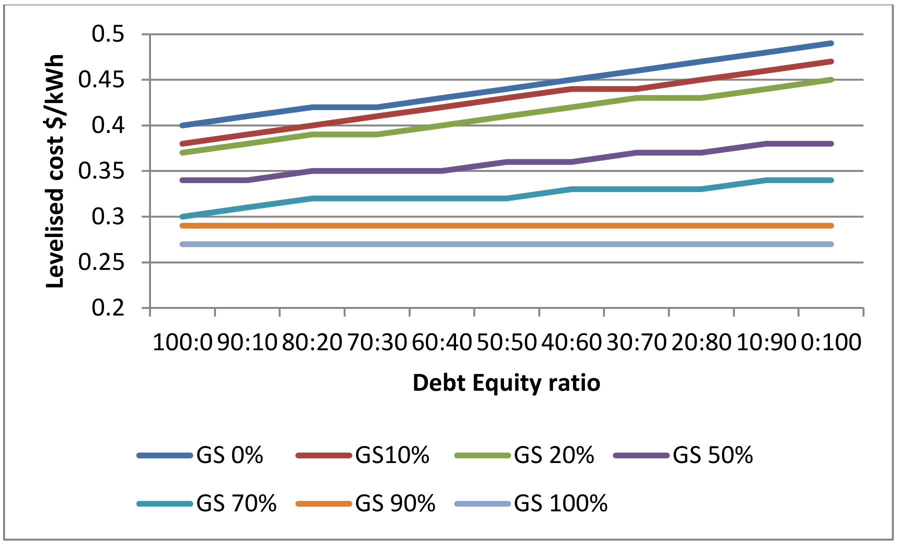
a) The cost per kW of capacity is $1300. This is taken from Sevea (2013). Pandey (2011) suggests a slightly lower value but the above cost appears to be in line with similar plant costs. DESI Power also suggests a lower capital cost of $800/kW but this may be underestimating the capital requirement.
b) The cost of distribution network per kilometer is taken as $2000. This cost can vary depending on the quality of the network, materials used, terrain, and cost of labour. For underground cables, the cost may be higher while for distribution systems using bamboo poles, it may be lower.
c) The monthly operating cost is considered to be about $100 (Sevea, 2013) – or about 4% of the capital cost.
d) Each plant employs four employees with a salary of $100 per month on average, which is close to the monthly salary cost of $380 indicated in Sevea (2013).
e) The plant life is taken as 15 years and the plant operates 6 hours per day, every day of the year.
f) A price of $25/t is used for husk and it is assumed that the fuel price remains unchanged over the project lifetime.
g) The calorific value of husk is taken as 12.6 MJ/kg (Kapur et al., 1997) and the conversion efficiency of gasifier is taken as 20%.
h) The cost of debt is taken at 5.5% while the rate of return on equity is taken as 10%. The weighted average cost of capital is used to determine the discount rate.
i) A straight line depreciation is used after allowing a 10% salvage value for the asset at the end of its life. Where grant capital is used, it is assumed that the grant capital reduces the capital required for investment and the depreciation charge is reduced accordingly. Although the grant capital can be treated differently in accounting terms, the above provides a simple treatment of the grant.
j) It is assumed that the company is not paying any tax and hence the tax benefit arising from debt capital does not apply here.

Considering alternative debt equity combinations and grant capital share, the levelised cost of electricity supply is estimated. For scenario 1, the result of the levelised cost analysis is shown in Fig. 2. As expected, the lowest levelised cost is obtained when the entire capital requirement comes from grants and the cost for this scenario comes to $0.27/kWh. But if no grant is received, the cost of supply that has to be borne by the consumers varies between $0.4/kWh to $0.49/kWh depending on the share of debt and equity. This clearly shows that part load operation of the system is a costly option despite the low capital cost per kW compared to other technologies (such as solar PV or wind). Clearly, both HPS and

DESI Power have realized this and used adequate households and/or micro-enterprises to ensure high plant capacity utilization.

