Section 5
Business Models and
Case Studies

Market Opportunities for Anaerobic Digestion of Livestock and Agro-Industrial Waste in India

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The Global Methane Initiative

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5. Business Models and Case Studies

India has the world's largest population of dairy animals, the majority of which are located at small-scale dairy farms. While the potential for biogas project development in India is substantial due to the availability of feedstock, projects can always fail due to a number of operational and financial challenges.

Historically, agricultural biogas projects in India have been owner-operated and comprised of household-scale systems that are primarily located in rural areas. These small systems have capacities ranging from 1 to 1,000 m^3 of biogas per day and are generally managed by individual households to generate cooking fuel. The Government of India announced the Sustainable Alternative Toward Affordable Transportation (SATAT) Initiative in October 2018 to reduce India's dependence on oil and gas imports by producing bio-compressed natural gas (bio-CNG) using agricultural residues, cattle dung, sugarcane press mud, municipal solid waste (MSW), and sewage treatment plant waste. It is anticipated that 5,000 projects will be developed in 5 years. Due to universal challenges facing digester development such as high capital costs, variable energy prices, and infrastructure hurdles, there is an increased focus on opportunities to share project risk and reward, and diversify project revenue sources.

This section of the market opportunities assessment discusses business models, from India and those in use world-wide, including key aspects of successful anaerobic digestion (AD) systems, potential owner and operator models, and diversification of revenue generation; and provides case studies to highlight successful business models.

5.1 Aspects of Successful AD Systems

Many factors need consideration to implement and operate an AD/biogas system. The following list briefly introduces the essentials for a successful farm-based digester project. The AgSTAR Project Development Handbook (EPA, 2004) developed for the United States domestic biogas projects identifies 10 keys to digester success, which are summarized in Table 18.

Table 18. Foundations for a Successful AD/Biogas System

Action	Desired Outcome
Plan for Success	Identify and define project goals. Specify the parameters to address and how to meet them.
Recruit and Secure an Experienced Team	Work with an experienced team to initiate and successfully implement your project.
Secure a Continuous and Quality Feedstock Supply	Identify all suitable feedstocks. Test them for biomethane potential and anaerobic toxicity.
Use Most Appropriate Technology	No AD technology can be used for all situations or feedstocks. The technology plan must match the feedstock type and amounts used.
Analyze Options for Most Favorable Biogas Use	Consider market availability, capital and operating costs, and potential revenue to determine the best use for biogas.
Assess Digestate Use	Determine the need for onsite use and consider external markets for products such as bedding, fertilizer, or compost.
Develop Off-Take Agreements	Establish off-take agreements for energy, digestate, and co-products, including the price, amount, and specifications for delivered products.
Evaluate Added Benefits	Consider climate, health, soil, sustainable food supply, community relations, and odor control.
Use a Sustainable Business Model	Not only should the project be cost-effective, it must meet your financial goals.
Plan for Operation and Maintenance	Good process and maintenance practices are key for optimal and uninterrupted operation.

5.2 Owner and Operator Models

There are a number of business models with respect to who owns and operates the AD system. Successful business models:

- Involve partners along the value chain, such as co-operatives, customers, suppliers, and processors
- Draw on strengths such as marketing, contracting, permitting, energy, design, or operations
- Search for common goals such as financial, public relations, or market expansion
- Evaluate third-party investment, ownership, and operation
- Look to traditional cooperative models for use with manure solids, nutrients, energy, or fuel.

General types of business model ownership structures may include:

- **Farmer owned and operated.** A farmer typically owns and operates a digester onsite and uses manure from the farm, at a minimum, as feedstock. In some cases, the farmer may accept manure or other organics from offsite, generally for a tipping fee.
- **Third-party owned and operated.** A site owner may receive a rental fee or a share of the project's net income, but the third party owns, operates, and invests in the digester. The third party may be a venture capitalist or an investment group specializing in green energy projects. The third party may also manage the feedstock.
- **Third-party operated.** A third party, who does not own the digester, operates the digester, manages the feedstock, and manages other aspects of the energy and effluent sale. The digester and feedstock can be owned by a single entity or many entities.
- **Hub and spoke.** This business model can take two general forms: centralized digester or centralized processing, either of which could be owned by a municipality or third party. It could also be part of a cooperative, which relies on a voluntary partnership of individuals that jointly own and democratically control the project.
  - **Centralized digester.** Feedstocks from multiple locations are collected and transported to a centralized anaerobic digester. It can be advantageous for communities to build one digester and distribute the biogas and digestate generated.
  - **Centralized processing.** Digesters at multiple locations send the biogas and/or digestate to a centralized processing facility. Biogas and digestate processing equipment can be expensive and a centralized processing facility could be a cost-sharing opportunity, lowering the financial burden for each entity.

