CASE

Power from municipal solid waste at Pune Municipal Corporation (Pune, Maharashtra, India)

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Supporting case for Business Model 7	
Location:	Pune, Maharashtra, India
Waste input type:	Municipal solid waste (MSW)
Value offer:	Biogas to electricity
Organization type:	Public
Status of organization:	Biogas plant operational since 2009
Scale of businesses:	Medium
Major partners:	Mailhem Engineers Pvt Ltd, Solid Waste Collection and Handling (SWaCH), Janwani, Cummins India, MITCON, Kirloskar and Maharashtra Plastic Manufacturers Association (MPMA)

Executive summary

The case demonstrates power generation from organic fraction of MSW in Pune Municipal Corporation (PMC) through generation of biogas. With population of more than 31 million, area of 243 km^2 and 48 zones, Pune is the seventh largest metropolitan area in India and the second largest in the state of Maharashtra. The biogas from MSW initiative in Katraj Gaon region in Pune is part of a larger Zero Waste Electoral Ward Initiative. The biogas plant provides street lighting services for about 4 km long Katraj–Kondhwa road in Pune. The bio-sludge is used as a manure in the 112 municipal parks and gardens maintained by PMC. The project is with a partnership between PMC; the Solid Waste Collection and Handling (SWaCH), an NGO, for door-to-door collection of waste and Mailhem Engineers Pvt Ltd, a waste management technology firm to process the MSW collected to produce biogas, electricity and bio-sludge. SWaCH has employed waste pickers to collect segregated waste from households and ensuring it reaches the secondary collection system, while PMC is providing support in various ways.

KEY PERFORMANCE INDICATORS (AS OF 2014)						
Land use:	0.03 ha					
Water requirement:	1.25 m^3/day					
Capital investment:	180,000 USD					
Labor:	4 persons, 3 persons at full-time employment and 1 person at half-time employment					
O&M cost:	18,000 USD/year					
Output:	300–325 m^3/day processing 5 tons/day and electricity generation of 144 MWh/year, 180 tons/year of bio-sludge used manure					
Potential social and/or environmental impact:	Created 4 jobs, processing a significant share of municipal solid waste of Pune and providing municipal lighting services; Project also reduces 76.1 tCO_2eq of GHG emissions by reducing electricity consumption.					
Financial viability indicators:	Payback period:	Approx. 6 years	Post-tax IRR:	16%	Gross margin:	62%

Context and background

The average annual MSW generated in India is 120 kg/capita/year. PMC generates 2,550 tons/day of MSW, with 40% to 60% organic matter, and hence is useful for generating energy. Most of the cities in India collect only 60% to 70% of waste actually produced, have insufficient landfill sites and find it difficult to locate new sites at affordable transportation distances. The composition of MSW varies greatly from municipality to municipality (country to country) and changes significantly with time. There is no single approach that can be applied to the management of all waste streams.

The term "digestible wastes" defines organic waste materials which can be easily decomposed by the anaerobic digestion process. The digestible household waste, such as food and kitchen waste, green waste, and most paper waste, includes not only waste from households, but also from institutions, digestible municipal park and garden trimmings, vegetable residues and discarded food from markets and catering businesses, out-dated food from supermarkets, etc. Not all of this organic waste would be suitable for anaerobic digestion. Wood and other lignin containing waste materials are typical examples of organic wastes that are not suitable for anaerobic digestion. PMC is the civic body responsible for providing waste collection and management service to its residents and has initiated a number of waste management projects. Katraj Gaon, as part of admin ward of Dhankawadi, is among the largest electoral wards in terms of area and has population of 15,377 with the blend of high and low-income and nearly 12,000 commercial establishments. Every day about nine tons of waste is collected by waste pickers organized as SWaCH. Nearly three tons of wet waste segregated by waste pickers is sent to biogas plants. Because of the project, the burning and dumping of waste on open plots and public spaces has also reduced considerably. Dry waste collection has also gone up as a result of the efforts and a lot more dry waste is now being sold for recycling. A substantial amount of waste consisting of dry non-saleable and low-value waste and mixed waste, however, still has to be sent to the landfill.

