D-Lab Waste
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Angela Hojnacki, Luyao Li, Nancy Kim
Claire Markgraf, Drew Pierson

Biodigester Global Case Studies

The following report consists of several case studies on biodigester systems from around the world. The research was conducted by a team of students from D-Lab Waste Fall 2011 in order to brainstorm ideas for the implementation of a large-scale biodigester in partnership with Waste Ventures, in India. Our team gathered data on biodigesters located in five different parts of the globe, including China, Brazil, Central America (Costa Rica and Honduras), India, and the United States. We gained a broad understanding of the technology and we learned that the types of biodigesters (in terms of size, construction, supply, model, use, etc) vary widely, even within the same country.

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Overview

The motives behind the use of biodigestion are usually related to waste management (agricultural and food waste, animal or human manure, and other organic waste), or energy generation (in the form of biogas or electricity). An added benefit to biodigestion is the leftover high-grade organic fertilizer that can easily create value in agricultural areas, where biodigesters are typically used.

The size, cost and output of the biodigesters we researched ranged from small, single-family use, to large scale industrial production that generates millions of cubic meters of biogas per year. There are many different business models for the biogas produced, including typical uses such as on-site use, power generation, and direct sale. Some innovate uses include a model for purified biogas as a car fuel in retrofitted taxis,

There are several "models" of biodigesters used around the world, including the Canadian, the Indian, and the Chinese. India has many examples of successful small-scale biodigesters, including the floating drum model and the fixed dome model. As a cleaner alternative to wood stoves, these biodigesters are popular in rural India and other countries, and are typically designed for single families or small communities.

As more communities are driven to investing in "greener" technologies, biodigesters provide a relatively simple solution for waste management and energy production. Even in countries like the United States, that have a climate least suited for this technology, the use of biodigesters is growing.

Some of the main challenges faced when implementing the use of any biodigester include proper material use, operation, and maintenance. Proper training and quality control, along with an adequate feedstock and end use, all within the context of the local community and climate, are necessary for a successful biodigester.

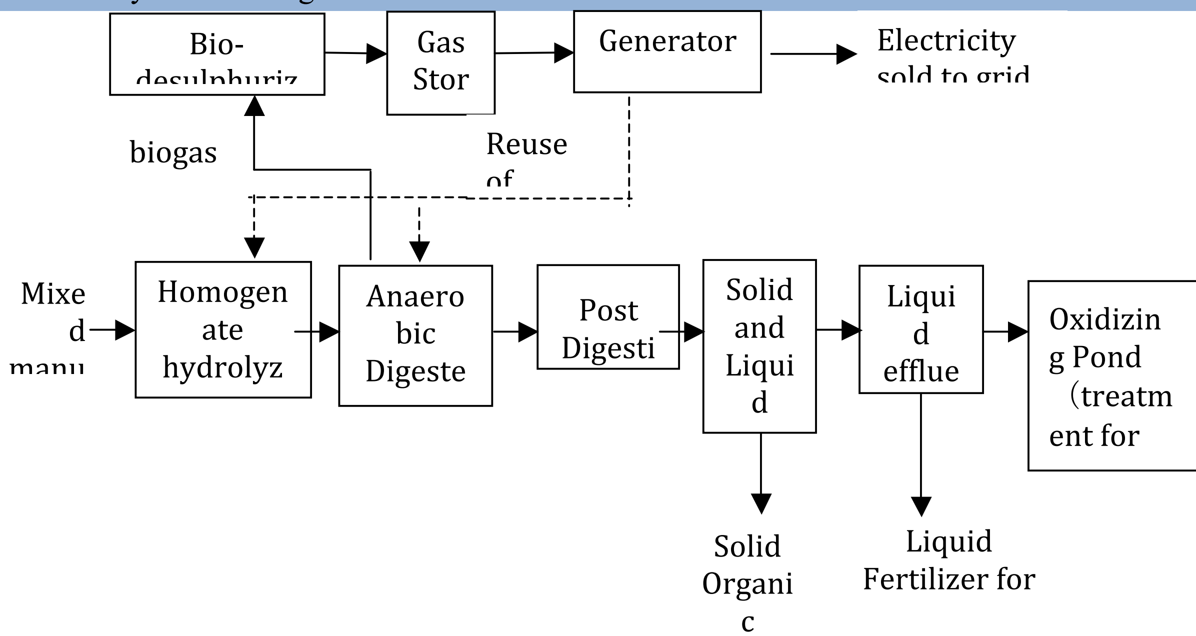
The following sections are divided by country, and we present one case study for each business model with background, facility specifics, investments and the input/output for each case. For more information, contact the DLab Waste team at biodigestors@mit.edu.

China

According to our research, there are three main business models for existing medium-to-large scale biodigesters in China, including:
a) direct sale of biogas;
b) biogas generators → sell electricity to grid;
c) intensive animal farm circular agriculture
Additionally, the use of purified biogas as a fuel is an emerging model in China.

The following case studies can be used as a general review for existing Chinese medium-to-large scale biodigesters, providing a few options for similar development initiatives in other developing countries.

General Layout of a Biogas Plant



Case Study #1 Central Biogas Supply System

Project

Beijing Fangshan District Doudian Village Central Biogas Supply System

Context

Animal farms in rural areas are usually lack of treatment for the large amount of animal waste produced each day. Meanwhile the local villages are not connected to the national natural gas grid so they have to either by LPG tanks or rely on burning wheat straw for cooking fuel. Several large-scale biodigesters has been build near rural villages, using cow dung as the main feedstock and providing biogas to villagers at a discounted price.

Large scale biodigester directly piping biogas to household cooking stoves

Purpose of Implementation

Treatment of cow dung for intensive cow farms, cooking fuel and heating

Type

Pretreatment -> Upflow Solids Reactor or *Continuous-Stirred* Tank *Reactors* (CSTRs) -> purification -> gas supply

Initial Investment	Tank Volume
$1 million	1100m^3

Input

44 tons of cow dung/day (~1000 cows)

Output

Daily production of methane: 2000m^3; providing cooking as for 1900 households
Effluent: sold as organic fertilizer to local farms

Use

Cooking stove – pipe directly from digester facility and connected to natural gas cooking stoves

Economic Benefits/Profitability

User pay by IC card at the price equivalent to 30 US cents per m^3, 20% cheaper than market natural gas price.

