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SIGNIFICANCE OF IMPLEMENTING DECENTRALIZED BIOGAS SOLUTIONS IN INDIA: A VIABLE PATHWAY FOR BIOBASED ECONOMY

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ABSTRACT

In recent years, world economy has achieved considerable economic and social development, but this has resulted in the widespread degradation and depletion of our natural environment. Solid-waste generation increases exponentially due to the rapid urbanization, but inappropriate waste handling causes health hazards and urban environment degradation. The goal of strengthening bio-based economy is potentially related to biogas solutions with respect to solid waste management in several ways. Bio based economy demands new ways of philosophy and co-operation within and across sectors to minimise the environmental footprint and climate change throughout the value chain. The range and significance of biogas technologies has increased rapidly during the last 30 years for the treatment of organic waste. The typical way of perceiving the role of biogas solutions is as a last step in cascading the biomass where renewable energy in the form of biogas is produced along with bio-fertiliser. Among the existing technologies for waste treatment, anaerobic digestion (AD) plays a key role in reducing waste along with the generation of renewable energy as it plays a key role in reducing the adverse effects on environmental and climatic changes of the biosphere such as the reduction of NOx and CO_2 emissions in the atmosphere, leading to reduced carbon foot print and reduction in solid waste accumulation. However, AD of organic waste with conventional digesters is not practicable for the processing of large quantities of waste generated in India. The aim of the present work is to present knowledge and technological gaps between slow rate and high rate biogas solutions that emerged in India, used to replace conventional fuels with renewable and green fuel (biogas) through initiatives taken up by the governmental and private organizations.

1. INTRODUCTION

Energy demand in various sectors is continuously increasing due to enourmous growth in population and industrial development. Natural energy resources like coal, oil and gas are fulfilling the energy demand globally, however, due to complete dependence on natural reserves and continuous exploitation, it is leading to depletion of resources besides deteriorating the natural environment. Hence, there is the need to explore alternative forms of energy which are renewable and, at the same time, subside the usage of conventional energy forms. One of the solutions to such problem is the evolution in alternative renewable and sustainable energy technologies like biogas and bioenergy (Cantrell et al., 2008, Begum et al., 2017, Juntupally et al., 2017). Currently, 10% of the world's energy demand is met by bioenergy (Thomas et al., 2017). Sustainable and economically viable way of producing biogas and bioenergy is to purposefully utilize the wastes as resources that are enormously increasing due to urbanization and rapid industrialization. For instance, about 62 Million Metric Tons (MMT) of waste is generated in India per year of which about 50-55% is biodegradable in composition (Begum et al., 2016). Current global municipal solid waste (MSW) generation levels are approximately 1.3 billion tonnes per year, and are expected to increase to approximately 2.2 billion tonnes per year by 2025 (Daniel and Perinaz, 2012). The production of biogas from biode-