5.3 Diversification of Project Revenue Sources

Business models, irrespective of ownership and operators, may also incorporate the following aspects to help improve project revenue and ensure economic feasibility of the project:

- **Codigestion.** As with sales of coproducts and biogas, a business model that includes codigestion of different feedstocks can offset costs and generate revenue for a facility with an anaerobic digester due to tipping fees and increased biogas production. Codigesting waste can help to diversify and financially stabilize a facility's business. For example, a digester built to process agricultural waste could also process organic MSW and the digester operator/owner could charge a tipping fee.
- **Value-added products.** Some owners/operators may develop innovative products in order to make their AD systems more economically feasible. For example, digestate can be composted and sold as a fertilizer. An emerging trend is to upgrade produced biogas to renewable natural gas (RNG), which can be used interchangeably with conventional natural gas.
- **Closed loop.** A biogas system can be a self-sustaining system when the feedstock generators, the biogas producers, and the energy and digestate users are all linked to use each other's products efficiently and economically (see Figure 32). For example, a dairy or community could provide cow dung or other organic waste to a biodigester, the electricity or biogas generated from the biodigester could be sold back to the dairy or the community. Similarly, biodigester could supply digestate to a farm as

fertilizer that could support the growth of fodder to the dairy, which would supply cow dung to the biodigester.

- **Cooperative/value chain inclusion.** The viability and success of projects can be improved if entities throughout the value chain invest in the digester and/or equipment, thus spreading the risks and rewards.

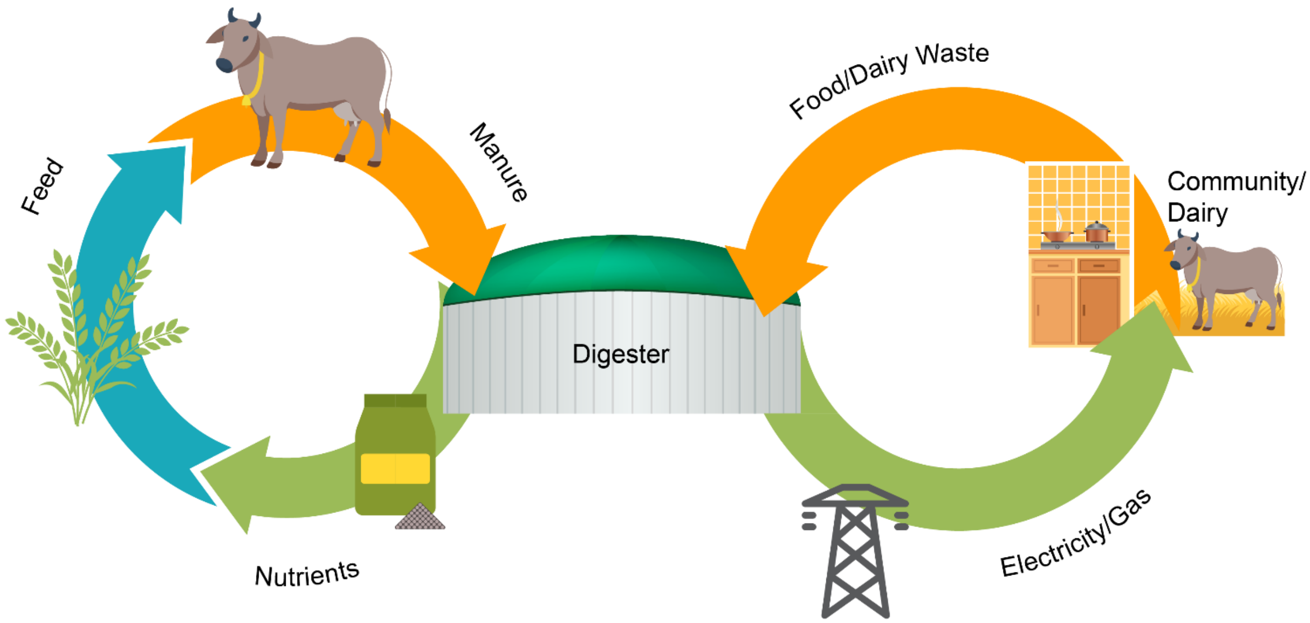


Figure 32. Closed Loop Biogas System

5.4 Case Studies

Case studies, summarized in Table 19, are presented in this section to illustrate different business models.