Case Study #2: Power Generation

Project

Beijing Yanqing Deqingyuan Eco-Garden 2 Trillian Watts Poultry Manure Biogas Generator

2 Trillian Watts Poultry Manure Biogas-Power Conversion System

Context

This facility is an example of the ultra-large scale biogas plants. It is built around the biggest layer hen farm in China, with a daily feedstock of 212 tons of chicken manure. The facility has been functional since 2007 and is recognized as UNDP/GEF Large Scale Biogas-power demonstration project.

The plan has achieved an annual green house gas reduction of 80,000 ton of CO2 equivalent. The waste heat from generator is transmitted to heating the digester and heating greenhouses, achieving a >80% of energy utility rate.

Purpose of Implementation

The facility was built as part of the clean energy movement initiated by the Yanqing County government. The goal was to control pollution and providing clean energy in meeting the goal of the central government.

Components

- Gas storage: low pressure double membrane dry balloon, cost 30%-60% less than wet tanks, no ice formation during winter times, low gas pressure ensures easy maintains
- Anaerobic digestion tank: four of 3000m^3 tanks
- Effluence storage pool: one of 4000m^3 and one of 50,000m^3
- Generator: two generator of 1064 kw with bi-production of heat and electricity
- Desulfurizing tower: one of 60m^3 and one of 120m^3

Investment

$10 million

Scale/Technical Specifications

- Input needs to have total Solids ≥10%
- Type: CSTR (*Continuous-Stirred* Tank *Reactors* (CSTRs))
- Digestion temperature 38℃

Input

Daily chicken manure of 212 ton (30% total solids)

Output and Usage

- Biogas production: 7 million m^3/ year
- Biogas generated power sold to grid, capability of 2 trillion watts and a total generation of 14 million kilowatt-hour/year
- Excess biogas sold as cooking gas to: 300 households
- Effluence: 180,000 tons, used on 6500 acre of apple and grape orchard and chicken feed production

Resource

http://tech.lanbailan.com/view.php?id=3309&cid=963

Case Study #3: Circular Agriculture

Project

Anhui Fuyang Jingwei Agro Recycling Co. Integrated Biogas Project

Context

This biogas plant is built on a warm as a key element in closing the wheat-pig-biogas-vegetable food production cycle. The plant uses animal waste to provide clean energy and fertilizer, reducing the cost of energy and fertilizer consumption and avoiding pollution due to mistreatment of animal waste

Type

This farm uses a combination of High Solid Underground red-sludge plastic digesters (300 m^3), and low solid buried tunnel digesters (300m^3).

Investment

$170,000

Scale/Technical Specifications

Gas tank: wet tank of 100m^3, steel and concrete structure

Input

Pig manure

Output and Usage

- Generator: 60kW, powering it's own factory and living regions
- Effluence used in it's own 800 veggie greenhouses

Economic Benefits/Profitability

The farm is nearly energy self-sufficient, with an annual saving of $30,000 on fuel and fertilizer.

Case Study #4: Purified Biogas as Car Biofuel

Project

Nanning Anning Starch Co.

Figure 3: Filling Taxi Gas Tank with Compressed Biogas

Context

The Naning Anning Starch Co. has huge amount of wastewater from their starch production and has put a lot of effort into researching for effective wastewater treatment systems. One the other hand, the Nanning government has an interest in investing in local clean energy projects. In early 2010, the Naning government and Anning Starch Co. signed an agreement to co-develop a large scale wastewater biogas digester and providing the biogas as car fuel for local taxis.

Up to now the project investors has already set up 2 gas stations in Nanning and has transformed 120 taxis to use biofuel. The treated waste water meets the irrigation water standard. The project has achieved an annual CO reduction of 20% and CO2 reduction of 99%.

Components

- Gas storage: low pressure double membrane dry balloon, cost 30%-60% less than wet tanks, no ice formation during winter times, low gas pressure ensures easy maintains
- Anaerobic digestion tank: four of 3000m^3 tanks
- Effluence storage pool: one of 4000m^3 and one of 50,000m^3
- Generator: two generator of 1064 kw with bi-production of heat and electricity
- Desulfurizing tower: one of 60m^3 and one of 120m^3

Investment

$6 million

Annual Revenue

$4 million

Scale/Technical Specifications

Use UPFLOW ANAEROBIC SLUDGE BLANKET - TURBULENT, LAMINAR, PULSATION (UASB – TLP) technology - most suitable for factories working with starch, tapioca and noodles.

Input

1000 ton/day of waste water from tapioca alcohol manufacturing and 5000 ton/day of waste water and solids from tapioca starch manufacturing (1 ton of starch or alcohol production requires 15 ton of water) with high organic content

Output and Usage

- Biogas production: 30,000m3/day. After purification: 21,000 m3 biofuel/day. Annual biofuel production of 6 million m3.
- Water: the waste water meets irrigation standards and is provided free for local farmers
- Biofuel for taxi:
  - 1 m3 of biofuel = 1.2 L gasoline
  - cost $0.5/m3 (50% cheaper than gas)
  - Taxi drivers save $15/day on gas, an annual saving of ~$5,500 (assuming a save of 3 cents/km). Considering the annual income of a taxi driver in Naning is ~$5,000, this project has doubled the taxi drivers income

Brazil

Strong agribusiness, potential carbon credits, and highly polluted waterways led to a strong interest in biogas production in Brazil thirty years ago. However, despite an ideal climate, biodigesters in Brazil have not been successful due to a lack of appropriate technical instruction and poorly chosen materials.

One of the most successful models, Sadia's Program for Sustainable Swine Production (3S), was started by a Brazilian company that produces chilled and frozen foods. The program partners swine farms with fish farms and renewable energy producers in order to run large-scale biodigesters for maximum value and profit.

