CASE

Power from rice husk for rural electrification (Bihar, India)

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Supporting case for Business Model 6	
Location:	Bihar, India
Waste input type:	Primarily rice husk; Currently testing other biomass waste
Value offer:	Electricity to households and small businesses and biochar
Organization type:	Private
Status of organization:	Operational since 2007
Scale of businesses:	Medium
Major partners:	Shell Foundation, Acumen Fund, Bamboo Finance, International Finance Corporation, LGT Philanthropy, CISCO, Ministry of New and Renewable Energy, Government of India, Farmers

Executive summary

Founded in 2008, Husk Power Systems Inc. (HPS) is promoted by first generation entrepreneurs Gyanesh Pandey, Ratnesh Yadav, Manoj Sinha (natives of Bihar, India) and Charles Ransler (USA). It has won several business plan competitions and secured foundation grants in the United States. As a rural empowerment enterprise, HPS has a mission to provide renewable and affordable electricity to rural people in a financially sustainable way. Most of rural Bihar suffers from poor access to modern energy with majority of households relying on either kerosene for lighting or other low-quality energy source, such as candle or batteries. HPS owns, installs, operates and manages decentralized rice husk/biomass gasifier-based 25–100 kW generation and distribution systems to deliver lighting and electrification services to 200–600 households on a "fee for service" basis to households and 5–10 irrigation pump sets and small businesses in rural Bihar. HPS procures rice husk/feedstock at negotiated rates. The consumers prepay a fixed monthly fee, ranging from USD 2–3 to light two fluorescent lamps and one mobile charging station which is at least 30% cheaper than the cost of kerosene and diesel and enables savings of up to USD 50 for each household every year. HPS uses a franchisee-based business model and uses three distinct approaches to deliver electricity services: a) Build-Own-Operate (BOO) b) Build-Own-Maintain (BOM) – operation is managed by a local partner or entrepreneur and c) Build-Maintain (BM) – a local partner/entrepreneur owns and operates the plant. At the time of this assessment, the company had more than 84 plants, enough to provide electricity to over 250,000 people across 300 villages and hamlets and employing 350 people across the state of Bihar.[1]

KEY PERFORMANCE INDICATORS (AS OF 2014)						
Capital investment:	USD 1,300/kW					
Labor:	Full-time: 3; Part-time: 5–10					
O & M cost:	Estimated to be less than USD 0.15 /kWh					
Output:	25–100 kW of electricity					
Potential social and/or environmental impact:	Each unit serves about 200–600 households, 5–10 irrigation pump sets and small businesses; improved energy access and cleaner local environment, reduction in GHG emissions, employment generation					
Financial viability indicators:	Payback period:	6–8 years	Post-tax IRR:	N.A.	Gross margin:	45%

Context and background

Despite significant efforts and resources deployed by the Government of India towards rural electrification, about 480 million citizens residing in about 125,000 villages in India (45% of the total population) do not have access to reliable power. Of those who do, almost all find electricity supply intermittent and unreliable. When grid rationing takes place, villages often receive power only after midnight when "priority" demand from cities and industry is low. This is of little use to rural households and businesses. The Indian government has designated several thousand villages as "economically impossible" to reach via conventional grid. Without electricity, these villagers are forced to live at the whim of natural forces and lack basic communication, education and healthcare infrastructure. Common energy supply options, such as kerosene lanterns or diesel generators, are uneconomical, inefficient and environmentally unfriendly.

The state of Bihar is third largest with 82.9 million population and 12th largest with 94,163 km^2 geographical size in India. Only 52.8% of villages and 6% of households of the state are electrified, leaving about 85% of the population with no access to electricity. Even the villages connected to grid have frequently interrupted poor quality of power supply. However, Bihar is blessed with fertile soil and good rainfall. It has several geographic and climatic advantages to harness renewable energy. The decentralized electricity generation is the possible solution to reduce transmission losses and to provide electricity to densely populated villages with scattered but large number of small-scale commercial activities. The decentralized power generation can make use of readily-available biomass, which is typically transported out of state. Bihar is a part of the rice belt of India, producing about 4.7 million metric tons of rice per year, generating about 1 million tons of rice husk which is underutilized and is a good source for fuel. Each 32 kW gasifier installed by HPS requires approximately 60 kg of rice husk per hour or 15,000 kg rice husk per month assuming eight hours of operation per day. It was in this context that HPS initiated its operations in 2007, using rice husk as fuel to generate electricity to provide safer, better and cleaner lighting solution at an affordable cost to rural households in Bihar.