However, the important issue is whether or not a flat rate charge of $2 or $2.5 per month per household can recover the expenses in Scenario 1. As the consumers use only 5.5 kWh per month, their effective tariff varies between $0.36 and $0.46 per kWh depending on $2 and $2.5 monthly charges, which is considerably higher than the prevailing rate for grid-based electricity. Therefore, as long as the levelised cost of electricity supply is below the above tariff, the business becomes viable in this scenario. If the company charges $2.5 per month, even without subsidy it can operate the business profitably as long as the debt – equity ratio is not worse than 50:50. If it charges $2 per month, the company needs at least 50% capital grant subsidy to run the business, unless other sources of income can make up for the loss. As other income tends to be limited in nature, it becomes clear that providing access to poor households with limited demand remains a vulnerable business.

Fig. 2: Levelised cost of electricity supply for scenario 1

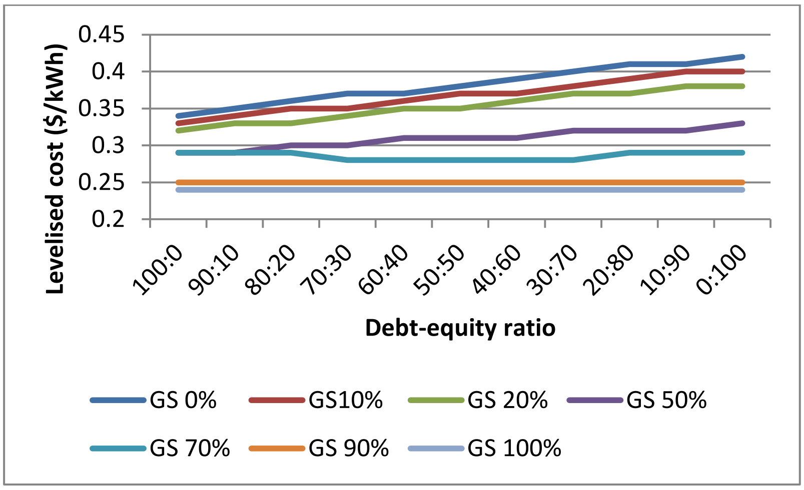


Note: GS – grant share

In scenario 2 as the plant utilization rate improves, the cost of supply reduces to $0.24 per kWh for a capital subsidy of 100% while the cost varies between $0.34 and $0.42 per kWh for no capital subsidy (see Fig. 3). However, although the cost per kWh of electricity reduces, the income would not change if all residential consumers are charged at the flat rate. Consequently, when different consumer categories use different levels of electricity, a single flat rate will not be sufficient to recover the cost. But a higher flat rate for the high-end consumers could generate adequate revenue in this case and those consuming higher quantities will end up paying a lower average rate, due to higher consumption. The tariff per Watt instead of watt-hours is thus a simple but effective way of passing higher charges to poorer consumers in disguise.

In the third scenario, the levelised cost reduces even further due to higher demand. In fact, this scenario, as expected, produces the lowest cost of supply (see Fig. 4). It needs to be mentioned here that the levelised cost of supply still remains quite high compared to the grid-based supply particularly when there is no capital subsidy, which arises due to low efficiency of the system and a comparatively higher capital investment required per kW of capacity. But compared to other renewable energy sources (such as solar PV or wind), the cost of supply is lower. This supports the claim made by HPS that they are in an advantageous position compared to other renewable technologies. However, the tariff for grid-based supply may not be a true comparator given the unreliable and poor quality of supply. Consumers tends to spend considerably higher amounts for alternative sources of supply (e.g. from generator sets). Accordingly, the willingness to pay for a reliable supply is likely to be higher than the tariff for grid supply, particularly for commercial and industrial consumers.