Agribusiness – Agriculture, livestock, processing industry, and distribution

- 36% of Brazil's GDP
- 37% of all employment
- 43% of national exports
- World's second largest cattle herd

Resource

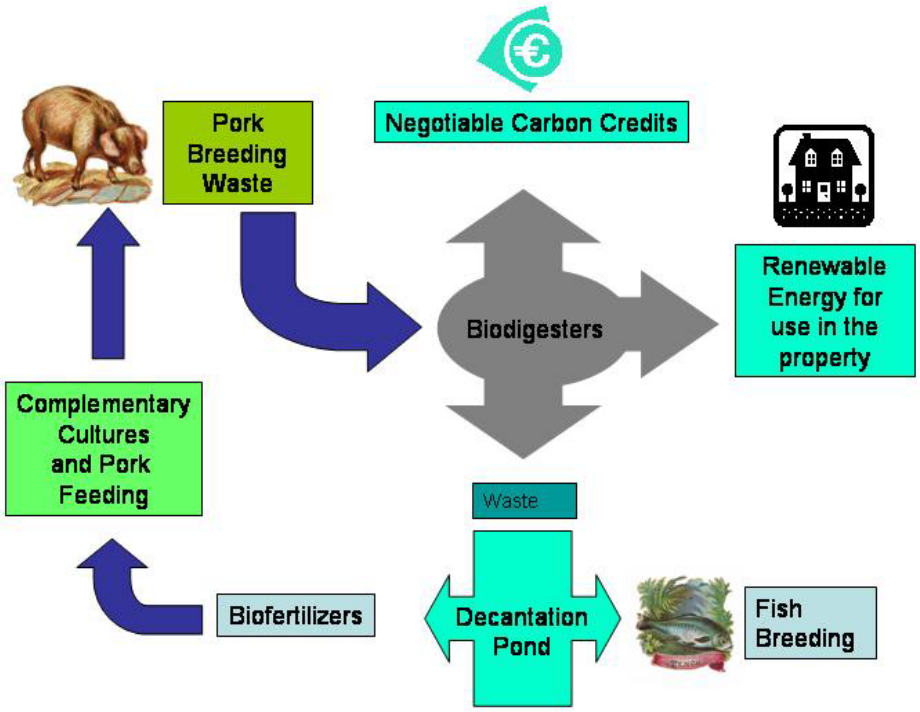
Source: Aparecida de Lima, Magda. "Methane to Markets Agriculture Subcommittee." Brazilian Agricultural Research Corporation. 01 December 2006

Case Study #1: Clean Development Mechanism
Project
Bom Despacho Farm, Minas Gerais
Context
The Bom Despacho Farm is located in a small city within the state of Minas Gerais. The biodigester installed there is the largest of a series of biodigesters implemented by AgCert, a Clean Development Mechanism (CDM) project developing company headquartered in Dublin, Ireland, working in Central and South America
Purpose of Implementation
This project was a series of CDM projects implemented in Minas Gerais used to reduce greenhouse gases and to improve the animal waste management – particularly pig manure
Type
Large-scale, mesophilic
Costs
Unknown – paid by AgCert, AgCert builds and commercializes biodigester until 90% of carbon credits are generated.
Construction Time
Unknown
Scale/Technical Specifications
Large-scale, produces enough energy to generate 100 kWh per day
Input
Pig manure from 500 pigs
Output
12,500 cubic meters biogas per day
Use
High-grade fertilizer
Economic Benefits/Profitability
Carbon credits, fertilizer, electricity generation. This particular project still faces problems in terms of long-term maintenance, so not one particular end use is currently being utilized.
Resource
http://www.ccap.org/docs/resources/538/Final%20Brazil%20Report%20(Nov%2021%202006).pdf

Case Study #2: Public-Private Partnership

Project

Sadia's Sustainable Swine Production Program (3S Program)



Context

Sadia is a Brazilian company that produces chilled and frozen food. Sadia started this project by enrolling their current swine suppliers to build and operate biodigesters for added income and less environmental impact.

Purpose of Implementation

This project was started by the company to reduce greenhouse gases emissions from over 3,500 swine producers in Sadia's supply chain, as well as to benefit from selling Carbon Credits

Type

Constructed by Sansuy and Avesuy

Costs

5-year pay back time

Project Plan

- Phase 1: Sadia enrolled 96% of its suppliers 2005-2007
- Phase 2:Biodigestors were installed and commissioned by Sadia, and producers were given instructions on how to operate it
    - Reduced GHG emissions and produced fertilizer
    - Partnered with both Sansuy and Avesuy to produce the biodigestor
- Phase 3: Equipment to burn and measure the amount of gas emitted was installed and commissioned so the producer could certify and negotiate carbon credits
- Phase 4: Equipment to burn the methane was installed by producers to reduce their own

energy costs

- 5-year pay back time

Challenges
Technological discrepancies between Sadia and producers. The project also faced cultural, financial and institutional challenges.
Input
Pig manure
Output
Electricity through on-site combustion engines
Use
Electricity used on site to lower operational costs of pig farms
Economic Benefits/Profitability
Carbon credits, reduced energy-use
Resource
http://www.undp.org/gimlaunch/press/docs/BRAZIL%20SADIA%20CASE%20SUMMARY.pdf

Case Study #3: Small-Scale USAID Project
Project
Cabra Forte (Strong Goat) – Bahia, Brazil, 2003

Context
USAID initiated this project in the Northeastern State of Bahia, one of largest poor, rural populations in Brazil. These small-scale biodigesters were disseminated through two, 2-day hands-on training courses that taught technicians, students, and leaders of the farming community about biodigestion. Since, however, USAID has stopped training and microfinancing this project.
Purpose of Implementation
The project was started to use goat waste to produce organic fertilizer and biogas for lighting and cooking. The goal was to create healthier goatherds by properly managing their waste.
Costs
$700 – partnered with Bank of the Northeast and Bank of Brazil to help poor families microfinance this technology
Construction Time
N/A
Input
Goat manure
Output
Biogas
Use
Lighting
Resource
http://www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/success_stories/brazil_biodigester.pdf http://brazil.usaid.gov/en/node/1013

Central America

This section highlights four scales of biodigesters in Central America, namely Costa Rica. Biodigester technology has been ideal for many regions in Central America due to much of the region being made of agricultural land and access to animal waste. In general, it has had an economic and environmental benefit to the communities who implemented the technology. Firstly, biodigesters create methane, which serves as an alternative energy source.