Market environment

HPS has identified 25,000 villages as feasible sites within India's rice producing area (Bihar and neighbouring states) for its projects. Promotion of the plants is largely by word-of-mouth and also through local press and media, and their benefits are now well known in Bihar. HPS receives several hundred enquiries about installations each year.

While the minimum services offered by HPS to a household is two light connections and one mobile charging point, a small percentage of households in each mini-grid request and obtain additional

supply to power household appliances, such as a fan, television, radio, etc. The cost of services offered by HPS is significantly higher than that of the state utility, but the grid is practically non-existent across Bihar. Even if the grid were to penetrate these areas in future, HPS plants can feed its energy to the grid with minimal additional investment. Also the state of Bihar has numerous private diesel-generator-run electricity providers whose service provision is similar to services offered by HPS. With rising diesel prices, in the long run, it would be difficult for them to compete with HPS.

The residue from gasification is a carbon-rich ash, or biochar, is rich in alkaline components (Ca, Mg and K) high in silica, and this may contribute to the neutralization of soil acidity and to a decrease in the solubility of the phytotoxic metals such as aluminium in the soils. Biochar can bind and release nutrients (N, P, K and Ca) and could reduce nutrient leaching to the subsoil. It also retains water in soils with low plant-available water and helps draining flood-prone areas. It can be used to improve the fertility of the soil for growing rice or vegetables. *Biochar also has appreciable carbon sequestration value. These properties are measurable and verifiable in a characterization scheme, or in a carbon emission offset protocol.*

Macro-economic environment

India has been promoting biomass gasifier technologies in its rural areas to utilize surplus biomass resources such as rice husk, crop stalks, small wood chips and other agro-residues. The goal was to produce electricity for villages with power plants of up to 2 MW capacities. During 2011, India installed 25 rice husk-based gasifier systems for distributed power generation in 70 remote villages of Bihar.

The Electricity Act 2003 de-licenses power generation completely and the techno-economic clearance from the Central Electricity Authority (CEA) has been done away with for any power plant, except for hydroelectric power stations above a certain amount of capital investment. The Independent Power Producers (IPP) can sell electricity to any licensees or where allowed by the state regulatory commissions to consumers directly. However, the act provides for imposition of a surcharge by the regulatory body to compensate for some loss in cross-subsidy revenue to the SEBs due to this direct sale of electricity by generators to the consumers. As per the Act, 10% of the power provided by suppliers and distributors to the consumers has to be generated using renewable and non-conventional sources of energy so that the energy is reliable.

The Government of India launched the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) – Programme for creation of rural electricity infrastructure and household electrification in April 2005 for providing access to electricity to rural households. As on 30.04.2012, against the targeted coverage of 1.10 lakh[2] un-electrified or de-electrified village and release of free electricity connections to 2.30 crore[3] Below Poverty Line (BPL) households, electrification works in 1.05 lakh un-electrified or de-electrified villages have been completed and 1.95 crore free electricity connections to BPL households have been released under RGGVY. Under RGGVY, electrification of un-electrified BPL households is provided free electricity service connection. Infrastructures created under RGGVY can be used for providing connections to Above Poverty Line (APL) by respective distribution utilities by prescribed connection charges, and no subsidy is available for this purpose. On one side, the program improves access to energy, while on the other side, it creates further problems for India's electricity sector. In addition to RGGVY, there are subsidies provided by the Ministry of New and Renewable Energy for renewable energy projects such as biomass gasification.

Business model

The business offers multiple value propositions, and the primary value proposition is to provide high-quality electricity service to household and businesses in rural areas that have either no access

to electricity or it is unreliable (Figure 73). The enterprise uses rice husk from rice farmers and rice mills to generate electricity using biomass gasification technology. The enterprise partners with local community and the government. HPS uses a franchisee-based business model through three distinct approaches to deliver electricity services: a) Build-Own-Operate-Maintain (BOOM), b) Build-Own-Maintain (BOM) – operation is managed by a local partner or entrepreneur and c) Build-Maintain (BM) – a local partner/entrepreneur owns and operates the plant.