Table 19. Summary of Case Studies

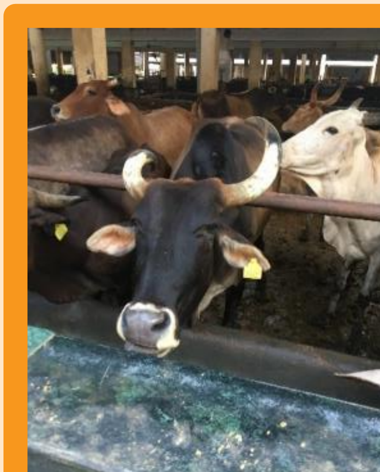
	Govind Goudham Gaushala	Haibowal Dairy Complex Project	Rohtak: Source Facility and Biocity
Biogas use	▪ Cooking fuel ▪ Electricity	▪ Electricity ▪ Bio-CNG ▪ Bio-CO_2	▪ Bio-CNG for cooking
Project benefits	▪ Environmentally friendly and sustainable waste disposal ▪ Income from fertilizer and savings on electricity ▪ Community independence ▪ Houses are cooler, light is reliable, and food can always be made	▪ Reduced risk of run-off and leaching nutrients ▪ Conversion of nutrients from organic to inorganic form ▪ Plant visibility nationally and internationally	▪ Income from fertilizer
Project start date	2014	September 2004	Unknown
Baseline system	Direct discharge	Direct discharge or manual collection for cow dung cake as fuel	Manual collection for cow dung cake as fuel
Digester type	Khadi and Village Industries Commission (KVIC) floating drum	Intermittently stirred tank reactors	Unknown
System designer	Unknown	Original biogas system: Entec Biopower Bio-CNG and bio-CO_2 expansion	Source facility
Digester inputs	Manure from 1,780 cattle	Manure from 80,000 dairy cattle	Manure from 2,000 cows
Biogas production potential	150 m^3 per tank	10,000 m^3/day	6,000 m^3/day
Generating capacity	40 kW	1 MW	Unknown
Project costs	44.5 lakh INR (71,000 USD) total cost, reduced to 14 lakh INR (22,000 USD) with subsidy from the Ministry of New and Renewable Energy (MNRE)	1,500 lakh INR (2.2 million USD) for demonstration project; 521 lakh INR (820,000 USD) for bio-CNG and bio-CO_2 expansion	N/A
Business Model Aspects	▪ Value-added products	▪ Centralized digester ▪ Value-added products ▪ Bio-CNG ▪ Considering codigestion	▪ Third-party operated ▪ Centralized digester ▪ Bio-CNG ▪ Value-added products ▪ Considering codigestion

Table 20. Summary of international Case Studies (continued)

	ARC Bio Fuel	Kern Dairy Biogas Cluster	Philippines Tube Digesters
Biogas Use	Bio-CNG (varies by end user)	▪ Electricity ▪ Renewable Natural Gas pipeline injection ▪ Bio-CNG for vehicle fuel	▪ Cooking fuel ▪ Electricity/lighting ▪ Vehicle fuel (on one example farm)
Project Benefits	Restore organic carbon content in soil through digestate fertilizer use	▪ Reduced risk of run-off and leaching nutrients ▪ Adds to the local economy	▪ Reduced odors ▪ Improved water quality ▪ Reduced cooking and electricity costs ▪ Fertilizer for farms
Project Start Date	January 2016	2013	July 2011
Baseline System	Direct discharge	Storage lagoons	Direct discharge
Digester Type	Continuously stirred tank reactor	Covered lagoons	Tube digester
System Designer/ Project Developer	CEID Consultants & Engineering Pvt Ltd.	4 creeks/California Biogas LLC (CalBio)	Environmental Fabrics, Inc. (demonstration system); Buklod-Unlad (subsequent systems)
Digester Inputs	Manure from cows and poultry	Manure from 100,000 cattle (approximate planned total)	Manure from pigs
Biogas production potential	5,000 m^3 per day	5 million diesel gallon equivalents (approximate planned total)	Varies by project
Generating capacity	1,847 kg per day	12 MW (approximate planned total)	Varies by project
Project costs	573.91 lakh INR (850,000 USD)	Unknown	Unknown
Business Model Aspects	▪ Centralized digester ▪ RNG ▪ Value-added products ▪ Third-party operated	▪ Centralized gas processing ▪ Codigestion ▪ Renewable Natural Gas	▪ Community AD cooperative for household-scale systems