Market environment

The output of the project is biogas, electricity and sludge slurry. Biogas is a methane-rich gas (45–80% methane content), which can be used as renewable fuel for direct combustion for heating applications in commercial and communal kitchens in the city, co-generation (renewable electricity and/or heat generation) or upgraded to bio-methane (typically>94% CH_4) and injected into the gas grid or used for vehicle fuel. Electricity generated in this way will then be used to power streetlights and water and sewerage pumps through a distributed generation-based model. Katraj biogas plant is able to light only 140 street lights which are limited by waste availability. The liquid sludge rich in plant macro and

micro nutrients can be used as soil improver and as fertilizer for plants, provided that it meets the strict quality requirements imposed for such application. Its application to land brings humus and slow-releasing macro and micro nutrients to the soil, contributes to moisture retention and improves soil structure and texture. Using compost made from recycling, such as organic wastes, is considered environmentally sustainable.

If a sustainable zero waste system is successfully put to test in such an area, its replicability would be high. PMC has 144 electoral wards, and in 2012, it had 22 biogas plants in operation. The market share is relatively small, and the waste management to municipal street lighting is only provided in one out of 144 electoral wards in Pune. There is a need for more waste management solutions for Pune including composting. PMC spends a considerable amount of resources on municipal street lighting and is looking for waste to energy solutions like the Katraj project. The attractiveness of the opportunity increases with passing time as the waste generation in the city is on the increase as well as the energy prices. One of the challenges for the waste input is segregation and making sure that only the organic waste is sent to the biogas plant.

There are also opportunities for similar waste-to-energy solutions for other cities in India. Competition for this business model is primarily from the energy utilities as the competing product is electricity. However, following historical trends, it is likely that the electricity tariffs will only increase in the future making biogas to electricity from MSW even more attractive. The impact of waste prevention and resource efficiency initiatives is likely to increase in the future, and food waste per capita may well start to decrease.

Maharashtra has an assessed potential to generate 637 MW from MSW, industrial waste and sewerage (out of the country's 3,400 MW potential in the sector). Of this, Maharashtra has achieved just 22.51 MW, and the new grid-connected renewable energy policy, which was approved by the state cabinet recently, aims at generating another 300 MW from such waste.