It also mitigates the fuel producing methods that are detrimental to health and the enviroment. Some of these practices include burning of wood for fuel, which leads to deforestation in many Central American regions. The deployment of biodigesters also resolves animal waste issues on farms. In some instances, it also has economic benefits beyond cutting energy costs. Its byproducts can be profitable if appropriated in an entrepreneurial way.

Central America region

Case Study #1
Region
Costa Rica, Sante Fe de Guatuso

Polyethylene tube biodigester

Cooking stove powered by methane

Context
This area is in a rural part of northern Costa Rica, where much agriculture and cattle farming occur. The town of Sante Fe de Guatuso is a historically and traditionally a dairy-producing town.
Purpose of Implementation
The Sante Fe Women's Cooperative was established in 2003 in collaboration with the UN Women's Group Vienna and The Guatuso Agriculture Ministry Office is dedicated to community organization in Sante Fe. Their specific focus was to take advantage of the amount of animal waste in the surrounding cattle farms. The purpose of this endeavor was to improve the quality of life of local children in low-income neighborhoods.
Type
This type is a polyethylene small-scale tube, which is the most basic and most widely implemented in Central America due to its affordability.
Costs
$300 per biodigester
Construction Time
The construction time is extremely manageable, only lasting one week.
Scale/Technical Specifications
The typical size of the sausage biodigestor is 1.9m x 1.5m x 3 m long. The ratios using cow manure is 10 gallons of water per 5 gallons of manure. Using pig waste, the ratio is 1 to 1.
Input
The Sante Fe Woman's group inputs cow and pig manure from the surrounding farms.
Output
Combusted methane biogas is the output, which is used as fuel for appliances.
Use
The main use of the methan is for cooking stoves in place of woodburning.

Economic Benefits/Profitability
This technology is especially beneficial to this community because it enables them to generate fuel from animal waste that would otherwise cause hygienic issues
Resource
http://www.ruralcostarica.com/biogas.html *All image credits to The Santa Fe Woman's Group

Case Study #2

Region

Costa Rica, Alajuela

Polyethylene tube biodigester

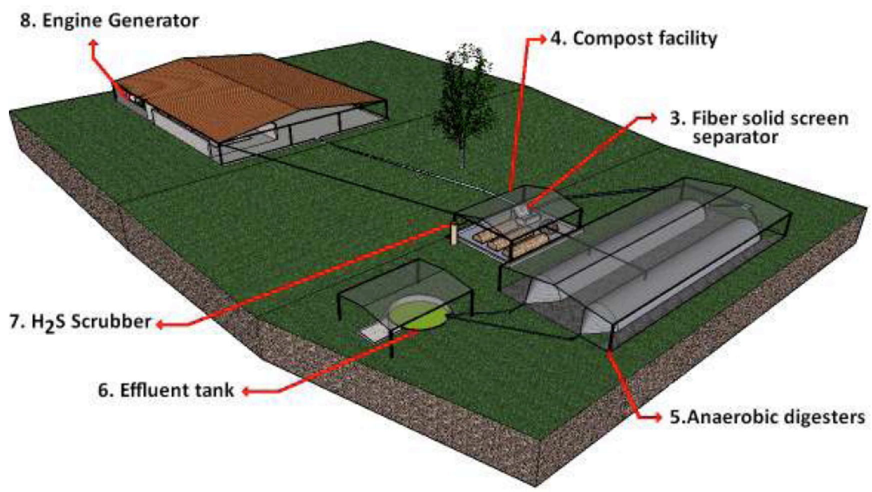


Diagram of the integrated system

Composting section

Effluent collection tank

Context

This case is in Dos Pinos Dairy farm at an altitude of 260-330 feet. The annual precipitation accumulates to 160 inches with an average temperature of 82 degrees F and 80% humidity annually. This project was advised by the local Environmental-Agriculture Program and led by farmer Alejandro Romero Barrientos.

Purpose of Implementation
These biodigestors were produced to be a critical part of an integrated closed loop system.
Type
Polyethylene Large-scale Tube
Costs
The whole integrated system cost $19,275 according to the research.
Construction Time
N/A
Scale/Technical Specifications
The size of the tube biodigestor is 66ft long, 8.2ft diameter. The ratios using cow manure is 10 gallons of water per 5 gallons of manure. Using pig waste, the ratio is 1 to 1.
Input
The input consists of manure from approximately eighty cows with an average weight of 770 lbs. Nineteen pounds of manure in fed into the biodigester per day.
Output
The electricity output is 100 tons. There is 300,000 gallons of effluent (fertilizer) produced annually. Compost is also generated through the solids separation stage.
Use
Biodigestor for electricity generation for facility and farm System Components: -Rainfall runoff separation -Sand separator system, -Fiber solid screen separator -Compost -Anaerobic digestion system -Effluent tank -Hygrogen sulfide scrubber -Biogas engine generator system
Economic Benefits/Profitability
This integral system is economically beneficial to its owner because the byproducts (i.e. as compost and effluent) can be sold.
Resource
http://www.adelaide.edu.au/biogas/anaerobic_digestion/casestudy.pdf

Case Study #3

Region	Purpose of Implementation
Costa Rica, Guapiles (2011)	Chiquita Brands Inc., a marketer and distributor of bananas and other fresh produce incorporated biodigestor technology in their manufacturing plant in an effort to increase corporate sustainability and reduce carbon emissions. The system uses excess fruit and water to create energy for local growers. The tailored design allows for the circulation of processing water without using electricity, thereby creating a carbon neutral circulation process, according to the company said. "It provides a sustainable energy source for our facility, nutrient rich fertilizer for local farmers and filters processing water. It benefits our company, our communities and our planet. The Biodigestor is the latest demonstration of Chiquita's global citizenship and our drive to incorporate sustainability into everything we do. *- Corporate Responsibility Officer, Manuel Rodriguez*
Company logo	
Context	
This case study resides in the Mundimar manufacturing facility of Chiquita Brands.	