Value chain and position

The rice husk (or hull) is the outermost layer of the paddy grain that is separated from the rice grains during the milling process. Around 20% of paddy weight is husk which is largely considered a waste product with no commercial value and is often burned or dumped in the rivers or on landfills. As per estimates, about 1.8 billion kg of rice husk are produced every year in Bihar. The franchise partners procures rice husk from local rice farmers. HPS is dependent upon farmers and rice mills for rice husks and to mitigate any potential shortfall, HPS reaches out to more farmers/rice mills (Figure 74).

The cost of rice husk is approximately USD 0.02–0.025/kg. HPS faced significant challenge in procuring rice husk for the gasifier for a suitable price. At one point suppliers – rice mill operators and farmers – started demanding higher price. HPS countered this by establishing its own rice mills, where it offered milling services at no cost in return for the rice husk. This forced the suppliers to enter long-term contracts at a fixed price. HPS is exploring other input feed stocks such as wheat husk, mustard stems, corn cobs, wood chips, etc. HPS business suffers from substitutes and new entrants.

HPS's value proposition lies in making the plants so simple to operate and maintain that high-school-educated people from the village can be trained to manage and run them. Tars and other particulates in the producer gas can damage equipment, in particular engines, so a key factor for successful operation is the rigorous HPS maintenance program. HPS also requires high safety standards and detailed monitoring. It is through this attention to maintenance and monitoring that HPS plants achieve over 93% availability.

Electricity fees start at USD 2.2 per month for a basic connection of two lights and one mobile phone charging. "Pay for use" service approach is being followed by HPS for raising revenue and supplying electricity at a low cost. Low-cost prepaid meters have been installed that can efficiently regulate the flow of low-watt electricity and reduce electricity theft to less than 5%. One month's deposit is required when a customer signs the supply contract with HPS. The local HPS collector goes from house to house to collect the fee each month in advance and checks that everything is working well. All complaints are logged and followed up. Under the terms of the contract, HPS agrees to provide service for at least 27 days every month and pro-rates the fees if this level is not met. However, average provision is now over 28 days per month (93% availability). All customers are trained in safe use of electricity. The biochar, the residual waste from the plant, is used in making incense sticks, rubber and manure. About 1,200 women have been employed in incense-stick manufacturing.

HPS has set up a first-of-its-kind 'Husk Power University'. The university will serve as a training facility where new recruits and existing staff will be trained in large engine repair and maintenance, facility management and continuous improvement processes. It will help in job creation for Bihar youths, particularly those living in rural areas, and also in enhancing health and safety conditions at the existing operational sites located in rural areas. HPS has developed significant public support in the local community since it not only provides access to electricity but also creates local employment opportunities either through direct employment in the plant or in the making of incense sticks.

FIGURE 73. HUSK POWER SYSTEMS BUSINESS MODEL CANVAS

KEY PARTNERS

- Local community and businesses
- Entrepreneur
- Government of India, donors and private investors to fund the enterprise
- Rice farmers and rice mills in Bihar

KEY ACTIVITIES

- Obtaining the rice husk
- Biomass gasification for electricity generation
- Electricity distribution
- Bill collection
- Community mobilization
- Maintenance of existing plants
- Franchise management
- Selling of biochar

KEY RESOURCES

- Developed technology
- Rice husk/ agro-waste
- Partnerships
- Local staff
- Mini-grid

VALUE PROPOSITIONS

- Residents and businesses of rural Bihar get higher quality electricity services for a fair price
- Opportunity to start a business based on proven technology in partnership with a successful company
- Additional income source for households making incense stick from biochar
- Carbon offset

CUSTOMER RELATIONSHIPS

- Direct interaction with the users
- Direct relationship with franchisee, technology transfer, maintenance services, and continuous support
- Direct

CHANNELS

- Mini-grid maintained by HPS
- Direct contact to reach potential franchisee
- Biochar from gasification process of rice husk is given away by HPS to businesses making incense stick

CUSTOMER SEGMENTS

- Rural residents and businesses in Bihar
- Local entrepreneurs
- Incense stick makers
- Carbon trading companies

COST STRUCTURE

- Investment cost (land, building, machines)
- Operational cost (input cost, labor, maintenance cost)
- Debt repay and equity