Macro-economic environment

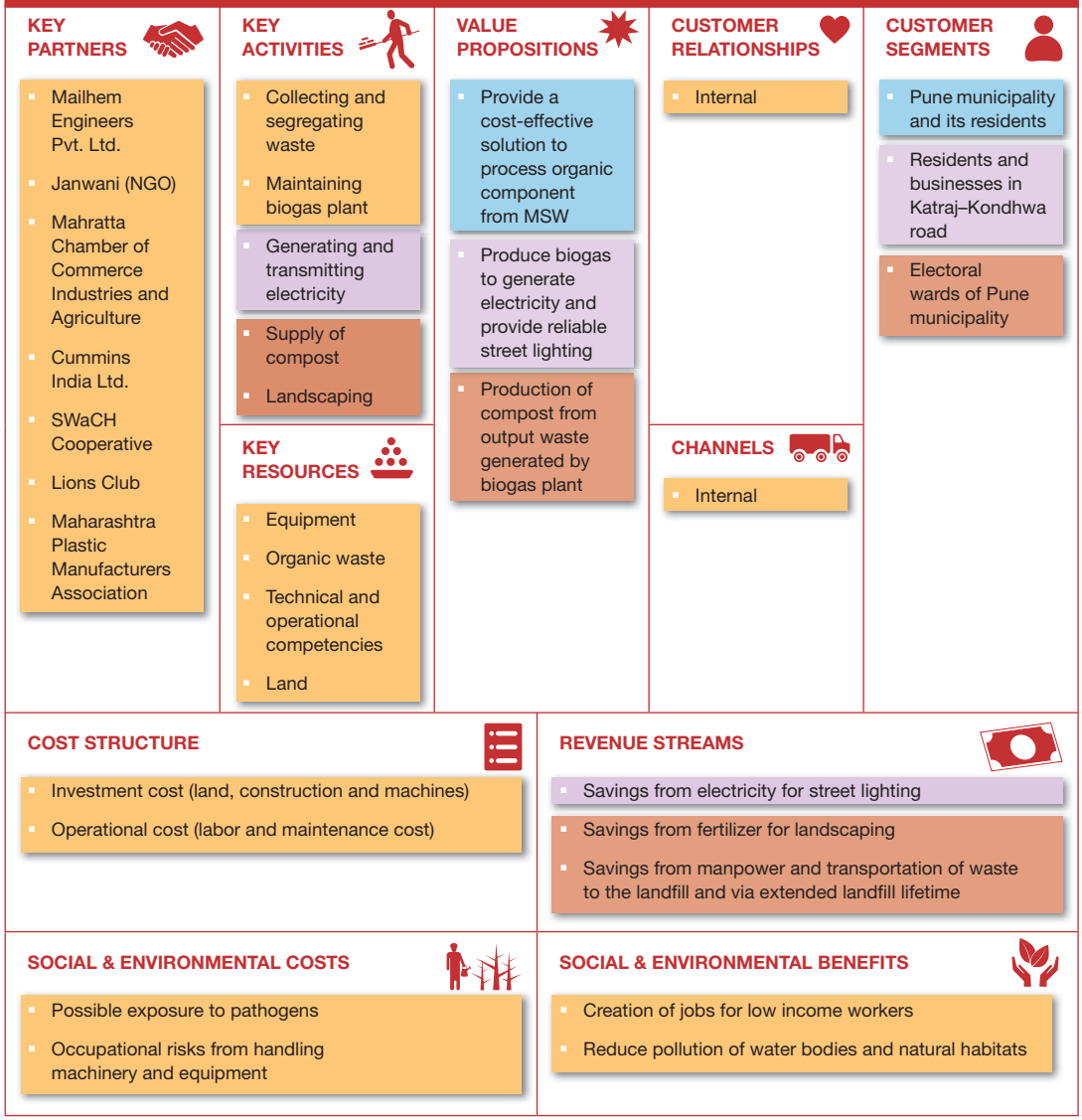
As per the rules by Central Pollution Control Board (CPCB), every municipal authority shall be responsible for collection, storage, segregation, transportation, processing and disposal of MSWs. Municipal authorities shall adopt suitable technology or combination of such technologies to make use of wastes so as to minimize burden on landfill. The biodegradable wastes shall be processed by composting, vermicomposting, anaerobic digestion or any other appropriate biological processing for stabilization of wastes. Landfilling shall be restricted to non-biodegradable, inert waste and other waste that are not suitable either for recycling or biological processing. All of the Municipal Corporation, including PMC, spends a substantial amount of their annual budget on waste collection and transportation. With the dual objective of catering to the ever-increasing demand for electricity as well as the promotion of environmentally-friendly renewable energy technologies, the State Government of Maharashtra had issued guidelines to encourage power generation from MSWs into electricity. Apart from the pollution it causes, disposal of waste has also become a major problem with the continued depletion of potential landfill sites. As a result, 52.88 MW proposals in four cities in Maharashtra are under active consideration through private sector participation using municipal solid waste as raw material.

The Government of India launched Jawaharlal Nehru National Urban Renewal Mission (JnNURM), a massive city modernization scheme under which state governments and city municipalities can apply for funds to improve city infrastructure. Pune is eligible under this scheme and could potentially access these funds to install the biogas to electricity from MSW at other 143 electoral wards.

Business model

The business model canvas is from the perspective of the entity managing the biogas plant to generate electricity. PMC biogas plant in Katraj Gaon has several interlinked value propositions (Figure 81): production of biogas to generate electricity to provide street lighting services to Katraj–Kondhwa Road in Pune and organic compost produced from slurry and waste output from the biogas plant for landscaping of electoral wards within the Pune municipality. The biogas plant contributes to carbon offset, and therefore there is potential to realize revenue from sales of carbon. Janwani, an initiative of the Mahratta Chamber of Commerce Industries and Agriculture along with PMC, Cummins India Ltd, SWaCH Cooperative, Lions Club and Maharashtra Plastic Manufacturers Association is working towards a common goal and supports the project.