Fig. 3: Levelised cost of supply for scenario 2

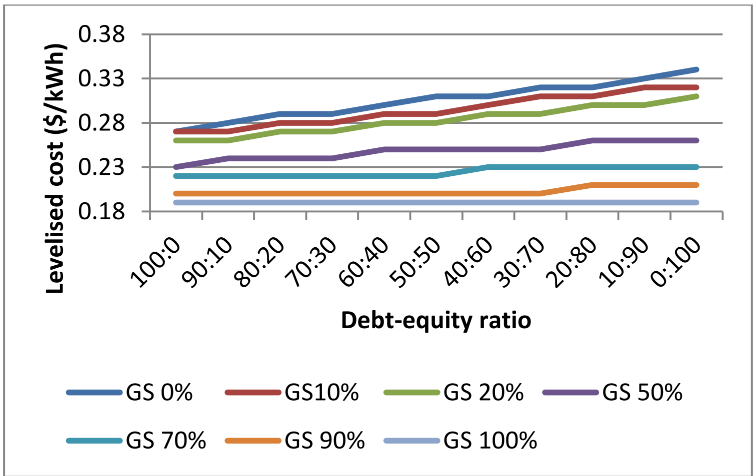


Note: GS – grant share

Once again, a differential tariff will be required to ensure adequate revenue generation. From the company’s perspective, running the plant near its full load will ensure higher profitability and clearly, this will ensure that the operation can be sustained with limited or no financial support. But grant capital surely contributes towards risk mitigation and acts as an incentive for the supplier.

It can be concluded that limited electricity supply for a fixed duration can be effectively provided using the rice-husk based system. The cost-effective operation of the system however requires that the plant is operated near full load by enlisting adequate number of consumers, preferably with some demanding more than just the basic level of supply (30W per household). Although the cost of supply remains higher than the prevailing grid-based supply, the business can be run viably with a suitably designed tariff system. The difference in the approach between HPS and DESI Power can be understood from this analysis. HPS has ensured viability by enlisting adequate number of residential customers whereas DESI Power enlisted the support of micro-enterprises. This avoids reliance on a large number of very small consumers as the business or commercial load tends to be much higher than the basic level of residential demand. However, the cost per kWh incident on the poor tends to be higher than those consuming more in the absence of any cross-subsidy or direct subsidy[8]. Hence any support for additional income generation will surely be beneficial.

Fig. 4: Levelised cost of electricity supply for Scenario 3



Note: GS – grant share

3.2 Providing electricity access to households and supplying electricity to the rice mill

In the previous case, the power plant just procures the husk from one or more rice mills but does not supply electricity to the mill. However, given the poor quality of power supply in

[8] This tends to be true in any electricity system – more so in a privately owned and operated system, but mitigating measures are often used through direct social safety nets and/or subsidised supply schemes.

many places, the possibility of supplying power to the rice mill can also be considered. Clearly, the energy demand for a rice mill will depend on its size, processing activities involved, level of automation, operation time and such factors.

For the purpose of this analysis, the following assumptions are made:

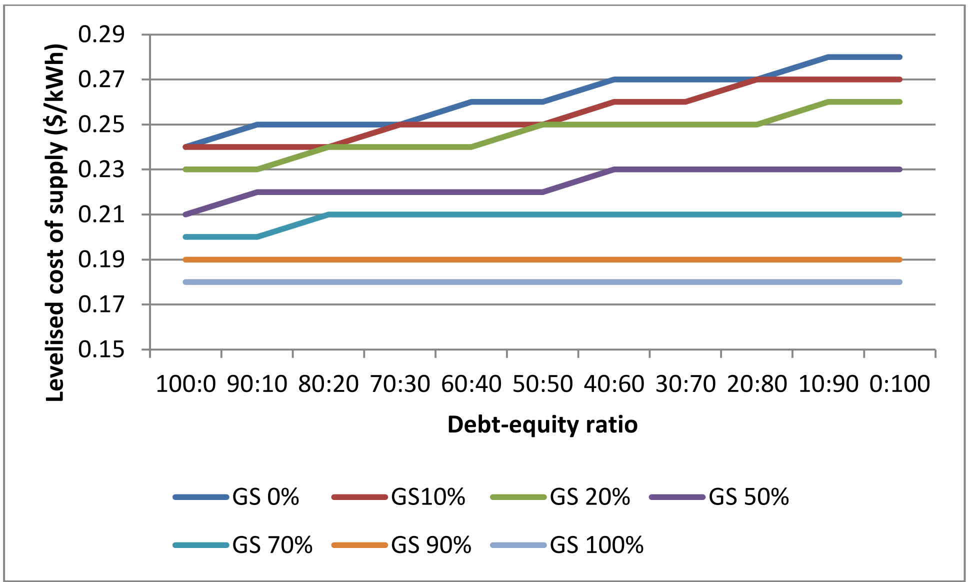
a) The rice mill capacity is chosen in such a way that adequate husk can be sourced from the mill to meet the demand for electricity generation;
b) Small mills in a village or small town location tend to be indigenously made and tend to consume more energy. It is assumed that the electricity consumption requirement per ton of raw rice processed is 43 kWh/ton (Sookumnerd et al., 2007)[9].
c) Rice mills in India can be categorized into two broad groups: small sized ones with less than 1 ton/h processing capacity and bigger mills. Small mills generally operate a single shift of 6-7 hours for about 200 days (i.e. 1200 hours of annual operation) while larger mills run two shifts (between 2400 to 3000 hours of annual operation). In this case, we assume a single shift operation for 1200 hours per year.
d) Husk availability is estimated considering a husk to paddy (or raw rice) ratio of 0.2.
e) It is assumed that the rice mill operates during day time when the residential demand is not serviced. This in effect extends the hours of operation of the power plant. Electricity demand is unlikely to be constant for the entire period of operation. It is likely that the evening load may be higher than the day load. For the sake of simplicity of financial analysis, an equivalent plant loading is used that generates the total amount of electricity required to meet the total demand.
f) Scenario 3 from the previous section is used for electricity demand for non-mill purposes.
g) The power plant operates two shifts of 6 hours and instead of 4 employees uses 6 employees, each receiving a monthly wage of $100. This is logical given that the work for bill collector and the plant technician does not increase proportionately with hours of plant operation.

The rice mill has to be such that it produces enough rice husks in a year to meet the electricity needs of the mill and the village community. Given that the electricity demand corresponding to Scenario 3 is 43,800 kWh, and considering 43kWh electricity required for processing one ton of rice, we find that a rice mill of 0.4t/h capacity operating in a single shift of 6 hours for 200 days in a year will produce sufficient rice husk. The rice mill will require 20,640 kWh of electricity and the power plant needs to produce at least 64,440 kWh per year. The rice mill will process 480 tons of raw rice per year and will produce 96 tons of husks per year. The power plant will require approximately 93 tons of husks for its operation, which can be procured from the rice mill directly.

[9] Depending on the processes used in a rice mill, the energy requirement changes.

Figure 5 presents the levelised cost of supply for the integrated power supply operation to the rice mill and the village community. As can be seen, the cost of supply reduces considerably in this case due to higher plant utilization rate. The lower end prices with capital subsidy will be quite attractive to most consumers. Even otherwise, the cost of supply reduces significantly. Hence, it makes economic sense to extend the supply to the rice mills, particularly when the operation does not coincide with the peak demand. This will benefit the rice mill by reducing its dependence on grid electricity, and providing a reliable supply at a reasonable price. Other consumers also benefit from this integration as the overall cost of supply reduces.

Fig. 5: Levelised cost of electricity supply for integrated operation



Note: GS – grant share

Although rice mills can install power generating stations for own use, such installations do not qualify for government support schemes for rural electricity supply. Moreover, the skill requirement is very different for operating a power plant and electricity distribution business compared to running a rice mill. In organizational terms, it makes better sense to have separate entities dealing with two separate businesses but linked to each other through contracts for fuel supply and electricity supply. Such contractual arrangements are important to ensure risk sharing, bankability of investments and reliability of business operations. The captive power supply model used by DESI Power is a good example.