Type

Not too much literature published because project is so recent - Industrial scale, designed by Biosinergia (http://www.biosinergia.es/)

Costs	Construction Time
N/A	N/A

Scale/Technical Specifications

The company processes more than 320 million pounds of bananas, pineapples, papayas, passion fruits and mangos used as ingredients by customers in more than 40 countries for the production and commercialization of fruit juices, smoothies, baby food, yogurts, bakery and other food items requiring the incorporation of natural tropical fruit ingredients.

Input	Output
Food waste	Electricity, effluent (fertilizer)

Use

Used mainly to power parts of the existing functioning manufacturing plant and provides rich fertilizer for local farmers

Economic Benefits/Profitability

-Saves company capital on energy costs

Resource

http://www.fastcompany.com/1685821/chiquita-goes-carbon-neutral-harnesses-fruit-power-with-new-biogester;
http://www.prnewswire.com/news-releases/chiquita-launches-innovative-biodigester-in-guapiles-costa-rica-

101727538.html

Case Study #4

Region

Honduras, El Progreso, Yoro (2006)

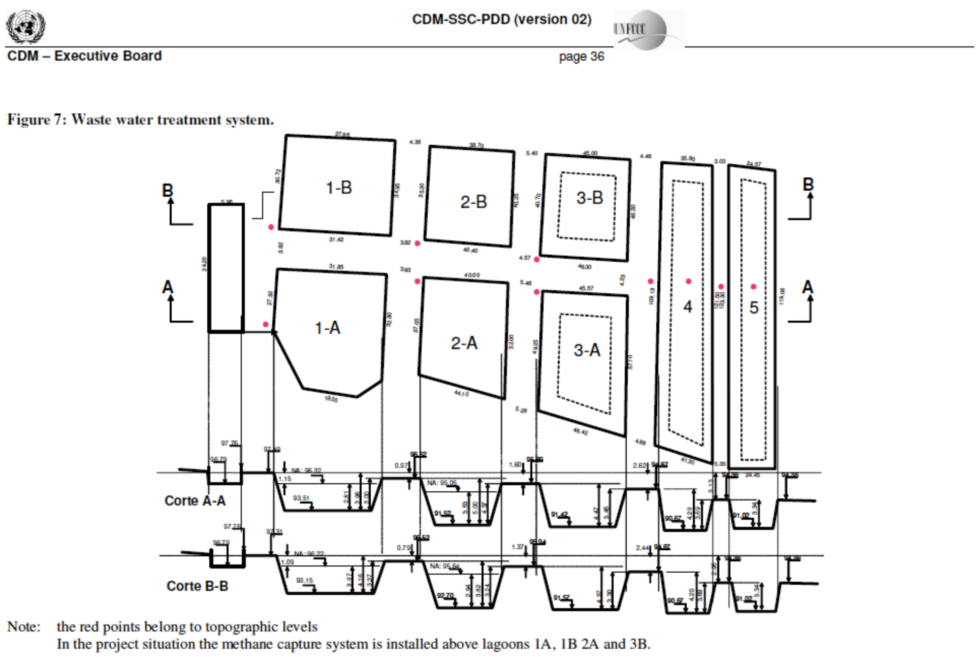


Figure 8: Plan of Lagoons

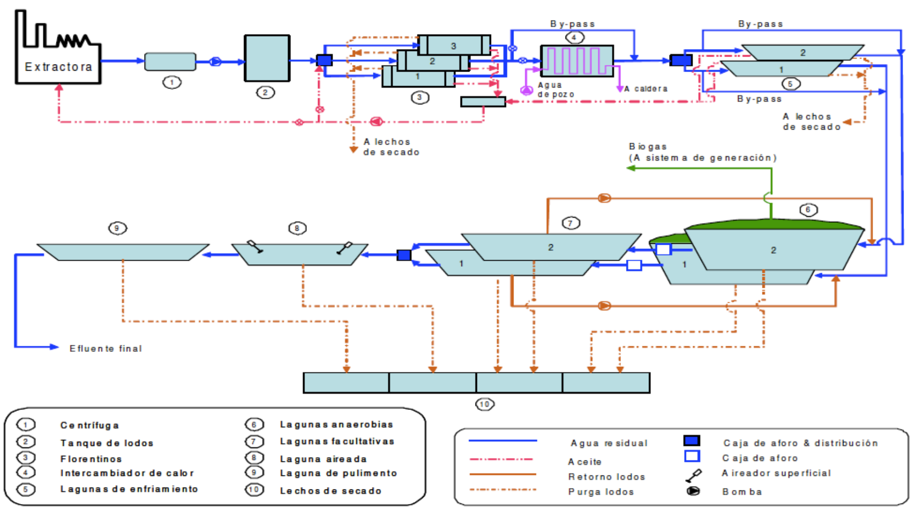


Figure 2: System description of the treatment system

Figure 9: Sectional diagram of system

Context

This case study in an industrial site where a large-scale palm oil mill operates.