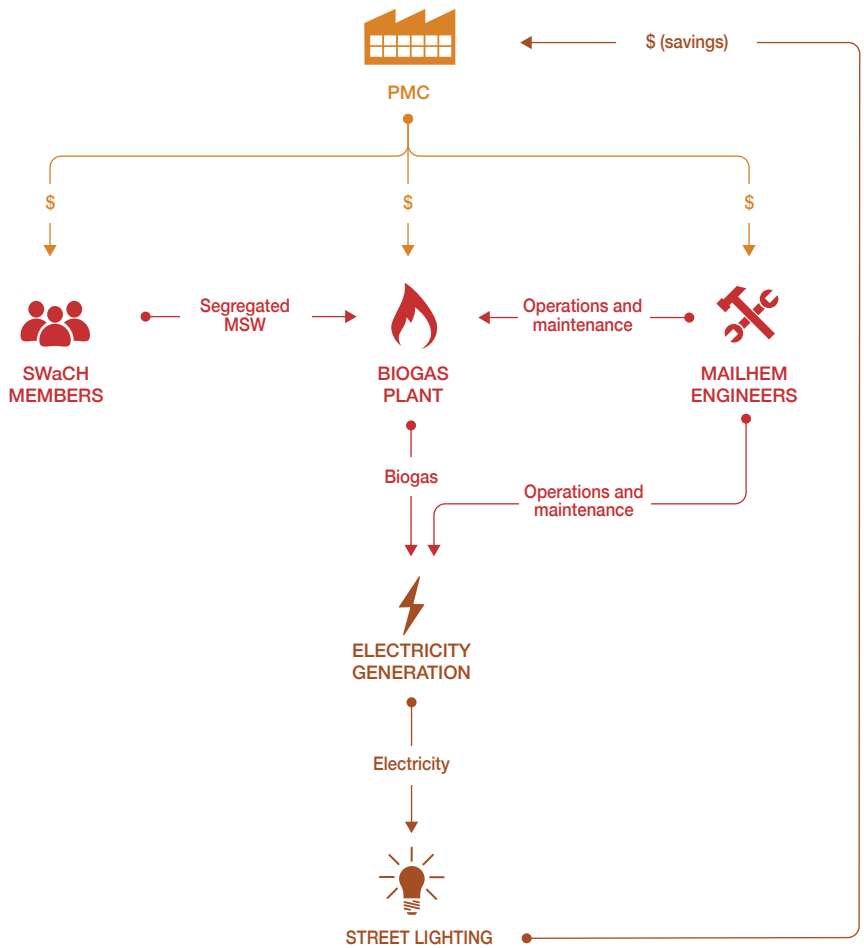
FIGURE 81. MAILHEM-PMC BIOGAS PLANT BUSINESS MODEL CANVAS



Value chain and position

The value chain consists of waste collection, waste segregation, waste-to-energy conversion and street lighting (Figure 82). The citizens helped by initial segregation of their waste. The waste is then collected and further segregated by SWaCH, which has signed a memorandum of understanding with PMC under which an annual payment is made by PMC for waste management. Each household also pays a fee to SWaCH on a monthly basis for waste collection. Solid waste other than MSW, i.e. garden waste, domestic hazardous waste, e-waste, biomedical waste, hazardous waste, construction and demolition waste, animal carcass, street sweeping, etc. was to be collected by SWaCH for additional user fees. PMC provided equipment, slum subsidy, push-cart maintenance amount, sorting centre and admin desk/office space to SWaCH. Post-segregation of waste, members of SWaCH deliver organic content of the waste collected to the PMC biogas plant, which is linked to electricity generation facility. This electricity is used to provide street lighting to Katraj–Kondhwa Road of the municipal area and also as back-up power for the municipal administration building. PMC does not have required skills or expertise in maintenance of waste-to-energy conversion and municipal street lighting. PMC engaged

FIGURE 82. PMC BIOGAS TO ELECTRICITY VALUE CHAIN



with Mailhem to install waste-to-energy infrastructure and contracted Mailhem for operation and maintenance of the biogas digester and electricity generator.