4.0 From kW-scale to larger power generating plants

India produced about 144 Mt of raw rice (or paddy) in 2010 (FAO, 2013) and has a total rice milling capacity of about 200 Mt per year (NSDC, undated). In addition, Bangladesh produced 50 million tons of paddy in 2010 while Sri Lanka, Nepal and Pakistan produced about 15Mt of paddy in 2010 (FAO, 2013). Thus South Asia produces more than 200 Mt of paddy per year. Rice milling takes place both at the household level (using hand pounding or pedal operated systems) and in rice mills. Generally, a small amount of raw rice is processed at the household level, mostly for own consumption. The processing of raw rice takes two forms: dry hulling which tends to account for a small share of total paddy processing and processing of parboiled rice. Rice milling in the region was a licensed activity for a long time that reserved the activity to small and medium-scale industries. This resulted in the proliferation of small mills throughout the region. However, these mills tend to be inefficient and produce poor quality output (higher percentage of broken rice). Moreover, because many of them fall under the unorganized sector, there is no systematic information about the number, distribution and size of rice mills. However, it is generally believed that the mini mills can process 250-300 kg of paddy per hour, small mills have a capacity of 1 t/h whereas larger, modern mills have capacities ranging from 2t/h to 10t/h. Smaller mills operate a single shift of 6 hours while modern mills operate 2 shifts or even 3 shifts but tend to have a seasonal operation.

Assuming a 2-shift operation of modern rice mills for 200 days per year, and considering that about 30% of the electricity that can be produced from the husk can be used to meet the energy needs of the mill, a simple estimation is made of potential excess electricity and the potential number of consumers that can be served to meet the basic demand of 30W per consumer for 6 hours a day for every day of the year (see table 2). It can be seen that thousands of consumers can be served by such power plants and a large cluster of villages (or blocks) can be considered as the basic unit of electrification. Alternatively, excess electricity from the mills can also be sold to the grid if mills are grid connected or can be sold to a small number of local productive users (e.g. irrigation pumps, flour mills, food storage, etc.). Such larger plants thus open up the possibility of including productive applications of electricity beyond rice mill use, which in turn can catalyse economic activities at the village level. Although agriculture is the main rural activity in South Asia, food processing and other agro-based industrial activities (such as storing and warehousing), play a limited role yet due to lack of infrastructure and reliable electricity supply. While small-scale generating plants can only provide limited supply to households and small commercial consumers, larger plants can act as an agent for rural development.

Table 2: Potential for serving large consumer bases

Mill capacity (t/h)	*Husk production (t/year)*	*Potential Electricity Output (kWh)*	*Mill consumption (kWh)*	*Excess electricity (kWh/year)*	*Number of basic demand consumers that can be served*
2	960	672,000	206,400	465,600	7087
3	1440	1,008,000	309,600	698,400	10630
4	1920	1,344,000	412,800	931,200	14174
5	2400	1,680,000	516,000	1,164,000	17717
6	2880	2,106,000	619,200	1,486,800	22630
8	3840	2,688,000	825,600	1,862,400	28347
10	4800	3,360,000	1,032,000	2,328,000	35434

In terms of cost of supply, two opposing forces are expected to operate. On one hand, the unit cost of generating plant ($/kW) is likely to reduce as the size increases. On the other, the fuel cost, distribution cost and wages would increase. The fuel cost increases proportionately with power generation. The area to be served may increase disproportionately and the extension of low voltage lines over long distances will increase distribution losses and affect power quality. This will require a distribution system at 11kV or higher voltage level and accordingly, the cost will increase. Finally, the staff requirement will increase in proportion with the area being serviced. Billing and collection cost can increase rapidly. Accordingly, the accurate cost estimation is rather difficult in this case.

However, to obtain a rough idea about the economic viability of a larger plant, we consider husk obtained from a 2 ton/h rice mill. This can feed an electricity plant of 200 kW. For the cost calculations, we assume the following:

a) the capital requirement per kW to be $1000 for a 200 kW plant;
b) 25 staff will be employed for generation, distribution and supply management;
c) The distribution system is extended over a distance of 20 kilometres;
d) Other assumptions remain unchanged.[10]