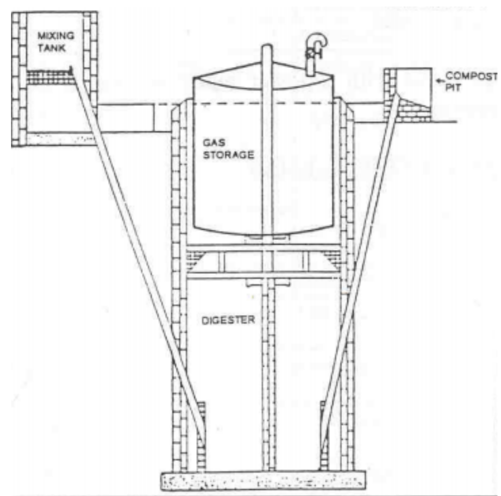
Purpose of Implementation
The reasons for the implementation of biodigestor technology for this industrial plant were largely for environmental reasons of mitigating the amount of methane that was being released into the atmosphere as well as filtering the wastewater that was being released back into sewage. Additionally, capturing methane to convert it into grid-connected renewable energy was key. On average, the mill operates 4,000 hours per year and 10 hours per day.
Type
Industrial scale, Anaerobic Covered Lagoons (8 lagoons) -This study was to experiment with covering two of the eight – shifting from open ponds to closed digester systems.
Costs
N/A
Construction Time
N/A
Scale/Technical Specifications
The Palm Oil Mill was designed with two anaerobic biogas collection lagoons. Soon after, four open-air lagoons were built. The first step of the process begins with water that goes through a cooling tower (71K COD / 48K TSS) and then goes into the two parallel lagoons. The flow is 5to 7 m3 per hour and produces 300 m3 gas (50-60% methane) / hour in each collection lagoon, capable of running two 633KW Generators. The biogas lagoons are 70m x 35m x 4m deep. They have an effluent of 10K COD and 25K TSS. Biogas retention time is over 160 days. The wastewater passes through a solids separator. Then it passes through four open air lagoons that are 35m x 35m x 4 deep.
Input
The input into the anaerobic pond is wastewater from grinding of fruit (30 tonnes/hour) The mill processed 80,000 tons of palm fruit/year in 2005, 120,000 by 2015 and 16,000 tons of raw palm oil results in 68,000m^3 of palm oil effluent (POME).
Output
Electricity, effluent (fertilizer) The effluent is used as irrigating water on the adjacent farmland, though during heavy rains there is some waste water release.
Use
The captured methane emitted by the open lagoons at the PALCASA Palm Oil Mill is converted and connected to the grid to provide renewable electricity. This processing plant shifted from open anaerobic ponds to a closed digester system.
Economic Benefits/Profitability
-Saves company capital on energy costs -Net present value – 621,120 needed from CDM, gain 542,299 in ten years
Resource
http://brazil.usaid.gov/en/node/1013

India

Janta Model

There are two basic designs used currently, the floating drum and fixed dome biodigesters:

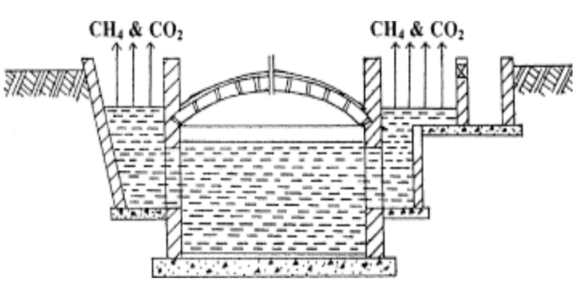
Floating drum. This basic design involves a deep, underground well surrounded by a partition wall that is capped by a metal drum, which floats up and down on a track or guide pipe, depending on the volume of gas and organic materials in the well. There are have in-spouts and out-spouts that are connected to the partition wall, with the in-spout higher than the out spout so the effluent flows to the out-spout. The floating metal drum regulates the pressure inside the biodigester to pressurize the gas. This model is also known as a KVIC model, as it was developed by the Khadi & Village Industry Commission. This model is simple and easy to operate, though the metal drum is relatively expensive to purchase and maintain, given its tendency to rust or have its moving parts get stuck.

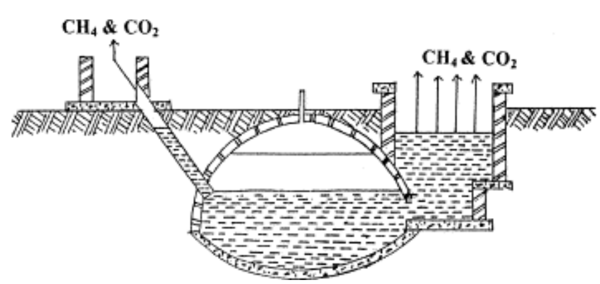


Floating Drum Model

Fixed dome. Fixed dome models have gained popularity in rural communities because of their low cost to install. They split into two main varieties, known as Janta biodigesters and Beenbandhu biodigesters (see photos below):

- Janta: The distinguishing feature of this biodigester is that it is fully integrated brick structure that has a well in the ground and a brick dome that extends out of the ground. The Janta model began to be used in India the late 1970s.
- Deenbandhu: This model is similar to the Janta model, but makes efforts to reduce surface area outside the ground, which reduces installation costs and increases efficiency, particularly in terms of insulating in colder areas. The fermentation chamber is integrated with the gas-holding chamber. The Deenbandhu model was developed in the mid-1980s.





Deenbandhu Model

Resources

http://www.ganesha.co.uk/Articles/Biogas%20Technology%20in%20India.htm;
http://www.cd3wd.com/cd3wd_40/BIOGSHTM/EN/APPLDEV/DESIGN/DIGESTYPES.HTML#FLOAT;
http://www.globalmethane.org/expo/docs/postexpo/ag_kishore.pdf;
http://cat.inist.fr/?aModele=afficheN&cpsidt=15511144

Case Study #1

Region

Pune, South India

Roof installation of home-biodigester

Urban biodigester on apartment roof

Context

Biodigesters that are used in rural areas often use cow dung as the main feedstock. However, Pune is a relatively well-off urban center in South India where dung is less available. Like most cities, Pune has issues with discarded food waste, which attracted pests and creates a public health concern. In response, the Appropriate Rural Technology Institute (ARTI) developed what they call 'balcony' biogas plant for apartments to use household food waste to generate biogas to be used to cook and heat bathing water.

Purpose of Implementation

Disposal of household food waste in urban area where other types of disposal (animal feed, composting) may not be appropriate and where dump space is limited; cooking fuel; heating

Type

This is an approximation of a moving drum digester. These are high density polythene (HDPE) water tanks that are retrofitted for biogas production using heat gun and HDPE piping. The digester uses tanks (volumes of 0.75 m^3 and 1 m^3 each), with the large tank used for the food waste input and the smaller used as a holding tank for gas. There is a shoot for adding feedstock, and an overflow for removing the digested effluent. This system is efficient and so the effluent contains less solid matter than the residue from a manure-based plant. The biogas plants are placed high, such as on a roof. The gas-holding tank gradually rises as gas is produced, and sinks down again as the gas is used for cooking.