The main challenge was to teach citizens to separate biodegradable and non-biodegradable waste, because the two kinds of waste are treated differently, and to collect user fees from citizens/waste generators. Janwani used tools like home visits, announcements from vehicles and street puppet theatre to deliver its message. A second challenge was to create value from the waste by processing all organic or wet waste within the ward and by recycling dry waste. Dry trash like plastic, glass and paper is sold for recycling by the waste-pickers.

Institutional environment

The solid waste management in developing countries has received lesser attention from policymakers and researchers than other environmental problems, such as air and water pollution. However, the legal and regulatory framework in India mandates the treatment of solid waste. According to governmental policies, the organic waste component of MSW has to be bio-digested or composted and the inorganic portion landfilled. There are a number of other relevant waste management policies for controlling hazardous waste, plastics, construction and demolition waste, e-waste, battery waste and MSW. The State Government of Maharashtra has banned the sale and use of plastic bags across the state since 2006 after the Mumbai floods of 2005.

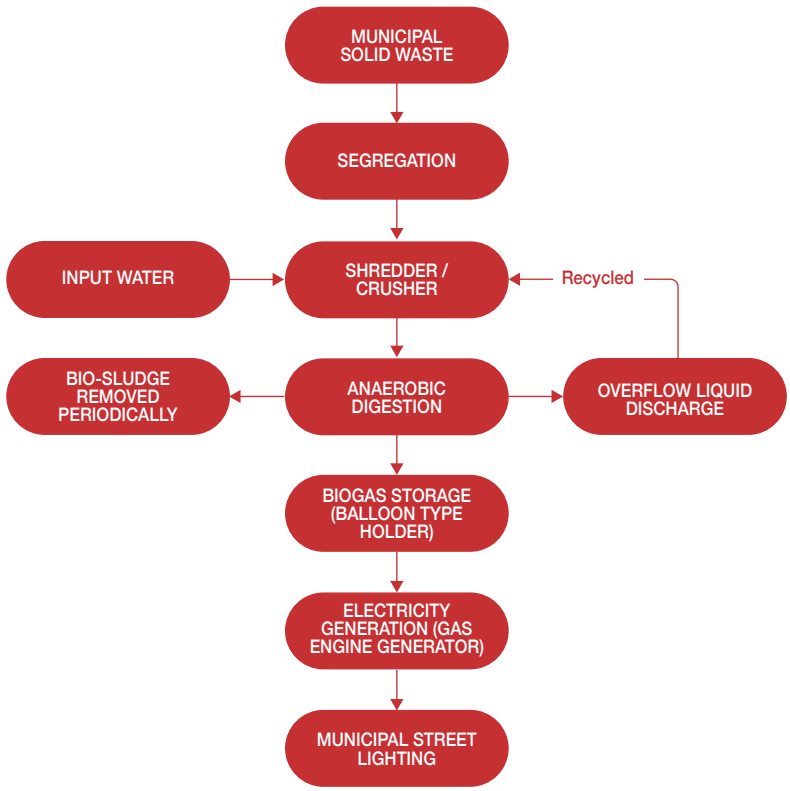
The Government of India has established JnNURM with an aim to encourage reforms and fast-track planned development of identified cities. Focus is to be on efficiency in urban infrastructure and service delivery mechanisms, community participation and accountability of ULBs/parastatal agencies towards citizens. Assistance under JnNURM is additional central assistance, which would be provided as grant (100% central grant) to the implementing agencies. The sectors and projects eligible for JnNURM assistance includes sewerage and solid waste management. The Ministry of New and Renewable Energy (MNRE) promotes power generation from MSW projects by providing a capital subsidy for power generation from MSW of USD 0.3 million per MW, with max of USD 1.55 million per project. Each proposal will be examined and concurred by Integrated Finance Division of the Ministry on a case-to-case basis. The Maharashtra Electricity Regulatory Commission (MERC) has also been very proactive in promoting energy generation from renewable energy sources. MERC has been in the forefront of determining preferential tariffs for renewable energy technologies, with its first tariff order for non-fossil fuel based co-generation projects issued even before the enactment of Electricity Act 2003.