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gradable waste through anaerobic digestion (AD) process presents significant advantages over other forms of renewable energies. AD is an established technology that is proven to be most energy efficient and eco friendly, but it is under used in majority of the developing countries. A few biogas installations for the treatment of animal wastes of smaller capacitites (50 to 200 kg/day) operated in the past two decades ago but now it is highly important to set up decentralized biogas plants to treat the waste at source to obtain benefits in terms of methane rich biogas for decentralized cooking applications and organic fertilizer with notable N, P and K content to replace chemical fertilizers. This kind of approach not only results in effective waste management and renewable energy generation but also avoids transportation and disposal costs involved in handling wastes. The waste management plan lays out quantitative targets for recycling, as well as many initiatives deal with encouraging the development of green technologies, improve waste policies and an increase focus on citizens and their role in the waste management cycle. Energy recovery from organic waste can offset operational costs, generate revenue, increase the share of renewables in the energy mix and reduce GHG emissions. A salient reason for advocating biogas technology exploiting waste as a resource is to effectively manage waste, reduce the burden on natural energy resources through environmental friendly process and drive the nation towards improving biobased economy. The idea of creating a bio-based economy where waste derived renewable resources are used for industrial purposes and energy production, without compromising on food and feed provision, has already been set out by the Organization for economic co-operation and development (OECD) in 2009. Around the world, countries are promoting the circular and biobased economy agenda and the number of solutions provided by companies is increasing rapidly. To implement these solutions several barriers need to be overcome to shift the system towards one aligned with biobased economy principles. These include regulatory barriers – such as inconsistent and biased definitions of waste, and economic hurdles, including the absence of accurate externality pricing – which tilt the field towards traditional systems, rather than designing it to obtain biologically derived materials and energy. Overcoming such barriers will further enable the technological advances required to realise the economic opportunities. It is estimated that the total number of biogas plants in India has increased from 1.23 million in 1990 to approximately 4.54 million in 2012, despite an estimated potential of 12.34 million digesters (Lohan et al., 2015). Apart from the direct benefits gleaned from biogas systems, there are other, perhaps less tangible benefits associated with this renewable technology. By providing an alternative source of fuel, biogas can replace the traditional biomass based fuels, notably wood. Benefits can also be scaled up, when the potential environmental impacts are also taken into consideration; significant reductions in emissions associated with the combustion of biofuels, such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), total suspended particles (TSPs), and poly-aromatic hydrocarbons (PAHs), are possible with the large-scale introduction of biogas technology unlike small scale biogas plants. However, AD of biodegradable waste helps to reduce massive amounts of CO_2 eq. emissions, produce valuable renewable energy and recover nutrients. It is estimated that per every ton of organic waste disposed off in an unsuitable manner about 1.2 ton of CO_2 is released in to the atmosphere leading to global warming (Mahapatra et al., 2009; Pathak et al., 2009; Hashmi et al., 2007). The aim of the present work is to present the decentralized biogas solutions that emerged in India to replace conventional fuels with renewable and green fuel (biogas) through initiatives taken up by the governmental and private organizations. It also highlights the proactive factors in spreading the biogas technology, tackling the waste management issues and barriers that hindered the process of adopting biogas technologies, e.g. lack of awareness, financing etc. A comparison between the conventional and high rate digesters in terms of its design, process, product yield and its economic feasibility at small and big scale is also presented. This paper also describes a case study emphasizing practical experiences witnessed in installing, commissioning and working of a decentralized biogas plant for the treatment of organic waste, together with its output in terms of biogas, digestate, techno economic and environmental assessments combined with the discussion on technology transfer and commercialization. An understanding on the significance of setting up decentralized biogas plant that could strengthen the biobased economy is also presented.

2. METHODOLOGY

The initial part of the study focused on investigating the type of biogas solutions that evolved in India, its installations in rural areas promoted by government projects and on barriers that hindered the spread of biogas technology due to limited access to information and lack of awareness on the scientific innovations. The study was based on the documents that were available in the internet, formal discussions with the experts in biogas technology who developed the biodigesters suitable for Indian environment based on design principle and rawmaterials and a few spontaneous responses of participants on the biogas concept in the bioenergy conferences. A second part of the study focused on presenting a case study describing the installation and commissioning of the biodigester at site (Bellary, Karnataka, India), operation and maintenance, retrofitting the digester during unstable conditions by the technology contractor, an estimate on its products utility and pay back period by the beneficiary of the project.

3. RESULTS AND DISCUSSION

3.1 Necessity for promoting biogas technology in India

About 70% of the population in India lives in rural areas. The rural energy scenario is characterized by inadequate, poor and unreliable supply of energy services and large dependance on traditional biomass fuels (Begum et al., 2017). Every year several large and small scale farmers in India burn agricultural crop residues after harvesting, to reduce the costs involved in storage and handling that resulted in release of atmospheric pollutants such as aerosols, suspended particulates, SO_x and NO_x. In addition, burning crop residues leads to decrease in soil nutrients and fertility. As India is considered an agriculture-based country, huge quantitites of animal waste is generated. However, it is possible to convert this waste into a valuable resource by exploiting modern waste to energy conversion technologies. Considering the technological innovations and the availability of waste like biomass, animal manure etc., Indian government started to install biogas (gobar gas) plants exploting dung as substrate for the production of biogas as a cooking fuel. Hence, necessity for promoting biogas technologies in India arose and accordingly the Indian government under different renewable energy schemes has taken initiatives to promote further use of biogas solutions in rural India. The detailed information on the biogas solutions emerged is discussed in subsequent sections.