5.4.1 – Govind Goudham Gaushala

In the Village of Hambran in the Ludhiana district of Punjab, a cattle shelter and neighboring school that once struggled with high energy costs and unreliable electrical availability are now generating their own power, thanks to AD. The small community of Govind Godham is home to 80 families and a cow shelter (gaushala) that cares for nearly 2,000 sick, injured, or retired cattle. Adjacent to the shelter is Ek Muskaan, a temple-run school that strives to eradicate poverty and slavery in the region. The biogas plant, installed in 2014, provides reliable electricity to keep the shelter machinery running smoothly and the lights on at the school, as well as cooking fuel for the shelter's kitchen. Savings from the electricity generation, in addition to income received from the sale of fertilizer, have allowed many improvements to be made to the shelter and school.



Govind Godham cow shelter

Project Costs and Revenues

The total cost of the plant, which was promoted by Punjab Energy Development Agency, was 4,450,000 INR (71,000 USD). Nearly 70 percent of that total cost was covered by the MNRE, which subsidizes biogas power. The remaining 1,400,000 INR (22,000 USD) was paid for through local fundraising efforts to collect donations. In 2015, the plant was fully operational.

Cart for transporting cooked meals to the community.

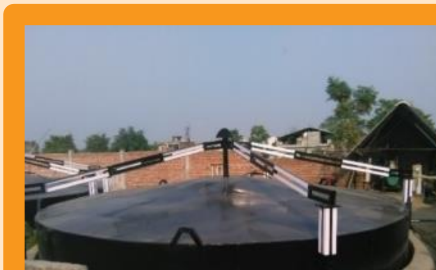
Ludhiana is an agricultural city, so the fertilizer produced from the plant is sold to generate additional income for the shelter, temple, and school. Each tanker load sold brings in about 500 INR (8 USD). Fertilizer is also used on farms at the shelter, which produce food and fodder for the cows to eat.

Cost savings from the self-generation of power in addition to the increase in funds resulting from fertilizer sales have provided significant benefits to the community. The Ek Muskaan school has expanded, with new classrooms and facilities for students. Many improvements have been made to the cow shelter, including the installation of fans to keep the animals comfortable during the summer and special accommodations for injured cattle. An onsite hospital for cattle and humans is now fully equipped with professional veterinarians and medicine. Children are happy because their houses are cooler, light is always available, food can be made at any time, and the shelter machinery is in good condition.

System Components and Operation

The Govind Godham biogas plant consists of the following elements:

- Mixing pit
- 3 KVIC floating drum digester tanks
- 50 kVA biogas engine
- Biogas stoves



One of three floating drum digesters

Shelter staff cart cattle manure via wheelbarrows from the stalls and deposit it into a mixing pit, where it is combined with water to reduce its viscosity. From the pit, the mixed slurry is sent through one of three channels, each leading to one of three digester tanks. Only one tank operates at a time, so valves to the non-operating tanks remain closed. Biogas produced in one tank is sent directly to the community kitchen, where food is prepared for students, shelter workers, and other community members and visitors. Gas from another tank is passed through a 40-kW generator, which produces enough electricity to run the fodder cutting machines used to make food for the cattle, as well as fans for the cows and fans and lighting at the school.

The floating drum model is the oldest digester type in India. It consists of an inverted steel gas storage drum, fitted over a deep well into which the manure slurry is piped The drum moves up and down around a guide pipe, depending on the volume of gas collected within the drum. Advantages of this model include a steady gas pressure (due to the drum movement) and the ability to judge gas volume based solely on the position of the drum.

One of the kitchen's biogas powered stoves

40-kW generator

5.4.2 – Haibowal Dairy Complex

Commissioned in 2004, the Haibowal Dairy Complex high-rate AD project demonstrates large-scale power generation from cattle manure in India. Located in Ludhiana, Punjab, the 1-MW project was the first of its kind and has proven the technical feasibility of developing such projects for energy recovery as well as producing large quantities of enriched organic fertilizer and reducing GHG emissions.

Haibowal Dairy digester tanks and biogas storage unit

Project Background

The Punjab Energy Development Agency (PEDA), in conjunction with India's Ministry of New and Renewable Energy under the United Nations Development Programme (UNDP), initiated this project to:

- Demonstrate the viability of large-scale energy recovery from cattle manure
- Reduce GHGs
- Improve water quality
- Help address the region's increasing energy needs.