Technology and processes

Anaerobic digestion is a collection of processes by which micro-organisms breakdown biodegradable material in the absence of oxygen. The best practice for bio-degradable waste is separation at source, as they need to be of high quality (i.e. free from physical impurities) in order to ensure stable operation of the anaerobic digestion process. The chemical and biological pollutants, contaminants, toxins, pathogens or other physical impurities must also be strictly monitored and limited to allow safe and beneficial utilization of sludge as fertilizer. Anaerobic digestion can be single stage, multi stage or batch process. Based on the content of total solids (TS) of the substrate to be digested; the anaerobic digestion processes can be low solids (LS), containing less than 10% TS; medium solids (MS), containing about 15–20% TS and high solids (HS), ranging between 22–40% TS (Verma, 2002). The industrial process takes places in a specially designed digester tank, which is part of a biogas plant.

The technology employed for anaerobic digestion is modified up-flow anaerobic sludge blanket. The technology is proven and is used in waste management systems around the world (Figure 83).

FIGURE 83. PROCESS DIAGRAM OF MAILHEM-PMC BIOGAS PLANT



Maintenance of the sludge blanket is an important factor in the efficient operation of the reactors. The biogas produced is combusted in gas engine coupled to an electrical generator to produce electricity for street lighting. The operation of the technology requires segregated MSW with only the organic portion with 80% moisture. Therefore, segregation of MSW is an important aspect, and the technology may not work properly when the input biomass deviates from the specifications.

The technologies – the biogas digester and electricity generator – are locally available and components that need replacement can be fabricated locally. The operation and maintenance of the plant is managed by Pune-based Mailhem, and the technicians employed have been trained and supervised also by Mailhem. The intellectual property rights for the specific digester construction and commissioning lies with Mailhem.

Funding and financial outlook

The operations of biogas plant at Katraj Gaon electoral ward in Pune started in 2009. The land and building costs were covered by the municipality at an existing facility. Investment was towards plant and machinery cost which was USD 180,000 with PMC financing the entire investment (Table 24). on financials. The annual operation and maintenance cost incurred is about 18,000 USD/year. PMC has a contract with SWaCH to deliver organic waste from MSW, and as a part of providing waste management service to households it pays an agreed amount. There is no additional amount given

TABLE 24. MAILHEM PMC BIOGAS PLANT FINANCIALS

Key capital Costs	Land building	No costs (uses PMCs own land)
	Plant and machinery and civil costs	180,000 USD
Operating costs	MSW costs	No costs
	Operation and maintenance	18,000 USD/year
Financing Options	Equity from PMC	180,000 USD
Revenue	Savings from electricity	About 15,840 USD/year
	Savings on manpower and transportation	About 21,000 USD/year
	Savings on manure	About 10,800 USD/year

to SWaCH for supplying organic waste to the plant. Therefore, no cost is considered for MSW input. In Katraj, Cummins India gave USD 45,000 to Janwani and offered 3,000 employees as volunteers, helping Janwani to create awareness. PMC biogas has indirect revenue sources in the form of savings from electricity and fertilizer. Based on these savings, PMC biogas plant has a payback period of 19 years on its investment with an internal rate of return of 2%. PMC can generate revenue from annual carbon sales. It offsets 76.1 tCO_2eq per year.