3.2 Biogas solutions that emerged in India

To tackle the waste disposal issue, various biogas solutions emerged in India. The biogas solutions that emerged in early 1960s in India are based on two types of digesters i.e. fixed masonry dome type and floating drum type. A cattle dung-based floating drum type biogas unit named Khadi and Village Industries Commision (KVIC) was the first solution evolved to treat cattle dung in rural India. This technology was approved by the Ministry of New and Renewable Energy (MNRE) and promoted under National Programme on Biogas Development (NPBD) (MNRE, 2010). Though it was a popular technology, high plant cost and the need to regularly apply paints on metal biogas holder to protect from corrosion were the drawbacks of the technology. Other biogas solutions, including Deenabandu and Pragati models, overcame the drawbacks of the aforesaid technology. The majority of researchers reported that the aforesaid biogas models are slow rate conventional digesters, suitable to treat only animal wastes and characterized by low organic degradation efficiency and biogas yield, while the associated disadvantages include choking and scum formation in the reactor. Hence, the main necessity was to develop high rate anaerobic digester model that could treat any kind of segregated organic waste for the generation of methane rich biogas and nutrient rich organic fertilizer with a high degradation efficiency and product yield. Hence, the different research organizations in India promoted an initiative aimed at the development of high rate anerobic digesters that could meet the standards set by the advanced digesters in European countries (EBA, 2016).

3.3 Principle and working of a biogas plant

The process exploited by a biogas plant is AD or biomethanation, which is defined as a sequential process including hydrolysis, acidogenesis, acetogenesis and methanogenesis. A typical biogas plant has a digester in which the slurry (substrate mixed with water) is anaerobically digested for the generation of methane rich biogas and digestate. Intially the slurry from feed preparation tank is pumped in to the digester and subject to microbial action. The microbes consume the available organic matter from waste and produce methane, carbon dioxide, nitrogen and traces of hydrogen sulphide which is collected in a gas holder. The digestate from the digester is collected in outlet tanks, for further use as organic fertilizer if the quality meets standard criteria (Arelli et al., 2018).

3.4 Slow rate V/s High rate digesters

It is a known fact that anaerobic digesters currently employed for solid waste treatment are broadly classified into two distinct categories, such as conventional (slow rate) and high rate digesters. Slow rate digesters are based on two basic designs, the floating dome type and the fixed dome type digesters, and are designed for very long hydraulic retention time (HRT) with large reactor volume and low volatile solids (VS) reduction. These digesters were suitable for the treatment of cattle manure with a low treatment capacity i.e 50 to 200 kg/day (Tiwari et al., 1988; Sonam et al., 2014). It was reported that majority of the plant installations in rural India were based on conventional slow rate digesters, which have been found to be failed due to chocking and scum formation due to lack of proper maintanence (Begum et al., 2017). Hence, for the biomethanation of organic solid waste in any case, conventional digesters are not suitable for the processing of large quantities of waste. Therefore, High rate digesters are basically designed to minimize HRT and increase the rate of biogas production by AD features optimization, such as appropriate mixing, ensuring high density of active biomass, providing good buffering capacity, controlling food to microorganism ratio and suitable slurry concentration in the digester, monitoring possible microbial culture inhibition mechanisms etc. High rate digesters also address the bottlenecks involved in conventional digesters. The high rate digesters design allows to treat waste from 250 kg/day to 10 ton/day. The innovative features that make the high rate digesters more suitable from conventional digesters are shown in Table 1.

3.5 Economic feasibility/viability

The applicability of any green technology is difficult to quantify unless its economic feasibility is studied. The costs associated with biogas technology can be categorized under the following heads:

1) Initial costs of construction and installation: cost of labor, excavation cost, costs of construction materials, pipes and their set up for biogas supply, transportation cost of materials.
2) Operative Costs: costs associated with mixing of feedstock in the slurry tank with water, pH boosters to operate the reactor in stable conditions, collecting the digested slurry from outlet tank, drying the digested slurry to obtain solid fertilizer (Braimakis et al., 2014). The economic feasibility along with remunerative benefits is discussed in detail in subsequent section.

3.6 Strategies for implementing decentralized small and medium scale biogas solutions

India has implemented a large biomass energy program, which involves the promotion of several bioenergy technology programmes (BETP) through several policies,

TABLE 1: Comparitive analysis of slow rate and high rate digesters.