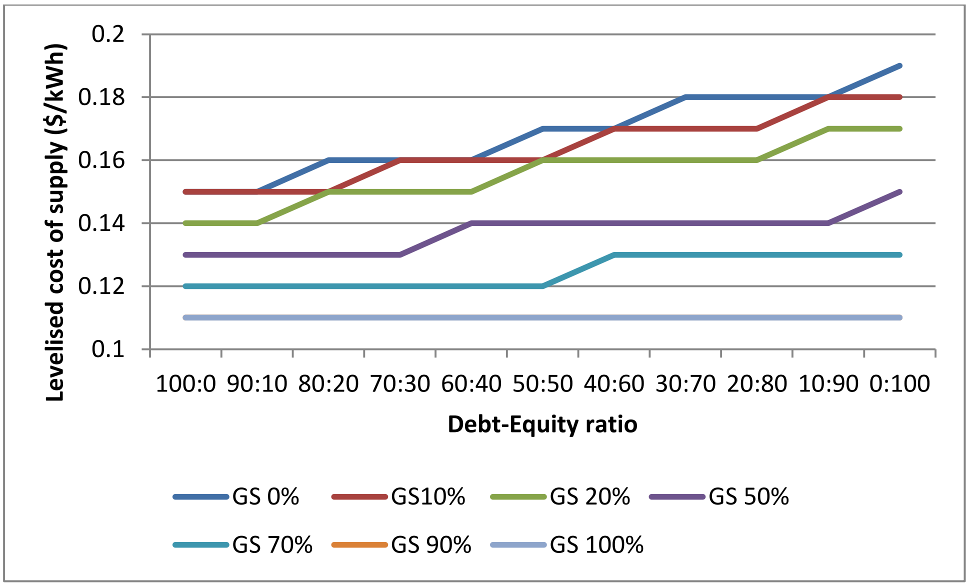
[10] It is possible to consider 24 hour operation of the power plant but in this case, the available rice husk can support a smaller power plant capacity. Moreover, a husk-based plant is unlikely to operate continuously for 24 hours. In this case, a back-up will be required. This can be looked into separately.

The levelised cost of electricity for no subsidy case comes to $0.19/kWh. The cost reduces further with different levels of subsidy (see Fig. 6). The levelised cost in this case is the lowest of all options considered in this study. Clearly, this shows that as long as sufficient number of willing consumers can be enlisted, and the power supply company can manage to run its village cluster level operations, a bigger business can be profitably run. Alternatively, the excess power can be sold to captive users or to the grid at a break-even price of $0.19/kWh to make the venture viable. However, the tariff offered by the utility for buy-back is not as remunerative as this, which hinders financial viability of such power plants.

In addition, such plants will also qualify for carbon credits under the CDM programme. Either, a Programme of Activities can be considered following the example of Husk Power or a bundle of small projects as registered by DESI Power can also be appropriate. Although the carbon credit may not contribute significantly to the revenue stream of the project, it will nonetheless improve the project viability.

Clearly, there are risks involved in any business and a full-scale electricity supply business envisaged above cannot escape them. The dependence on the rice mill for husk is a major risk. As the generating plant size increases, the fuel requirement increases considerably. A 200 kW plant would require about 1000 tons of husks per year for its operation and if the rice mill breaks down or goes bankrupt, the power supply business will also break down. For smaller plants, it may be possible to procure husk from other sources but larger plants will struggle to procure the fuel from other sources. In addition, transportation and storage of husk can be problematic for large plants. The transportation cost of feedstock can easily increase the fuel supply cost and render the electricity supply less cost effective. In addition, due to seasonal availability of husk, power plants may need to store significant volumes of husk to avoid shortage in fuel supply.

Fig. 6: Levelised cost of electricity supply for a 200 kW plant



Similarly, as the plant serves a larger area, any fault with the generating plant will result in a power supply disruption in the entire area. It may be possible to address this by installing two 100 kW plants but this may increase the cost of supply to some extent. In addition, the plant would need regular maintenance on a daily basis to ensure proper cleaning of the gas filters and this makes it difficult to run the system continuously. It is likely that a back-up system will be required to meet the essential demand for a limited period of time. Depending on the fuel or technology used, the back-up system can increase the overall cost of electricity supply.

As the number of small consumers increases, the transaction costs related to retail business increase. A number of customers may not pay on time, thereby creating bad debt problems. To mitigate this, it may be appropriate to find anchor loads that can provide some business stability. DESI Power has been experimenting with mobile phone towers as such anchor loads. Similarly, local agro-based activities can also act as anchor loads. However, the anchor load may also increase business risk depending on its credibility as a reliable customer.