REVENUE STREAMS

- Sale of electricity
- Subsidies
- Build – Maintenance fee from franchise
- Sale of biochar for incense stick making
- Sale of CO2 offset

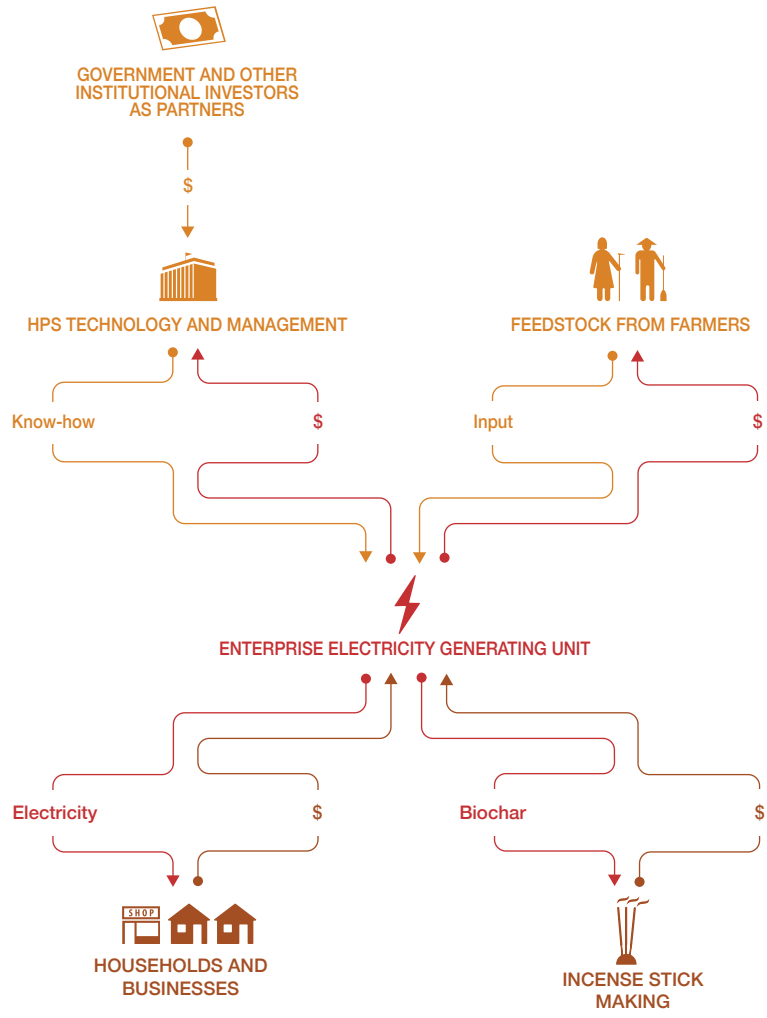
SOCIAL & ENVIRONMENTAL COSTS

- Potential laborers' health and safety risk if no proper safety measures are present in the electricity generation unit
- Potential safety issues on handling of biochar

SOCIAL & ENVIRONMENTAL BENEFITS

- Improved quality of electricity results in increased income/productivity opportunities (economic development) and healthier environment through reduction on kerosene usage for lighting
- Provides employment and create livelihood
- Reduction is greenhouse gas emissions

FIGURE 74. HUSK POWER SYSTEMS VALUE CHAIN



Institutional environment

The Ministry of New and Renewable Energy (MNRE) is promoting multi-faceted biomass-gasifier-based power plants for producing electricity using locally-available biomass resources such as wood chips, rice husk, cotton stalks and other agro-residues in rural areas. The biomass-gasifier programs of MNRE supports distributed or off-grid power for rural areas, captive power generation applications in rice mills and other industries as well as tail-end grid-connected power projects up to 2 MW capacities. The program envisages implementation of such projects with involvement of Independent Power Producers (IPPs), Energy Service Companies (ESCOs), industries, cooperatives, Panchayats, SHGs, NGOs, manufacturers or entrepreneurs, industries, promoters, developers, etc. Bihar Renewable Energy Development Agency (BREDA) promotes all renewable energy projects and programs in the state. The ministry is implementing a program for providing financial support for electrification of those