Socio-economic, health and environmental impact

Poor solid waste management is a threat to public health and causes a range of external costs. Mixed wastes from municipalities are often landfilled. Landfill deposits pose the risk of uncontrolled air, soil and water pollution. Left to degrade naturally in landfill sites, organic wastes from households and municipalities have very high methane production potential; thus, have a negative impact on the environment. Methane has a very high global-warming potential. Over a period of 100 years, each molecule of methane (CH_4) has a direct global warming potential which is 25 times higher than that of a molecule of carbon dioxide (CO_2). Anaerobic digestion can save up to 1,451 kg CO_2/t of waste treated compared to 1,190 kg CO_2/t in the case of composting. Source separation helps divert organic wastes from landfill, thus reducing the overall emissions of greenhouse gases and the negative environmental and health effects related to these waste disposal methods. In order to decrease the environmental and health effects associated with landfilling, waste management is nowadays moving away from disposal and towards waste prevention, reuse, recycling and energy recovery.

PMC biogas plant has a positive impact on socio-economic, health and environment for the region. It provides full-time employment to three people and part-time employment to one person. The waste collection and street lighting efforts have resulted in residents of Katraj electoral ward getting waste management as well as street lighting services. The waste picking members of SWaCH have increased their daily earnings and has improved their social and economic stature. The plant effectively manages municipal solid waste generated within the Katraj Gaon ward which is one of the biggest divisions in Pune, therefore providing environmental benefits as well as health benefits from proper waste management. The project also displaces electricity for street lighting in Katraj–Kondhwa Road and displaces 144 MWh/year of electricity purchases by PMC otherwise. It also mitigates 76.1 tCO_2eq/year of GHG as a result of the avoided electricity consumption.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Partnerships with SWaCH/NGO to deliver segregated organic waste to the plant.
- Technology partnership for operation and maintenance of the plant.

- Demand for end products – electricity and compost are internal and hence no significant competition risks.
- Government policy toward renewable energy.
- Rising electricity tariffs.

If the Katraj zero-garbage model proves itself, Janwani plans to set up a biogas plant in every ward. The potential for replication is high within the PMC and also in other metropolitan areas in India. The increasing quantities of MSW generation and rising electricity tariffs are likely to make replication opportunities further attractive.

Summary assessment – SWOT analysis

The key strength of the business model is its arrangement to secure reliable supply of organic solid waste for the biogas plant and the operation owned by a large urban body that can easily finance such investments (Figure 84). The business can be easily replicated. With an ever-increasing volume of household waste generated, the business has a high opportunity for replication to other areas of a city and to other cities in India. The weaknesses stem from its low rate of financial returns as the key

FIGURE 84. MAILHEM-PMC BIOGAS PLANT SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Established arrangements with reliable partners for waste collection and delivery and operation and maintenance of the waste-to-energy plant ▪ Large urban body with significant internal financial resources for waste management activities, which makes financing of the effort easy ▪ Use of an innovative public-private partnership (PPP) model for waste management	**WEAKNESSES** ▪ Government body as the key partner in the business model and subject to bureaucratic delays ▪ Financial model not attractive based on the avoided cost of electricity and bio-fertilizers purchases ▪ Households only pay a small contribution towards waste management significantly below the cost of waste management ▪ Non-availability of suitable land ▪ Inadequate manpower with the municipal corporation for implementation and compliance verification with MSW rules
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Favourable policy and regulatory environment for waste management and independent power producers in India ▪ Significant opportunities exist for replication of the model to other divisions/ parts of the urban civic body ▪ Availability of an ever-increasing volume of household waste and expected increase in power tariff in other parts of India ▪ Increased yields and beatification of city parks using bio-fertilizers	**THREATS** ▪ Changes in the composition and volume of household waste and the challenge of effective segregation of the waste ▪ Increased public awareness and active commitment and participation of citizens in local collection schemes required

revenue is from electricity savings, which is a relatively small amount in comparison to the amount investment. Therefore, investment does not look financially attractive.

The success of the project requires increased public awareness and active commitment and participation of citizens in local collection schemes. Some of the other constraints are non-availability of suitable land, lack of technical awareness of citizens with respect to waste processing technologies, inadequate waste pickers and manpower with the municipal corporation for implementation and compliance verification with MSW rules. The business model faces significant threat from any changes in composition and volume of input waste.

Contributors

Mailhem Engineers Pvt Ltd

References and further readings

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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 (2015/2016). As business operations are dynamic, data can be subject to change.