Municipal Corporation, Ludhiana, allocated 2.4 acres of land for the project, and Entec Biopower (Austria) designed the system. Work on the project began in April 2002, and the project was successfully connected to the grid in September 2004. The Punjab State Electricity Board laid the transmission line and committed to a power purchase agreement at a rate of 3.49 INR/kWh (5 cents/kWh), which was the amount assigned for the project as the project was set up with financial support from MNRE and the Government of Punjab; this amount is expected to cover only operating expenses. The total capital cost for the demonstration project was about 150 million INR (2.3 million USD), which was covered by a grant from the Government of India and the State Government of Punjab.

After the demonstration project was successfully operating, PEDA contracted out the biogas plant operation and maintenance to several companies. From 2012 to 2016, the Dutch company DSM Biogas improved the facility's operational practices by providing regular training for support staff, servicing and repairing electrical and mechanical equipment to increase reliability, and streamlining feedstock supplies from the local dairies.

In 2015, to improve its commercial performance in light of reduced power prices, DSM Biogas established a state-of-the-art bio-CNG plant and a CO_2 recovery plant. The new installations cost about 60 million INR and opened a new revenue stream through the sale of bio-CNG and its byproduct CO_2.

Improving Water Quality, Reducing Emissions, and Harnessing Renewable Energy

Manure from approximately 80,000 cattle on adjoining dairies at the complex serves as the feedstock for two 5,000 m^3 tank reactors. This waste would otherwise be discharged into Buddha Nullah, a seasonal stream that passes through the highly populated Ludhiana district before draining into a tributary of the Indus River. The plant is estimated to prevent 1.7 billion liters of manure wash from being discharged annually. Furthermore, the freshwater requirement for mixing is reduced by about 1.6 billion liters each year through water recycling.

Biogas engine genset

The digesters produce 47 tonnes per day of fertilizer, which is sold by PEDA for 1,000 INR (15.62 USD) per tonne. This fertilizer has the potential to replace the harmful, urea-based fertilizers that would be applied to 800 acres of land.

The system reduces GHG emissions by an estimated 4,800 $MTCO_2e$ annually and generates approximately 6 million kWh/yr of clean, renewable electricity. The plant also produces bio-CNG, a fuel that may be sold as an alternative to fossil fuels.

System Components and Operation

The following elements comprise the high-rate bio-methanation plant at Haibowal Dairy Complex:

- Two intermittently stirred tank reactors
- Biogas storage unit
- Biogas engine genset
- Biogas upgrade system
- Storage unit for upgraded biogas
- Compressor
- Liquid CO_2 tank
- Flare.

Flexible storage unit for upgraded biogas

The plant accepts about 160 tons of cattle manure per day, and is exploring other potential feedstocks including spoiled cattle feed, poultry waste, and pressed mud (waste from sugarcane processing). The plant is designed for a daily feed of 230 tonnes (consisting of about 16% total solids) of cattle manure per day. Recycled water is added, and the manure slurry is stirred intermittently in the digester tanks based on the biogas-induced mixing arrangement. Generated biogas is stored in a 1,000-m^3 bell-and-shell-type storage balloon made of neoprene-coated nylon fabric. Waste heat recovered from the engine is directed back to the mesophilic digester tanks to keep them operating at 37°C. Separated solids from the digesters' effluent contain less than 70 percent moisture and are sold as organic fertilizer.

Bio-CNG compressor unit

Biogas Use

In addition to being the country's first large-scale, manure-based biogas power plant, this facility is also the country's first plant to separate biogas into methane and CO_2 gases for domestic or commercial use. The trial period for bio-CNG filling began in July 2017. The facility has the capacity to generate 4,000 kg of bio-CNG per day and can fill 40 10-kg cylinders at a time. The cylinders are sold to customers at 450 INR (7 USD) each.

Bio-CNG can be used in many applications as a substitute for imported CNG as well as liquefied petroleum gas (LPG). The purified CO_2 can be used in the beverage, textile, or the welding industry; or for other applications such as in dry ice and fire extinguishers.