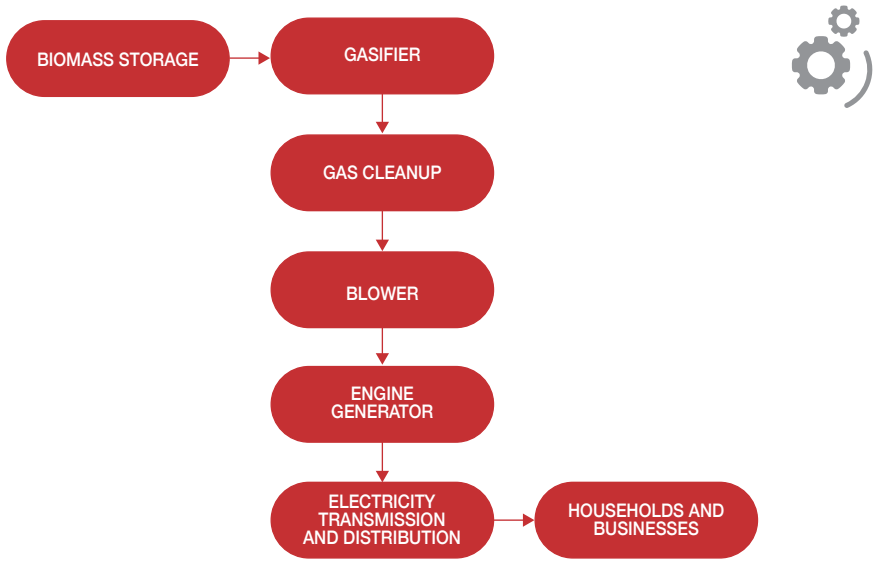
remote un-electrified Census villages and un-electrified hamlets of electrified Census villages where grid extension is either not feasible or not cost-effective and not covered under RGGVY.

About 150 MW equivalent biomass gasifier systems have been set up for grid and off-grid projects. More than 300 rice mills and other industries are using gasifier systems for meeting their captive power and thermal applications. In addition, about 70 biomass gasifier systems are providing electricity to more than 230 villages in the country. A system of cross-subsidization is practiced based on the principle of 'the consumer's ability to pay'. In general, the industrial and commercial consumers subsidize the domestic and agricultural consumers. Furthermore, government giveaways such as free electricity for farmers, partly to curry political favour, have depleted the cash reserves of state-run electricity-distribution system. This has financially crippled the distribution network and its purchasing power to meet the demand in the absence of subsidy reimbursement from state governments.https://en.wikipedia.org/wiki/Electricity_sector_in_India - cite_note-140 This situation has been worsened by state government departments that do not pay their electricity bills.

Technology and processes

Biomass gasification is thermochemical conversion of biomass into a combustible gas mixture (producer gas) through a partial combustion route with air supply restricted to less than that theoretically required for full combustion. The HPS solution consists of a gasifier, filters and a gas engine connected to a generator (Figure 75). The gasifier is a down-draft type, where the sack loads of rice husk is loaded from the top into the hopper every 30–45 minutes through to the combustion chamber. Air is drawn through the top, and partial combustion occurs under a restricted supply of oxygen to give energy-rich producer gas, which comprises of hydrogen, carbon monoxide and methane. The residual char drops to the bottom of the chamber and is subsequently removed. The gas that is generated is water-cooled and cleaned through a series of filters made of char or rice husk and finally a cloth filter to eliminate particulate matter. The clean combustible gas is available for power generation in

FIGURE 75. TECHNOLOGY PROCESS OF HUSK POWER SUPPLY



diesel-gen-set or 100% producer gas engines, which generates electricity at 240 V, single phase. Thus, electricity generated is distributed at the same voltage level through a single-phase-insulated cable system mounted on bamboo poles (for reduced costs). The distribution network is extended to a maximum of 2 km to keep the losses and voltage drops to acceptable levels. HPS has also developed low-cost prepaid meters (less than USD 8) that allow for better control and reduced theft.

The basic connection provides a household with two 15-W compact fluorescent lights and mobile-phone charging throughout the period each day the plant runs (up to eight hours in the evening). Sometimes, poorer households share a basic connection and get one light each. If a household or business wants to pay more for a higher-power connection, then this can be provided. A fuse blows if the customer attempts to use more than their agreed power.

