Benefits and challenges of anaerobic digestion of organic waste for biogas production in India: A review of established business models

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Introduction:

Throughout the last decades India experienced high population growth and rapid industrialisation driving the migration of people from villages towards towns and cities. Indian urban centres can hardly keep pace with provision and management of public services such as energy and water supply as well as disposal of huge quantities of municipal solid waste (MSW). Since suitable strategies, infrastructure and financial resources for organized MSW management are not established; 80 – 90% of the solid waste is currently disposed in open dumps or poorly managed landfills (Sharholy, et al. 2008, Kumar, et al. 2009, Central Public Health and Environmental Engineering Organisation (CPHEEO) 2016). Waste-to-energy technologies are perceived as solution to tackle both problems of meeting the increasing energy gaps and solid waste management in urban centres (Singh, et al. 2011, Annepu 2012, Kalyani and Pandey 2014, Task Force on Waste to Energy 2014). Indian MSW contains high fractions of organics (40-60%) and high moisture content (30-60%). These characteristics in combination with the high air temperatures throughout the year, render anaerobic digestion (AD) of the organic fraction of MSW (OFMWS) for biogas and subsequent electricity and/or heat production highly suitable in the Indian context (Rao, et al. 2010, Minde, et al. 2013). AD is a mature technology and biogas has been used traditionally for cooking purposes in developing countries such as rural areas of India or China for many years (Bond & Tempelton 2011, Surendra, et al. 2014). However, the inherent potential of AD as organic waste treatment or organic-waste to energy opportunity is largely unexploited in urban settings of developing countries (Vögeli, et al. 2014). So far, the technical and operational feasibility of biogas systems of different scales and their challenges and opportunities in India are poorly explored.

The Indo Swiss Joint Research Programme (ISJRP) Project "Optimisation of Organic Waste to Energy Systems in India" studies different centralized and decentralized scenarios for biogas production and utilisation from organic waste. The present study aims at shedding new light on the untapped potential of AD in the Indian context. By means of a comprehensive literature review, including secondary datasets from governmental reports, commonly applied biogas systems of different scales are identified and quantified, biogas utilisation purposes and end users defined. Subsequently, the biogas systems' underlying business models are analysed using the 'Business Model Canvas' to i) learn about enabling factors and challenges faced when implementing and operating biogas systems in India, ii) derive recommendations how to overcome these challenges and iii) estimate the potential of AD as waste treatment option for MSW.

Methodology:

The methodological approach is based on the Business Model Canvas, which was introduced by Osterwalder (2004). The Business Model Canvas serves as holistic analytical tool and framework for the comparison of business models and has been recently used by researchers in the renewable energy sector (Engelken, et al. 2016, Gabriel & Kirkwood 2016). It consists of nine 'building blocks' covering the four main areas of a business: the end users (E), the product (P), financial viability (F) and infrastructure management (I) (Osterwalder and Pigneur 2010). The Canvas framework was used to highlight important questions for the subsequent analysis of established biogas business models in India:

- **E1: End users:** Who are the end users? Who pays for the biogas related products?
- **E2: Delivery:** How is the product delivered to the end user?
- **E3: Services:** Which additional services/assistance is needed on the end user site?
- **Product:** What is the biogas related product delivered to the consumer?
- **P1: Value proposition**: What are the benefits/the incentives for the end user delivered through the product?
- **F1: Cost structure:** What are investment (CAPEX) and operating costs (OPEX), costs for staff, logistics/services?
- **F2: Revenue streams:** How to generate adequate revenues from the end user?
- **I1: Partners:** Who are key partners, key suppliers? Which funding opportunities and legal framework exist?
- **I2: Activities:** Which installation, O&M works are related to the biogas product?
- **I3: Resources:** Which substrate type, quality and quantity is required and how is the year-round availability?

Results and Discussion:

Different scales of biogas plants have been identified in the Indian context and categorized in centralized and decentralized systems. Based on literature findings and preliminary discussion with key informants, the underlying business models have been analysed (*cf.* table 1).