Costs

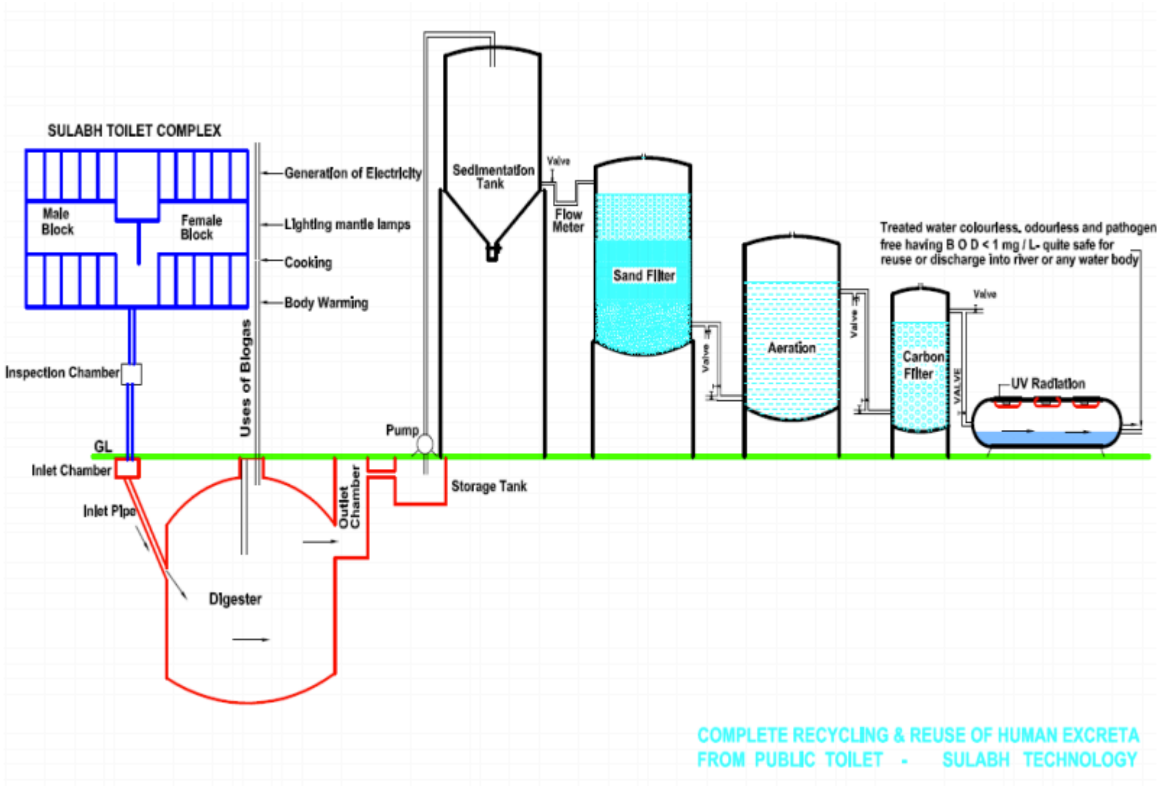
A compact biogas plant (including a biogas stove) costs approximately US $200 to purchase and is run on the discarded food waste of a household. According to ARTI, using just a household's kitchen waste in their plant, the biogas produced cuts the use of kerosene or LPG by half and saves the equivalent of 0.3 and 0.6 tons/year CO_2. The government does not offer subsidies, so owners must pay the full cost of their biodigester. However, ARTI says that a household can pay back the cost of the digester in two years with the amount of savings they get from not purchasing LPG.

Construction Time
Minimal – one day.
Scale/Technical Specifications
To build the biodigester, the household needs a space that is about 2m square and 2.5 m high, usually up high so the household can take advantage of gravity for gas distribution. To begin, the biodigester must have cattle dung mixed with water and waste flour as a starter, or one can use the effluent from an existing biodigester mixed with flour. Over two or three weeks, the biodigester is gradually fed until it can handle a daily supply about one kg/day of feedstock, which consists of ground up waste flour, leftover waste food, fruit peelings and rotten vegetables.
Input
The input is household food waste and water, but the waste must be mashed prior to being put into the digester.
Output
A very watery effluent is the output, but it can be re-used in the biodigester. ARTI recommends that the liquid is mixed with new household feedstock and recycled into the biodigester.
Use
Cooking stove – comes with the system.
Economic Benefits/Profitability
There are only household-level economic benefits – namely, the household does not have to pay for cooking fuel or water-heating fuel.
Resources
http://www.ashden.org/files/ARTI%20full.pdf; http://www.arti-india.org/index2.php?option=com_content&do_pdf=1&id=45

Case Study #2

Region

Shirdi, Maharashtra



Schematic of Sulabh Toilet-to-Biogas System

Context

An NGO called Sulabh International Academy of Environmental Sanitation (SIAES) designs and builds toilet-to-methane systems that serve small or large scale communities. Their largest-scale system is a "toilet complex" with a biogas generator attached in the town of Shirdi in Nasik District of Maharashtra. The toilets are pay for use and the complex has 120 WCs, 28 special toilets and other wash facilities that are attached to the biodigestion system and, because the site is used by a steady stream of religious pilgrims, they see 30,000 to 50,000 visitors every day.

Purpose of Implementation

The complex was built both as a way to get rid of public health hazards from human feces, and as a way to generate electricity that lights the site and, in other applications of this NGO's technology, to use methane as cooking fuel and for heating water.

Type

Fully submerged, Deenbandhu-style digester with a sophisticated array of sanitation and filtration mechanisms for effluent.

Costs

The toilet complex requires substantial investment, but the total cost of the biogas facility is undetermined. Because this NGO produces a variety of latrine-to-methane options, the costs vary based on construction. According to Sulabh, to build the toilet system, it costs $1,000 - $1,500 per seat, including facilities of the seat, bathroom, urinal, sink, room of the care taker and store room. If there is attachment of a biogas plant, it is an additional $2000.