5.4.3 – Source Facility and Biocity, Rohtak

Source Facility and BioCity are complementary companies founded by Abhishek Handa and Akshay Asija, entrepreneurial project developers based in India. The companies were established to address the operational challenges of biogas systems and meet the energy and fertilizer demands in India. Source Facility is a third-party operator of biodigester systems and manages the day-to-day operations of large-scale biodigesters. The company develops key relationships with local farmers and waste producers to source feedstocks, and manages the digester operations and production of high-quality biogas. BioCity markets and distributes the biogas and biofertilizer products to end users in rural and urban communities across India. It is an innovative business model that improves projects' economic, environmental, and social output through the entrepreneurs' involvement in all stages of biogas and biofertilizer production and use.

Source Facility

Source Facility works with owners of existing or planned biodigesters by:

1. Aggregating and supplying feedstock, including cow dung, sugar cane milling residue (press mud), and other agricultural residues
2. Analyzing feedstock chemistry to optimize biogas production
3. Providing an onsite technician to ensure proper operations
4. Building relationships with local farmers and waste production facilities to source feedstocks, and creating new jobs and income for rural communities.

Biodigester

Source Facility currently operates four biodigester facilities in India. Its facility in Rohtak, Haryana, has a design capacity of 80 tonnes/day. It processes manure from up to 2,000 cows from farms within 20 km of the project, and can produce up to 6,000 m^3 of biogas per day. The project can also codigest press mud from sugar cane mills and other agricultural residues.

BioCity

BioCity markets and distributes biogas and biofertilizer produced by the facilities operated by Source Facility. BioCity supports local communities by:

1. Providing cylinders of compressed biogas to local restaurants for cooking, manufacturers for production fuel, and others for vehicle fuel
2. Providing logistical support to transport the products to end users
3. Providing technical support to end users to ensure safe use of the gas
4. Meeting the fertilizer needs of rural and urban India.

Cylinders with compressed biogas

Source Facility and BioCity contribute to methane mitigation by capturing and using biogas from cow dung and agricultural residue. Additionally, because their projects offer an alternative use for crop residues that are typically burned in fields, they are helping to reduce black carbon emissions and protect local air quality.

Manure from digestate

5.4.4 – ARC Bio Fuel Private Limited

In the Barnala district of Punjab, India, ARC Bio Fuel Private Limited operates a bio-CNG and fertilizer plant that runs on manure. Incorporating India's first anaerobic digester with a double membrane cover, the plant was installed by CEID Consultants & Engineering Private Limited (CCEPL) and became operational in January 2016. It is a producer and supplier of bio-CNG and organic fertilizer.

Arc Bio Fuel CSTR

Plant Profile

The plant accepts 119 MT per day of cow and poultry manure from surrounding farms and produces over 1,800 kg of bio-CNG daily. With no pipelines available for distribution, the plant sells small canisters of CNG to end users such as commercial kitchens or industrial manufacturing facilities. Currently, Arc Bio Fuel has around eight customers.

The solid digestate from the plant's Continuously Stirred Tank Reactor (CSTR) anaerobic digester is packaged and sold as "Biovy Organic Manure." This product is composed of approximately 60 percent cow manure and 40 percent poultry manure. It is 1.5 to 2.0 percent nitrogen, 0.8 percent phosphorus, and 0.8 percent potassium (Arc Bio Fuel, Undated). The use of this organic fertilizer increases the organic carbon content of the soil.

MNRE, in collaboration with PEDA and Punjab National Bank, provided support for this project. MNRE and PEDA covered 20 percent of the project's capital costs.

System Components and Operation

ARC Bio Fuel's system consists of the following elements:

- Mixing pit
- CSTR
- Biogas storage bag
- Pressure swing adsorption system for biogas purification
- Bio-CNG cylinder cascades.

Cow and poultry waste are brought to the plant and placed in an intake pit, where it is mixed and pumped into a feeding pit. From the feeding pit, it is pumped into the plant's CSTR AD system. The digester is heated by an internal concentric-tube heat exchanger. Hot water is circulated through the heat exchanger by a central heating pump. Agitators inside the tank mix the substrate to distribute the nutrients in the biogas digester uniformly, to form a suspension of liquid and solid parts, to avoid sedimentation of particles, to ensure uniform heat distribution, to prevent foam formation, and to enable gas lift from the fermentation substrate at high dry matter contents.

Arc Bio Fuel Biovy Organic Manure

Source: Arc Bio Fuel, Undated.

Biogas is collected at the top of the tank and is pumped to a separate gas holder. The biogas flow is measured from the double membrane gas holder via low-level condensate traps. The gas holder is inflated by an air blower and pressure is maintained at a constant level.