The key advantages of HPS solution is that the various components of the system have been locally manufactured/adapted, rugged and durable and are simple to operate and maintain. HPS is still conducting research on the technology front to deal with the undesirable tar content of rice husk to explore other potential feedstock and alternative applications and uses of the resultant biochar. HPS has also recently implemented low-cost remote monitoring of its plants for better control and management of the same and shifted to solar - biomass hybrid mini-grids for 24/7 power supply (this information was not available when analyzing the case).

Funding and financial outlook

The capital cost (inclusive of installation) of each plant is less than USD 1,300/kW, and the operational cost is estimated to be less than USD 0.15/kWh. The gross margin at the plant level is expected to be around 45%, but sale of carbon off-sets and sale of biochar towards incense making is expected to each add 10% to the total revenues of a plant. Social enterprises, such as HPS, which step in to address the electricity gap in rural areas of India, are typically funded by a combination of grant and equity, with some support from the government by way of subsidy. HPS received significant grant support to the tune of approximately USD 2 million over four separate tranches from its strategic partner, Shell Foundation which contributed towards the early R&D costs, subsidized a portion of the costs of its high-profile management team, helped ramp up the rate of deployment and attract additional financing. In addition, HPS also raised funding (equity investment) of USD 1.65 million in 2009–2010 from Acumen Fund, Bamboo Finance, LGT Venture Philanthropy, Draper Fisher Jurvetson, CISCO and the International Finance Corporation. HPS also receives a government subsidy of approximately USD 7,100 for each plant from MNRE and the Government of India. Alstom Foundation recently announced a EUR 90,000 grant to upgrade 65 existing power plants by retro-fitting gasifiers using dry cleaning and cooling systems at the plants. The immediate positive impact of implementing the system would be dramatic reduction in water usage – by almost 80% – and also reduce operational cost considerably.

Socio-economic, health and environmental impact

Husk Power Systems has made a tremendous impact in the lives of rural people by supplying affordable electricity. The good quality lighting enables children to study properly and families to relax in the evening, as well as reducing snake and dog bites and petty crimes. Shops and businesses have lower costs and can work more easily even after dark without the need for diesel generators, and some new businesses have started. In one village, mobile-phone ownership increased from 10% to 80% of households after the HPS supply was installed, because previously, people had to go out of the village to have their phones charged. HPS is also using its plants as a channel for promoting and marketing other relevant products from different companies and foundations.

Furthermore, HPS is delivering economic and environmental benefits, as switching from traditional sources of energy by reduction in kerosene use by 6–7 L/month, saving about USD 4.40 per month or twice the cost of a basic connection. The overall portfolio of plants provides direct employment to over 350 people, with additional temporary work created during plant construction. HPS is starting businesses that use the char left over from rice-husk gasification, including that from the manufacture of incense sticks. As of now, more than 1,200 women have been trained (at two plant sites) for manufacturing incense sticks. This enables household to earn up to USD 16 per month and save USD 2.3 on kerosene costs while paying only USD 1.2 for electricity.

The HPS plant makes use of rice husk that is abundantly available but, until recently, was considered as waste. Rice mills are paid about USD 25 per ton of rice husk, so they earn an extra USD 3,000 per year by supplying an HPS plant as well as solving a disposal problem. The burning of rice residues in fields causes severe air pollution in some regions. The alternative, residue incorporation into the soil, in turn causes methane emissions from rice fields, contributing to climate change. Each megawatt of power generated from rice-husk plants has resulted in reduction of CO_2 emissions by about 25,800 every year. These reductions in emissions can be attained with the implementation of 32–33 rice-husk plants. Each plant serves around 400 households, saving approximately 42,000 L kerosene and 18,000 L diesel per year, significantly reducing indoor-air pollution and improving health conditions in rural areas. HPS has also offset a total of 2.2 million units of CO_2 by 2013. Further saving CO_2 from reduced use of diesel.

HPS is developing a program of activities for CDM to gain carbon credits. Moreover, processed wastewater and tar tank water is collected in a settling tank and recycled, which ensures that there is no water pollution. Rice husk char and tar and used filter media are mixed and stored on the ground. HPS is also working to reduce the water consumption in its char removal systems.

HPS makes sure that customers understand how to use electricity safely and that every member of the household agrees to abide by safety rules. HPS has facilitated the education of children of local communities by paying school-fee of USD 0.75 per month. Figure 76 summarizes the social impact of the project.