The investment requirement for a plant of 200 kW can easily reach $250,000. This is a substantial investment in a rural location, and companies willing to enter into such businesses will need to muster adequate financial resources and relevant experience. As there is no bankable sales agreement with most of the consumers, project financing of such mini-grids looks unlikely. Securing long-term debt funds from the financial institutions can be a major challenge as many of them require more than 100% guarantee for such loans. In addition, the loan term (period and interest rate) may not be favourable to this type of businesses. Any support from the government and international agencies in facilitating finances through credit facilities, grants and guarantees can be helpful.

A further issue arises due to regulatory uncertainties in the area of off-grid electrification. As indicated in Bhattacharyya and Dow (2013), the supply of electricity through a local off-grid network can be considered to qualify for the conventional utility regulatory supervision due to the possibility of monopolistic exploitation of the consumers, supply quality concerns and potential disputes between the supplier and the consumers. However, in India, the regulatory arrangement is not quite clear – it appears that the Electricity Act of 2003 has given some sort of exemption to certain organisations from the application of licence requirements for rural electricity supply. However, the conditions for such waiver and the roles and responsibilities of parties involved in the activities have neither been clearly specified in the Act nor in the regulations. More importantly, the rural areas covered by off-grid supply still come under the jurisdiction of the utility providing the central grid-based supply. Any decision to extend the grid subsequent to the installation of the off-grid plant can make the off-grid business unviable and stranded. Given the volume of investment involved and non-remunerative rate of grid buy-back of power, the investment can easily loose its alternative use. Thus, the regulatory uncertainty needs urgent consideration.

5. Conclusions

This paper has considered off-grid electrification through electricity generated from rice husk in South Asia. The Husk Power Systems has successfully used rice husks to provide decentralized electricity in rural areas of India and has so far installed 80 plants to electrify 300 villages. The success of the HPS can be traced to their choice of technology that is less capital intensive compared to other renewable energy options, their innovative approaches towards system cost reduction (e.g. using temporary structures made of bamboo poles for distribution network, local manufacturing of gasifiers) and additional income generation (e.g. use of carbon offsets and monetization of byproducts), careful tariff design linked to Watts of demand instead of Watt-hours of energy used and careful siting of plants where about 400 customers are willing to pay for the service. DESI Power on the other hand has placed emphasis on productive use of power and used husk-based systems to displace diesel-based electricity supply to micro-enterprises. It has also used anchor loads (such as supply to mobile telephone towers) to improve the financial viability of the business.

The financial analysis of rice husk-based power generation shows that the levelised cost remains high compared to the supply from the centralized grid when just the basic demand (of 30W) of households is met. This is due to low plant utilization factor but the tariff based on Watts helps generate the required revenue to run the system. As the system utilization improves either due to higher electricity consumption by some or by integration of the supply system to the rice mill, the levelised cost of supply reduces. However, the benefits of such cost reduction are enjoyed by those who consume more when an inverted block tariff system is used. The integration of rice mill's electricity demand brings the costs down considerably due to extended use of the facility during off-peak hours. Such integration can ensure an anchor load and can be beneficial for the electricity supplier. The rice mill on the other hand benefits from a reliable supply at a comparable price and reduces its cost arising out of electricity disruption. While the rice mill can develop a power plant for its own consumption, it is better to allow a specialized, separate entity to deal with the power generation business and develop contractual arrangements for fuel and power supply.

The extension of the analysis to include larger power plants for electricity distribution to a cluster of villages results in the cheapest cost of supply due to realization of economies of scale. The cost of supply in such a case can be very competitive even without any capital grants. This suggests that it makes economic and financial sense for a supply company to extend the business to cover larger areas as long as there are sufficient willing customers and adequate supply of rice husks from rice mills. This also can promote economic activities in rural areas and promote economic development urgently needed to reduce rural poverty. Yet, the regulatory uncertainty, limited access to financial resources and markets, increased complexity of the distribution network (i.e. it may require higher voltage permanent network systems to reduce losses), and higher dependence on a single or limited fuel supply source would have to be carefully considered. Such bigger systems would require careful system design to ensure adequate system reliability, appropriate maintenance and limited line loss in distribution

Being a major rice producing region, South Asia surely has a significant potential of utilizing a major agro-waste to produce electricity for rural supply and rural development. However, to realize the potential the barriers mentioned above need to be addressed. In addition, the potential for using rice straw alongside rice husk can also be considered for power generation. Similarly, the potential for replication of this business in South Asia needs further analysis.