The biogas produced by the plant's CSTR is purified using pressure swing adsorption. The purified gas is compressed and bottled into cylinders. One cascade of cylinders is able to hold around 150 kg of CNG. This bio-CNG is sold for cooking and heating uses.

The digestate is withdrawn from the base of the digester. The amount of digestate discharged and the time between each discharge is variable and can be adjusted by the operator.

Biogas purification system

Arc Bio Fuel bio-CNG cylinder cascade

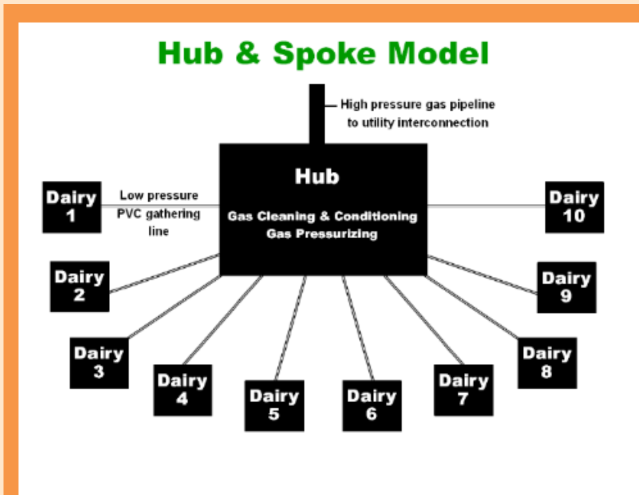
Bio-CNG being used for cooking

5.4.5 – Kern Dairy Biogas Cluster

In the United States, the State of California has 1.7 million dairy cows and 1,400 dairy farms. The state produces 20 percent of the United States' milk. Because of the concentration of farms in California and the incentives available for renewable energy projects, there is a good opportunity for AD project development. The Kern Dairy Biogas Cluster represents a business model that could translate to the Indian market.

Project Overview

California Biogas LLC (CalBio) was founded in 2006 to focus on dairy biogas in California. The group identified a cluster of 15 modern, large dairy farms in Kern County, California. CalBio is working to develop AD projects on these farms, which typically manage their manure in uncovered lagoons. Once complete, the project will be the state's first "hub-and-spoke" dairy digester cluster.



Planned Kern Dairy Cluster Project

As of August 2019, four systems are operating, including a covered lagoon system at the Old River Road Dairy, which is the largest dairy digester in California, accepting waste from over 15,000 dairy cows. It began operating in 2013 and includes a two-cell lagoon digester where it codigests manure and food waste. It currently uses a 2-MW generator to produce over 16,000 MWh of renewable electricity per year, which is exported to Pacific Gas and Electric's electricity distribution grid. Three additional farms in the cluster began operating covered lagoon digesters in January 2018. Each of these sites has a 1-MW reciprocating engine generator set for electricity generation. A second phase is planned in which generated biogas will be sent via low-pressure polyvinyl chloride (PVC) pipelines from each farm to a centralized hub for gas cleaning, conditioning, and pressurizing. From there, the upgraded gas will be injected into the local utility's natural gas pipeline or condensed for use as transportation fuel.

Lakeview Farms, one of the three most recent operating digester sites, is located within an 8-mile radius of 11 other diaries. It will serve as a mini-hub for electrical generation and a spoke for gas production. Seven new digesters are currently planned for the fuel-based phase of the cluster project, all of which will serve as additional spokes for biogas production. Of these, three digesters are in progress and expected to be completed in 2019.

Incentives and Funding

This project is receiving state-level incentives for construction, including pipeline construction and grants. For instance, the California Department of Food and Agriculture (CDFA) Dairy Digester Research and Development Program awards competitive grants to implement dairy digesters that result in long-term methane emission reductions on California dairies and minimize or mitigate adverse environmental impacts. In 2015, CDFA awarded a total of 4.8 million USD to the 3 Kern Cluster digesters that were most recently completed. The total cost of the three projects was 26.5 million USD. In 2017, CDFA awarded another 7.9 million USD for the next three digesters expected to reach completion in 2019. Projected costs for these three digesters total 22.1 million USD. There are also revenue incentives including the California Low Carbon Fuel Standard and the U.S. Renewable Fuel Standard.