Parameter	Slow rate digeters	High rate digesters
Type of substrate	Animal wastes like cow dung, cattle dung	Any kind of organic wastes like food waste, animal wastes, agricultural waste and organic fraction of MSW
Capacity of treatment (kg/day)	50 – 200	250 – 10,000
Material of construction (MOC) of digester	Concrete	Mild steel or stainless stell
MOC of biogas holder	Metal, plastic	Poly vinyl chloride balloons
HRT (days)	40 - 60	15 - 24
Volatile solids loading rate (kg VS/m^3 of digester/day)	1 -2	5 - 6
Total solids loading rate (kg TS/m^3 of digester/day)	3 - 4	6 - 8
Volatile solids reduction (%)	40 -50	70 - 80
Biogas generation (m^3/ton.day)	30 - 40	Cow dung: 40 – 50
		Poultry litter: 70 – 75
		Food waste: 120-140
Methane content (%)	45 - 50	60 – 65
Foot print area required (m^2)	-	55 (for one ton of waste treatment plant)
Payback period for one-ton plant	-	2.5 - 3 years

institutional and financial incentives and interventions. The importance of high rate digesters, developed by various research institutes/organizations to address the limitations of the slow rate digesters, increased in the past decade. Government has undertaken strategical approach by implementing a sequential process, in which Technology transfer, demonstration and dissemination leading to commercialization have been the corner stones of Ministry of New and Renewable Energy (MNRE) for the deployment of renewable energy technologies in India. Most of the BETP were implemented with direct capital subsidy support from the MNRE (MNRE, 2017). Other policy incentives, (e.g. income tax reduction, accelerated depreciation, concessional duty/custom duty-free import, soft loans for manufacture and state level policies on wheeling and banking, etc.), were also used to facilitate market development. Despite several supportive policies and incentives, the rate of spread of bioenergy technologies has remained low. About 3.83 million household biogas plants were installed till 2006 against a potential of 12 – 17 million. The total number of large community and institutional biogas plants installed until 2006 was 5,500 for the treatment of organic solid waste such as food waste (Ranjit et al., 2013; Viswanathan and Kavi, 2005). Implementing the aforesaid approach in diseminating biogas solutions has the aim of tracing the path towards the improvement of the national biobased economy. The slow rate of spread has been attributed to the existence of several barriers, which have been identified in several studies. To improve the spread of BETP it is essential to address the most important of the barriers and develop appropriate measures to overcome them.

3.7 Barriers: Factors hindering spread of biogas plants

3.7.1 Limited capacity to assess, adopt, adapt and absorb scientific options

Implementation of biogas solutions was primarily targeted at rural areas, who have limited capacity and knowledge to absorb these technologies. Due to the intervention of governmental subsidy schemes, the rural community gradually adopted the biogas technologies for the waste treatment and consequent biogas generation. Nevertheless, due to the increasing waste quantities and its associated disposal issues, biogas technologies are pursued by the urban bodies as well (Tiwari et al., 1988). A general resistance to change is noted, which is magnified due to lack of capacity to understand, adopt and adapt the technologies for improved benefits. The limited capacity towards the technological shift is not only linked to its use but also to its production and maintenance (Ravindranath and Ramakrishna, 1997). The limitations in knowledge and manufacturing capacity resulted in no significant innovation. However, nowadays, it is possible to record modern high rate plants, characterized by affordable costs and benefits.

3.7.2 Insufficient information and financing possibilities to assess the technological needs

The requirements correlated to technology differ from one stakeholder to another. For example, a user of a cooking stove might have different information needs as compared to a manufacturer of stoves. The generic approach of disseminating information on biogas solutions in rural and urban areas had only limited impact and hence the access to information also remains a key issue. High initial capital costs and investments associated with mass manufacturing of reactors and its accessories are additional barrier in promoting biogas solutions. Both users and manufactures have a very low initial capital; this fact is further accentuated by the rigid lending procedures that limit access to financing even when financing is available on standard norms. Large part of farmers are unaware of the possible ways in which farm and cattle wastes could be efficiently utilised. In this context, government agencies and NGOs are major stakeholders in creating awareness. Moreover, many farmers find difficult to bear the construction and operational costs of setting up the digester (Ravindranath and Ramakrishna, 1997). This again requires the government to introduce incentives (like soft loans) and subsidies to enhance the approachability of the technology and thus increase its market diffusion.