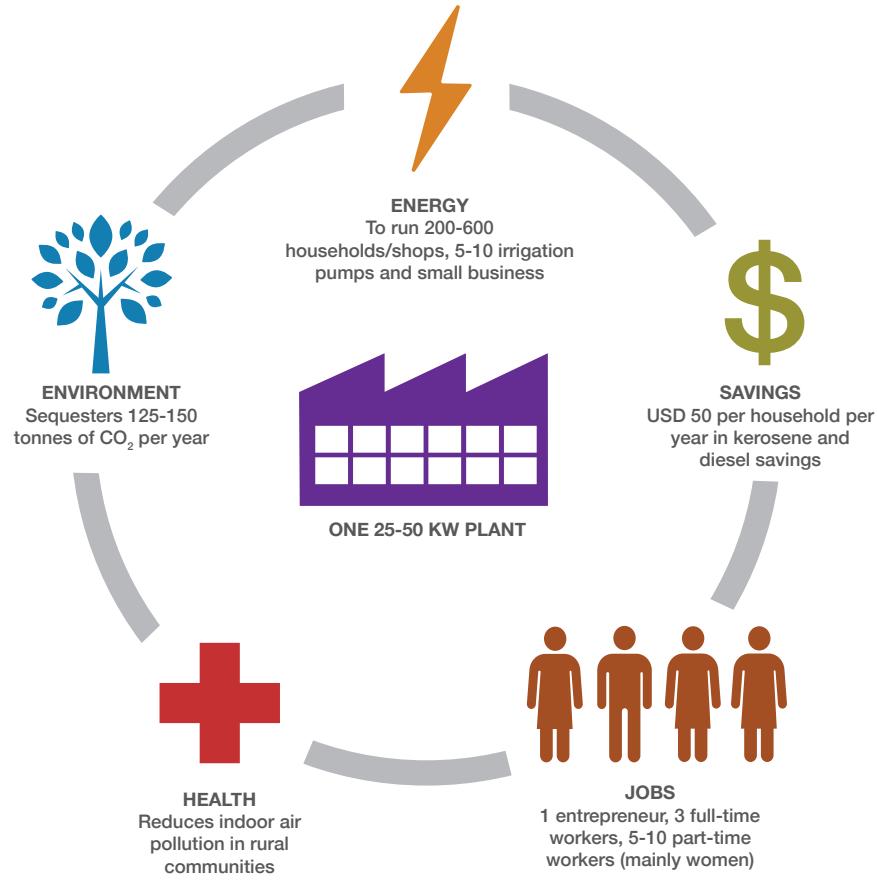
Scalability and replicability considerations

The key drivers for the success of this business are:

- High demand for electricity.
- Strong partnership with the Government of India.
- Central and state policy that promotes renewable energy and provides good incentives.
- Strong financial support from multiple institutional investors.
- Good availability of uniform fuel input (rice husk).

Given that HPS offers a decentralized, low-cost solution, which leads to lower transmission and distribution losses and makes use of a resource available locally which was earlier considered as waste. It has an immense potential not just across the state of Bihar but also across the entire country and the developing world, where over 1.6 billion people still do not have access to electricity/lighting. HPS has identified 25,000 villages as feasible sites within India's rice-producing belt (Bihar and neighbouring states) for establishing rice-husk-based power plants. Rice husk is a plentiful resource in India and many other countrie., Bihar alone produces 3 million tons/year of paddy, which could provide sufficient husk to supply electricity to 3 million households. HPS technology could therefore be used in many other rice-producing areas, as well as places with other biomass residues. HPS is exploring other avenues to increase its revenue other than fees collected for electricity service. Monetizing carbon offsets from biomass gasifier plant (125–150 tons CO_2/year per gasifier).

FIGURE 76. SOCIAL IMPACT OF THE PROJECT



Source: Husk Power Systems; modified.

HPS is planning to build a training centre and also provide some training by distance learning. New ideas under development and testing include programmable prepayment meters, char removal systems that cut water use and automated plant monitoring. Other ways of adding value to char are also under investigation.