5.4.6 – Philippines Tube Digesters

The 1991 volcanic eruption of Mount Pinatubo severely impacted croplands in the surrounding Philippine provinces. Local farmers in the province of Batangas, seeking to reestablish their farms, joined together to form the Buklod-Unlad Multipurpose Cooperative in 1992. Buklod-Unlad means "Unity for Progress."

With initial capital of only $100 and 44 members, the cooperative sought to support members by providing micro-loans. Today, with more than 2,000 members, the cooperative continues to help its members, not only with loans, but also with technological support to alleviate poverty and foster sustainability. The cooperative's mission is to better members' lives, alleviate poverty, promote family well-being, and maintain harmony within the community and the environment. With support from national and international partners, Buklod-Unlad began introducing AD technology to its members in 2011. This project represents a cooperative business model that could be implemented in the Indian market.

Cooperative Profile

The cooperative operates a swine breeding farm, a feed mill, and administrative offices. Through its "Paiwi" pig finishing project, the cooperative provides capital and 30 piglets to members who agree to raise the pigs per cooperative guidelines. The cooperative aids members in all areas of pig production, including financing, genetics, equipment, feed, and marketing; and the cooperative and the farmers share the proceeds from the market sales of the finished pigs and any offspring.

In consultation with the Global Methane Initiative, the Bureau of Animal Industry, the University of the Philippines, the Development Academy of the Philippines, and the Department of Science and Technology, Buklod-Unlad determined that tube-bag anaerobic digesters would be a cost-efficient and effective technology given the average size of member farms (approximately 30 pigs). To date, the cooperative has installed more than 20 tube-bag digesters both at its corporate breeding farm and at member farms. It has also assisted another cooperative (in Bulucan) with the installation of 4 tube digesters (2.2 diameter x 15 meters) and 2 gas holders on a farm with 500 sows.

AD System Installed at Bulucan Farm Cooperative

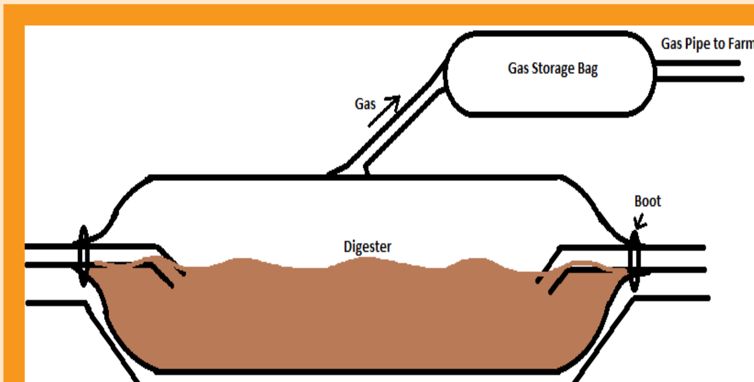
System components

While there is some variation in the individual systems, the digesters constructed by Buklod generally consist of the following elements:

- Mixing pit (optional)
- Tube bag digester
- Biogas storage bag
- Biogas engine (some sites)
- Gas handling system
- Biogas stove.

Mixing Pit (top) and Tube Digester (bottom)

Waste from the pig housing flows via a gravity conveyance system to a mixing pit. The mixing pit allows for the addition of more water if the waste is too thick for the digester. Waste is fed via pipe to the digester, which consists of two separate, tubular bags. Waste is collected in the first bag, and generated biogas flows to the second bag, where it is stored before exiting via an outlet pipe to the farm.



Simplified diagram of tube digester

Buklod used linear low-density polyethylene (LLDPE) geomembrane material for construction of both the tube bag digesters and the biogas storage bags. This material is flexible and easy to handle. Because the material can be rolled up or folded, Buklod can fabricate the digesters in its warehouse and transport them to the farm locations. Unlike other materials (such as PVC), this material offers resistance to ultraviolet light and can stand up well under intense heat and sun.

Biogas Use

All participating farms use the generated biogas for cooking. On Buklod's corporate site, the system generates enough cooking fuel for three families, in addition to powering an engine that provides lighting for the farm. Buklod retrofitted a car engine to run on the biogas generated from the digester.

The three families no longer need to purchase liquefied gas at a savings of approximately $5 per month. On the downside, the untreated biogas has resulted in some corrosion to the metal roof.

5.5 References

Arc Bio Fuel. Undated. Biovy Organic Manure. Manufacturers, Suppliers & Exporters. Arc Bio Fuel Private Ltd. Available: https://5.imimg.com/data5/HV/MI/MY-2918608/bio-cng.pdf. Accessed 5/29/2019.

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