3.8 Sustainability of decentralized biogas solutions

The efficiency of solid waste management could be enhanced by the installation of decentralized small and full scale biomethanation systems (Sonam et al., 2014). Decentralization offers several advantages, such as allowing immediate implementation of decision taken on site, and exploiting a higher degree of organic content of the OFMSW, available from the avoidance of possible degradation during transportation (MSW rules, 2000). Operational cost occurring in decentralized biomethanation systems is low compared to centralized biomethanation systems, since decentralization completely avoids the transportation costs and accidental hazards (Braimakis et al., 2014). Transportation cost linked to centralized approach would be reduced if the MSW collection system was designed focusing on local and decentralized management. The avoided cost will allow the municipalities to focus more on disseminating available green technologies for a safe waste treatment and disposal, thus contributing to achieve sustainable development. On the other end, employees can be empowered by having more autonomy to make their own decisions, giving them a sense of importance and making them feel as if they have more input in conducting the organization. Also, It allows them to make better use of the knowledge and experience they have gained and implement some of their own and creative ideas. The common people in rural areas who are ignorant about all these treatment methods and technologies could acknowledge the improvements occurred in their respective areas and support the government in undertaking solid waste management projects by implementing sustainable and decentralized biogas solutions.

4. CASE STUDY

Several institutions, research organizations and companies took up an initiative to develop high rate biodigesters for the treatment of organic solid wastes. Indian companies offering different biogas technologies, characterized by various working principles and design aspects (e.g. capacity, type of waste, output etc) is shown in Table 2. Subsequently, a case study has been presented to elaborate in detail the benefits (technical and economic benefits in terms of biogas and digestate production and utilisation) associated with decentralized high rate biogas plants for the treatment of waste at source of production.

4.1 High rate biometanation of organic solid waste based on Anaerobic Gas lift Reactor (AGR) Technology

CSIR-Indian Institute of Chemical Technology (IICT), Hyderabad is a research organization extensively working on transnational multidisciplinary research to resolve the societal issues. Considering solid waste treatment and disposal as a primary issue that should be be resolved, CSIR-IICT has made intensive research efforts to develop a novel high rate biomethanation technology called "ANAEROBIC GAS LIFT REACTOR (AGR)" (PT-609/0207NF2012) for the generation of biogas and digestate from organic solid waste (CSIR-IICT, 2014; Gangagni Rao and Swamy, 2012). This technology is superior in terms of biogas and digestate production as it incorporates novel pre and post processing processes. A pilot plant based on this technology has been installed at Toofran near Hyderabad and operated with various sustrates like poultry litter, cattle manure, napier grass, cooked and uncooked food waste to understand the performance of the digester in terms of biogas and digestate production, volatile organics degradation rate, hydraulic residence time etc. Subsequently, the technology has been licensed to M/s Ahuja Engineering Services Private Limited (AESPL), Secunderabad, (AESPL, 2017) that executes projects on turnkey basis. The Akshaya Patra Foundation is a non governmental organization (NGO) operating under the aegis of ISKON, and serves mid-day

TABLE 2: Comparative analysis on biogas solutions offered by different companies (Begum et al., 2017; GPS Renewables, 2017).

Company Name	Capacity (kg/day)	Type of kitchen waste	Working principle and design	Power consumption to operate the plant (kWh/day)	Products	Biogas production (m^3/day)
M/s AESPL	1000 and above	All type of organic waste (cooked and uncooked food waste, poultry litter, cattle manure, organic fraction of municipal solid waste)	All type of organic waste (cooked and uncooked food waste, poultry litter, cattle manure, organic fraction of municipal solid waste)	12 - 15	Biogas and Digestate	120 - 140
M/s GPS	200 - 2000	Cooked food waste	Cooked food waste	20 - 25	Biogas	90 - 100
NEERU	100 - 1000	Animal manure, kitchen waste	Animal manure, kitchen waste	10 - 15	Biogas and Digestate	50 - 60
Mailhem Ikos	100 - 1000	All types of organic waste including animal manure, organic MSW	All types of organic waste including animal manure, organic MSW	20 - 25	Biogas	50 - 60
Xeon Waste Managers LLP	250 - 2000	Cooked food waste	Cooked food waste	20 - 25	Biogas	70 - 80

meals to children in schools (TAPF, 2018). Several large-scale kitchens are set by TAPF across the country generating 1 Ton of organic waste per day. M/s AESPL, under the technical guidance of CSIR-IICT, has installed a plant at one of the kitchens of TAPF, in Bellary in Karnataka in 2015, for the generation of biogas and digestate from food waste (cooked and uncooked) produced by the kitchen, exploiting AGR Technology. Approximately 1000 kg of food waste (400 kg cooked food waste, 600 kg uncooked food waste) and 500 L of organic wastewater (rice water/ganji) is used for the generation of 120 to 140 m^3 of biogas per day to replace 50 to 60 kg of LPG (Kuruti et al., 2017).