The conditions across most parts of India, South Asia and sub-Saharan Africa, with regards to access to electricity in rural areas though not as severe, are quite similar, thereby offering significant potential for replication of the solution and business model offered by HPS. HPS started looking for funding to the tune of USD 6–8 million, to help achieve its ambitious target of establishing 3,000 plants to address the electricity needs of 10 million people across 10,000 villages.

Summary assessment – SWOT analysis

The key strength of HPS is its strong partnership with government, institutional investors along with buy-in from households and farmers (Figure 77). The weakness of HPS is its heavy dependence on rice husk as feedstock and subsidies from government. The business has a significant threat from government electrification programs and, in the event of flood or drought, it might not have access

FIGURE 77. SWOT OF HUSK POWER SUPPLY

	HELPFUL TO ACHIEVING THE OBJECTIVES	HARMFUL TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Strong government partnership to finance infrastructure investment for rural electrification ▪ Strong partnerships, also with donors and social venture finance to fund company's soft costs ▪ An inclusive business model ▪ More than one revenue source (sale of electricity, biochar, franchisee fees and carbon credits) ▪ Local buy-in ▪ Robust technology	**WEAKNESSES** ▪ Too much dependence on rice husk for input feedstock ▪ Technological adaptation required for different biomass inputs ▪ Strong dependence on one revenue source while HPS is diversifying to incense stick production and CO2 credits sales ▪ Heavy dependence on government subsidy for capital cost ▪ Lack of trained work force at the local level
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Low penetration of rural electrification ▪ Carbon credit market opportunities ▪ Huge potential for scaling and replication in India and other developing countries ▪ Rising crude oil prices weaken competitors ▪ The Government of India incentives to electrify un-electrified areas ▪ Locally available biomass (rice husk) ▪ A severe energy crunch in India ▪ Poor rule of law economic growth	**THREATS** ▪ Threat of entrants and substitutes, especially solar units and cheaper electricity by utilities under rural electrification program ▪ Business operations effected by poor rule of law ▪ Unavailability of rice husk in case of drought or floods ▪ Rice husk popularity could potentially drive up prices of inputs, undermining the business proposition

to rick husk. The business has opportunity to scale up and scale out and is already scaling using franchising model. It could improve its business stability by increasing its revenue source from sale of carbon credits and sale of biochar.

Contributors

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References and further readings

Ashden. Husk Power Systems: 21st century living arrives in Bihar. Ashden. https://www.ashden.org/winners/husk-power-systems (accessed November 7, 2017).

Boyle, G. and Krishnamurthy, A. October 2011. Taking charge: Case studies of decentralized renewable energy projects in India in 2010. Greenpeace India Society. www.greenpeace.org/india/Global/india/report/2011/Taking%20Charge.pdf (accessed August 18, 2017).

Development Alternatives. Case studies on decentralized renewable energy: A case study of rice husk power plant, Patna, Bihar. Development Alternatives. www.devalt.org/knowledgebase/case_studies.aspx (accessed 18 January 2018).

Gurtoo, A. and Lahiri, D. 2011. Empowering Bihar: Policy pathway for energy access. Greenpeace. www.greenpeace.org/india/Global/india/report/Empowering-Bihar-Policy-pathway-for-energy-access.pdf (accessed August 18, 2017).

Hartnell, C. June 2011. Case study: Husk Power Systems featuring an interview with Gyanesh Pandey. Alliance Magazine. www.alliancemagazine.org/feature/case-study-husk-power-systems-featuring-an-interview-with-gyanesh-pandey (accessed August 18, 2017).

Husk Power System. www.huskpowersystems.com (accessed August 18, 2017).

Pokar, K., Chaurasia, S. and Maheshwari, R. March 2012. Innovation at bottom of pyramid – Husk Power System: Electrifying rural India (A case study). SSRN. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2029639 (accessed November 7, 2017).

Singh, S. November 2010. Empowering Villages: A comparative analysis of DESI Power and Husk Power Systems. IFMR Lead. http://ifmrlead.org/empowering-villages-a-comparative-analysis-of-desi-power-and-husk-power-systems/ (accessed August 18, 2017).

Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2013–2014). As business operations are dynamic, data can be subject to change.

Notes

1 Towards 2017, HPS increased its promotion of solar - biomass hybrid mini-grids for 24/7 power supply (this information was not available and considered when writing the case).
2 One lakh = 100,000.
3 On crore = 10,000,000.