Decentralized family size biogas plants (Model A): These plants are mainly used by rural households on the basis of animal manure for biogas production. Capacities range from 1-10 m^3 biogas/d, (i.e. loading rate of 5-50 kg wet waste/d) which is mainly used for cooking purposes. Around 4.75 million family-size biogas plants are currently installed in India (MNRE 2014). Main challenges detected refer to lacking technical expertise of the end users in case system failures occurs (Surendra, et al. 2014, Bond and Tempelton 2011).
Decentralized community size biogas plants (Model B): Waste from small dairies, vegetable and fruit markets, poultry farms or restaurants is collected by community/institution and fed in a digester for biogas production of 100 – 1'000 m^3/d (i.e. loading rates of 500 – 5'000 kg waste/d). Biogas is manly used for cooking purposes or converted to electricity in combined heat power (CHP) plants (Vijay, et al. 2015, Vögeli & Zurbrügg 2008; 2014). During 2012 – 2016, 200 units have been commissioned or installed (MNRE 2017).
Centralized communal biogas plants (Model C): Centralised systems in modules with loading rates of > 5'000 up to 50'000 kg waste/d are in place (i.e. capacity of up to 1'000 - 10'000 m^3 biogas/d) (CPHEEO 2016). Biogas produced can be used for electricity generation in CHPs, gaseous fuel in automotive industry after being cleaned by removing CO_2 and H_2S as wells as compressed biogas (CBG). There are few examples of centralized MSW based biogas plants which have been installed, yet were not successfully running due to insufficient quality and quantity of MSW substrate. Lacking awareness and no incentives of end users to pay for centralized waste disposal and treatment services were other barriers encountered (CPHEEO 2016, MNRE, 2016).
Industrial Scale biogas plants (Model D): Distilleries, pulp and paper, sugar or food processing industries generate waste in large quantities (Vijay, et al. 2015). Several examples for successfully running industrial biogas plants with capacity ranges above 5'000 m^3 biogas production/day are known. Mostly industries use biogas for electricity/heat generation for their own use (Ministry of Non-conventional Energy Sources 2006).

Table 1: Business model comparison of established biogas systems in India

	End user (E)	Product and value proposition (P)	Financial aspects (F)	Infrastructure management (I)
Model A	**E1:** Households **E2**: on-site use **E3:** Easy-to-operate systems, low maintenance and operation works involved. Often built with assistance from NGOs. Provides technical assistance if needed	**Product: Biogas for cooking, fertilizer** **P1:** Economic incentive, replacement of liquid petroleum gas (LPG) for cooking, substitution for commercial fertilizers	**F1:** only CAPEX **F2**: not applicable	**I1:** CAPEX subsidized by National Biogas and Manure management Programme (NBMMP) of MNRE **I2:** low O&M works involved, for installation and system failures technical expertise and assistance required **I3:** Mainly manure, year-round availability
Model B	**E1:** community, households **E2**: on-site use, grid **E3:** medium maintenance and operation works involved. Often built with assistance from NGOs or private sector. Provides technical assistance if needed. Private companies also do O&M works	**Product: Biogas for cooking, electricity for lightning of residential area, fertilizer** **P1:** proper waste management, community based initiative (sense of responsibility and belonging)	**F1:** OPEX/CAPEX. Salary for operator **F2:** Organic waste disposal and treatment fee in return for electricity, biogas for cooking (partly replacing conventional energy sources)	**I1:** NGOs, private investors, CAPEX subsidized and training on O&M provided to community members by Biogas Power (Off-Grid) Programme of MNRE **I2:** Medium O&M works involved, for installation and system failures technical expertise and assistance required **I3:** different substrates, e.g. market waste, canteen waste, manure
Model C	**E1**: Different end users possible depending on product. **E2:** grid, natural gas networks, gas cylinders, etc. Expensive **E3:** awareness programmes on clean energy and proper waste management of municipalities towards end users important	**Product: Electricity, heat, gaseous fuel, CBG** **P1:** Value proposition: No direct economic incentive for households (electricity, CBG) Problem to find end-user for heat (by-product from electricity generation)	**F1:** OPEX, CAPEX. Salaries for operators and managers system, additional costs due to distribution networks/ transportation means of biogas products to end users **F2:** Difficult to implement waste disposal and treatment fees in the municipality. Common mind-set: 'Waste disposal is free'.	**I1:** NGOs, private investors, Financial incentives for biogas systems from Biogas based Power Generation programme (BGPE) by MNRE, Swacch Bharat Mission and new MSWM Management Rules 2016 (CPHEEO 2016). **I2:** depending on the biogas system and end product. High O&M and management activities involved **I3:** different substrates. E.g. Municipal solid waste (source segregation crucial), market or food waste
Model D	**E1:** Industry **E2:** in-house use **E3:** Technical expertise required for O&M works	**Product: mostly electricity/heat generation for in-house use** **P1:** Value proposition: Economic incentive, replacement of conventional energy sources	**F1:** industry specific cost structure **F2:** not applicable	**I1:** Technology providers **I2:** For installation and system failures technical expertise and assistance required **I3:** depending on industry

Preliminary results confirm applicability of the 'business model Canvas' for the identification of enabling factors and barriers of established biogas business models in the Indian context. In close collaboration with local stakeholders, the framework will be applied to existing biogas projects in the course of the continuing project work to generate new and important information about sustainable energy use possibilities from OFMSW through anaerobic digestion.

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References:

Annepu, Ranhiith Kharvel. *Sustainable Solid Waste Management in India.* Department of Earth and Environmental Engineering, Columbia University, 2012.

Bond, Tom, and Michael R. Tempelton. "History and future of domestic biogas plants in the developing world." *Energy for Sustainable Development 15*, 2011: 347-354.

Central Public Health and Environmental Engineering Organisation CPHEEO. *Municipal Solid Waste Management Manual- Part II: The Manual.* Swachh Bharat Mission Report, Ministry of Urban Development, Government of India, 2016.