Equipment required for the installation of biogas plant:

- *Major equipment*: Anaerobic digester with accessories.
- *Pre and post-treatment accessories:* Waste crusher/shredder, conveyor arrangement for loading waste into crusher, process pumps, biogas scrubber, biogas gasomether, biogas compressor, biogas pressure tank, biogas flare unit/gas blower.

The aim of this plant is to serve as a sustainable technology to provide a suitable waste disposal system to the kitchen as well as utilize the clean fuel (biogas) produced as a cooking fuel to replace LPG consumption and promote decentralized solid waste management through biogas installations. The plant runs like a closed-loop system where the kitchen's waste is converted into biogas and fertilizer on day-to-day basis. Based on the success at Bellary and satisfaction of beneficiary in terms of product yield, payback period, operation and maintenance and other intangible benefits achieved, TAPF has given consent to install and commission the biogas plants at its kitchen at Hubli in Karnataka, Ahmedabad, Surat and Bhavnagar in Gujarat. The techno-economical and the economic benefits created by the biogas plant is shown in Table 2. The full-scale biogas plant described above is shown in Figure 1.

5. FUTURE PERSPECTIVE ON DECENTRALIZED BIOGAS SOLUTIONS

Sustainability of a decentralised waste management and biomethanation system requires satisfaction of a minimum of three sustainability bottom-line factors, namely: economic, environmental and social sustainability. High rate biomethanation plants can be introduced within the community (colony, housing society, institution premises, local area etc.) through Resident Welfare Association (RWA), Community Based Organization (CBO), Non-Governmental Organization (NGO), Advanced Locality Management (ALM), Self Help Groups and so forth. However, certain factors limit its widespread application in rural societies in India. The federal and stage governments need to be more proactive in providing easy access to these technologies to the poor farmers. The policies and support of the government are decisive in persuading the farmers to adopt such technologies and to make a transition from wasteful traditional approaches to efficient resource utilization. The concept of creating biobased circular economy through biogas solutions unites the aspirations of delivering economic growth, job creation and protecting the global environment, which is under pressure, with eco friendly waste to energy systems. If the people in rural communities are aware about all the consequences of excess waste generation and the benefits of waste treatment at source, then the burden on local municipal bodies would fall. The central and state governments may jointly demonstrate how decentralized approach can work by setting up at least one decentralized waste processing facility in each state at full government cost and technical assistance and also utilizing it as a training ground and opportunity for other local bodies to follow. However, the journey towards a bio based circular economy has only just started, efforts need to be taken to overcome the barriers related to the spread of biogas solutions and enhance bio based circular economy by encouraging BETP.

CONCLUSIONS

It is worth concluding that the goal of strengthening bio-based economy is potentially related to biogas solutions with respect to solid waste management in several ways. Biogas solutions could contribute towards creating a bio-based economy provided that the importance and socio-economic benefits associated with biogas solutions is realised by the rural and urban population, citizens, policy makers and the respective governments. Among the existing technologies for waste treatment, anaerobic digestion (AD) plays a key role in reducing waste along with the generation of renewable energy as it mitigates direct and indirect GHG emissions, recycles nutrients in the form of organic fertilisers, prevents nitrogen leakage into groundwater and avoids the spread of harmful diseases through land filling. Valorization of organic solid waste by implementing decentralized biogas solutions in rural and urban India resolves the need for energy along with a potential solution for the disposal of wastes. Biogas solutions are generally versatile, flexible and cost efficient from a societal perspective and when adapted to local conditions may contribute to sustainable development as well.

TABLE 2: Technical features and revenue obtained from biogas plants based on AGR technology installed by M/s AESPL.

Quantity of food waste: 1 ton/day
Biogas generation: 120 to 140 m^3/day
Bio-manure generation: 150 kg/day
LPG replacement: 50 - 60 kg/day (4 domestic LPG cylinders)
Land area requirement for the plant: 55 m^2
Manpower requirement (semi-skilled): 2 people
Revenue/day from biogas = (4 LPG cyliners x USD 12) = USD 48 per day
Revenue/day from Bio-manure: 150 kg x USD 0.08 (8 cents) = USD 12 per day
Total Revenue per day: USD 48 + USD 12 = USD 60
Total Revenue per annum (considering 300 working days): USD 18,000
Capital cost – USD 46,153
Flat pay back of capital investment: about 2.5 years

Note: One USD = 65 INR; revenue created by the plant is calculated based on LPG replacement with biogas excluding biomanure sales.