References

Bhattacharyya, SC and SR Dow, 2013, Regulatory Issues Related to Off-grid Electricity Access, Chapter 11, in S Bhattacharyya (ed.) Rural Electrification Through Decentralised Off-grid Systems in Developing Countries, Springer-Verlag, London.

FAO, 2013, Rice Market Monitor, XVI (1), January 2013, Food and Agricultural Organisation of the United Nations, Rome, Italy.

IFMR, 2010, Empowering villages: A comparative Analysis of DESI Power and Husk Power Systems: Small-scale biomass power generators in India, Rural Market Insight Brief, Institute for Financial Management and Research, Chennai, India.

Kapur, T., TC Kandpal and HP Garg, 1996, Electricity generation from rice husk in Indian rice mills: Potential and financial viability, Biomass and Bioenergy, 10 (5-6): 393-403.

Krithika, PR and Palit, D., 2013, Participatory Business Models for Off-grid Electrification, Chapter 8, in S. Bhattacharyya (ed.), Rural Electrification Through Decentralised Off-grid Systems in Developing Countries, Green Energy and Technology, Springer-Verlag, London 2013.

NSDC, undated, Human Resource and Skill Requirements in the Food Processing Sector, National Skill Development Corporation, New Delhi.

Pandey, G., 2011, Rural Electrification Using Biomass – Husk Power Systems, Presentation at the OASYS South Asia Workshop on Decentralised Off-grid Electricity Generation in Developing Countries: Business Models for Off-grid Electricity Supply, TERI University, 6 January, 2011, New Delhi.

Sevea, 2013, Husk Power Systems – Power to Empower, Synergie pour l'Echange et la Valorisation des Entrepreneurs d'Avenir (SEVEA), France.

Sookkumnerd, C., N. Ito and K Kito, 2007, Feasibility of husk-fuelled steam engines as prime mover of grid-connected generators under the Thai very small renewable energy power producer (VSPP) program, J of Cleaner Production, 15: 266-74.

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Disclaimer

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OASYS South Asia project

The Off-grid Access Systems for South Asia (or OASYS South Asia) is a research project funded by the Engineering and Physical Sciences Research Council of UK and the Department for International Development, UK. This research is investigating off-grid electrification in South Asia from a multi-dimensional perspective, considering techno-economic, governance, socio-political and environmental dimensions. A consortium of universities and research institutes led by De Montfort University (originally by University of Dundee until end of August 2012) is carrying out this research. The partner teams include Edinburgh Napier University, University of Manchester, the Energy and Resources Institute (TERI) and TERI University (India).

The project has carried out a detailed review of status of off-grid electrification in the region and around the world. It has also considered the financial challenges, participatory models and governance issues. Based on these, an edited book titled “Rural Electrification through Decentralised Off-grid Systems in Developing Countries” was published in 2013 (Springer-Verlag, UK). As opposed to individual systems for off-grid electrification, such as solar home systems, the research under this project is focusing on enabling income generating activities through electrification and accordingly, investing decentralised mini-grids as a solution. Various local level solutions for the region have been looked into, including husk-based power, micro-hydro, solar PV-based mini-grids and hybrid systems. The project is also carrying out demonstration projects using alternative business models (community-based, private led and local government led) and technologies to develop a better understanding of the challenges. It is also looking at replication and scale-up challenges and options and will provide policy recommendations based on the research.

More details about the project and its outputs can be obtained from www.oasyssouthasia.dmu.ac.uk or by contacting the principal investigator Prof. Subhes Bhattacharyya (subhesb@dmu.ac.uk).

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