Engelken, Maximilian, Benedikt Römer, Marcus Drescher, Isabelle M. Welpe, and Arnold Picot. "Comparing drivers, barriers, and opportunities of business models for renewable energies: A review." *Renewable and Sustainable Energy Reviews 60*, 2016: 795-809.

Gabriel, Cle-Anne, and Jodyanne Kirkwood. "Business models for model businesses: Lessons from renewable energy entrepreneurs in developing countries." *Energy Policy 95*, 2016: 336-349.

Kalyani, Khanjan Ajaybhai, and Krishnan K. Pandey. "Waste to energy status in India: A short review." *Renewable and Sustainable Energy Reviews 31*, 2014: 113-120.

Kothari, Richa, V.V. Tyagi, and Ashish Pathak. "Waste-to-energy: A way from renewable energy sources to sustainable development." *Renewable and Sustainable Energy Reviews 14*, 2010: 3164-3170.

Kumar, Ashwani, Kapil Kumar, Naresh Kaushik, Satyawati Sharma, and Saroj Mishra. "Renewable energy in India: Current status and future potentials." *Renewable and Sustainable Energy Reviews 14*, 2010: 2434-2442.

Kumar, Sunil, J.K. Bhattacharyya, Tapan Chakrabarti, Sukumar Devotta, and A.B. Alkolkar. "Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: An insight." *Waste Management 29*, 2009: 883-895.

Minde, Gauri P., Sandip S. Magdum, and V. Kalyanraman. "Biogas as a Sustainable Alternative for Current Energy Need of India." *Journal of Sustainable Energy & Environment 4*, 2013: 121-132.

Ministry of New and Renewable Energy (MNRE). *Ministry of New and Renewable Energy. Government of India.* 2014. http://mnre.gov.in/schemes/decentralized-systems/schems-2/ (accessed February 2017).

Ministry of Non-conventional Energy Sources. *Green energy from wastes. Biomethanation Projects for Urban and Industrial Wastes set up under UNDP/GEF assisted Project on Development of High Rate Biomethanation Processes as meas of Reducing Greendhous Gases Emission.* Government of India, 2006.

MNRE. "Ministry of New and Renewable Energy, Government of India." 2017. http://mnre.gov.in/file-manager/UserFiles/Statewise%20_commissioned-installed_Biogas_offgrid_Power_Projects.pdf (accessed February 15, 2017).

Nixon, J.D., P.K. Dey, S.K. Ghosh, and P.A. Davies. "Evaluation of options for energy recovery from municipal solid waste in India using the hierarchical analytical network process." *Energy 59*, 2013: 215-233.

Osterwalder, Alexander. *The Business Model Ontology- A Proposition in A Design Science Approach.* PhD thesis, Université de Lausanne, 2004.

Osterwalder, Alexander, and Yves Pigneur. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers.* John Wiley & Sons, 2010.

Rao, P. Venkateswara, Saroj S. Baral, Ranjan Dey, and Srikanth Mutnuri. "Biogas generation potential by anaerobic digestion for sustainable energy development in India." *Renewable and Sustainable Energy Reviews 14*, 2010: 2086-2094.

Sharholy, Mufeed, Kafeel Ahmad, Gauhar Mahmood, and R.C. Trivedi. "Municipal solid waste management in Indian cities- A review." *Waste Management 28*, 2008: 459-467.

Singh, R.P., V.V. Tyagi, Tanu Allen, M. Hakimi Ibrahim, and Richa Kothari. "An overview for exploring the possibilities of energy generation from municipal solid waste (MSW) in Indian scenario." *Renewable and Sustainable Energy Reviews 15*, 2011: 4797-4808.

Surendra, K.C., Devin Takara, Andrew G. Hashimoto, and Samir Kumar Khanal. "Biogas as a sustainable energy source for developing countries: Opportunities and challenges." *Renewable and Sustainable Energy Reviews 31*, 2014: 846-859.

Task Force on Waste to Energy. *Report of the Task Force on Waste to Energy (Volume I) (In the context of Integrated MSW Management).* Planning Commission, Government of India, 2014.

Vijay, Virendra Kumar, Rimika Kapoor, Abhinav Trivedi, and Vandit Vijay. "Biogas as Clean Fuel for Cooking and Transportation Needs in India." In *Advances in Bioprocess Technology*, by Pogaku Ravindra, 257-275. Springer International Publishing Switzerland, 2015.

Vögeli, Y., and C. Zurbrügg. "Decentralised anaerobic digestions of kitchen and market waste in developing countries- "state-of-the art" in South India." *Proceedings Venice 2008, Second International Symposium on Energy from Biomass and Waste.* Venice, Italy: Environmental Sanitary Engineering Centre, Italy, 17-20 November 2008.

Vögeli, Y., C.R. Lohri, A. Gallardo, S. Diener, and C. Zurbrügg. *Anaerobic Digestion of Biowaste in Developing Countries: Practical Information and Case Studies.* Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag), 2014.