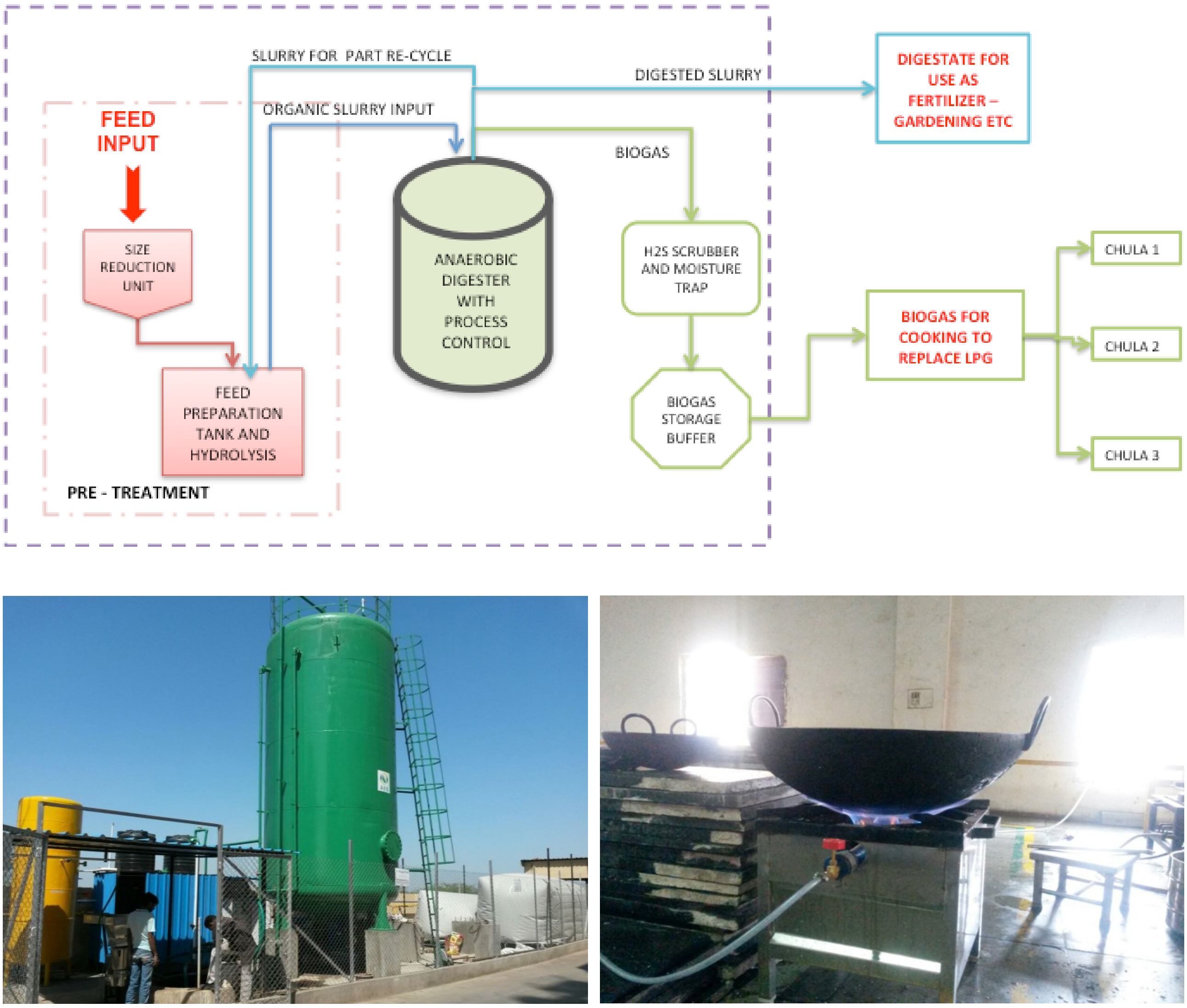

FIGURE 1: Biogas plant layout and full-scale installation at site based on AGR technology at the kitchen of TAPF at Bellary in Karnataka.

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