Construction Time
One year+ for large systems
Scale/Technical Specifications
Enormous, but technical specifications about the plant unavailable.
Input
Human waste, waste water
Output
The effluent is used as fertilizer, as it contains nitrogen (5.5%), potassium (2.4%) and phosphate (4.2%). However, to get it to a useable state there is significant infrastructure and technology deployed to ensure that the effluent is "free from odor, colour and pathogens and lowering its Biochemical Oxygen Demand (BOD) around 10mg/l only." In particular, the system uses sedimentation and filtration through sand and activated charcoal as well as through ultraviolet rays. With this system, the effluent can either be used as an excellent fertilizer, or put into bodies of water without harmful impact.
Use
Electricity generation, methane for cooking stoves, fertilizer
Economic Benefits/Profitability
Depending on the scale of biodigestion, the Sublah system is able to generate amounts of methane gas that range from fueling one cook stove for one hour per day (family-sized biodigester) to electrifying an entire park area (as in the case of a fully integrated toilet complex).
Resource
http://www.sulabhinternational.org/downloads/pathak_opening_plenary_session_sulabh_17aug09.pdf; http://www.sulabhinternational.org/st/community_toilet_linked_biogas_pant.php

Case Study #3

Region

Kerala, South India

Figure 1: Institutional-scale biodigester at school in Trivandrum

Figure 2: Fabrication of biodigesters with ferro cement

Context

Biotech is a consultancy organization that works specifically on managing organic waste and the production of energy from it. Between 2004 and 2007, the organization served approximately 48,000 by building 12,000 small, home-use biodigesters and 200 biodigesters for institutions.

Purpose of Implementation

In suburban regions, there is demand for hygienic disposal mechanisms for households, institutions and municipalities. The implementation of biodigesters allows for the management of organic waste and wastewater at source, and produce methane gas for cooking, heating, electricity generation.

Type

The household digesters are free-drum floating style, with the floating drum weighed down with concrete to increase the gas pressure. The Biotech digesters use a water seal to prevent gas leakage. Biotech also makes portable digesters that can be used when digging into the ground does not make sense.

Costs

A cubic foot-sized household biodigester costs about US $220, with government subsidy available of up to 60%. According to Biotech, an average family can pay back contribution to the cost of the plant in about three years through savings in LPG use.
For institutional use, the integrated waste management systems cost around US $71,000 and Biotech charges an annual operating fee to run the biodigester.

Construction Time

These biodigesters are made from ferro-cement. The gas-collection portion is Fiberglass Reinforced Plastic (FRP). It is all pre-fabricated.

Scale/Technical Specifications

Biotech implements a range of biodigester sizes, from household to institution-sized digesters.

For a school, the biodigester tanks are from 10- 25 cubic meters and serve an average of 200 people. The large-scale biodigesters operate at the request of a municipality or a high-organic waste organization like a market. The digester space can be as much as 50 cubic meters. The organic waste much be ground or chopped prior to going into the digester. To convert the gas to electricity, a 3 kW engine generates electricity. To prevent corrosion, these systems require that hydrogen sulfide is filtered out of the gas before it goes to the generator.

Input
Food and other organic waste
Output
Methane gas to generate electricity, an effluent that can be used/sold as fertilizer, hydrogen sulfide that must be scrubbed.
Use
Electricity generation, methane for cooking stoves, fertilizer
Economic Benefits/Profitability
According to Biotech, the manufacturing, installation and maintenance of biogenerators from their organization has generated an estimated 13 individual work days for each domestic plant, 55 days for each institutional plant and 80 days for each waste to energy plant.
Resource
http://www.ashden.org/files/BIOTECH%20full_0.pdf

United States

Anaerobic Digestion in Urban Areas: Case Studies from the U.S. and Europe

This brief will cover two business models that use anaerobic digestion (AD) as a tool for economic development and environmental management. Drawing on cases studies from the United States, this section is intended to inform Waste Ventures' understanding of potential business models for implementing AD's in urban environments. This section is divided into the following categories:

1) Community Economic Development – Urban Agriculture & AD
2) Infrastructure Optimization – Wastewater Treatment, Food Composting & AD

Case Study #1 – Community Economic Development – Urban Agriculture

Milwaukee, WI

Context

Growing Power is a non-profit urban farm and training center that provides affordable produce to urban neighborhoods without access to fresh food in inner city Milwaukee – an industrial city of approximately 600,000 people. Built on the premise of recycling farm nutrients through highly integrated agricultural techniques, Growing Power processes organic wastes through *composting* and *anaerobic digestion* to maximize growing capabilities on limited urban agricultural land. This community-based model is taking root throughout Midwest cities in the U.S., representing a new avenue for re-using vacant, low-valued urban land in a highly productive manner.

Growing Power's two-acre farm has several basic components. These include six greenhouses, several hoop houses, and raised beds for herbs and greens, aquaculture, hydroponics, vermicomposting bins, anaerobic digesters, classrooms, and a retail store selling goods from a network of approximately 300 farmers. AD's are a central part of the Growing Power model, as they are intended to help improve the economic competitiveness of such enterprises as they scale up in size and production.

Economically speaking, Growing Power bases its model on a revenue goal of approximately $5 / square foot (or $200,000 / acre). It does so by integrating multiple anaerobic digesters into a "zero-waste" system based on maximizing all available resources and nutrients from separate agricultural processes taking place on-site. These AD's are used to both heat and power the greenhouses and surrounding buildings. They are also built to handle approximately 5 tons of food waste per day.

Scale/Technical Specifications

No projects have been built to date. Business model in early stages

Input

Agricultural wastes, food residues

Output

Heat and electricity for the greenhouses and surrounding buildings. Exact scale not provided.

Case Study #2 – Infrastructure Optimization; Wastewater Treatment and AD

Oakland, CA

East Bay Municipal Utility District – Oakland, California
http://www.epa.gov/region9/waste/features/foodtoenergy/

Conext

Infrastructure optimization is opening up new avenues for anaerobic digesters, particularly in the sectors of wastewater treatment and organic waste disposal. The U.S. EPA and East Bay Municipal Utility District (EBMUD) in Oakland, California are currently collaborating on an AD project that would allow the EBMU to co-digest food waste with wastewater discharge. This patented process is allowing EBMU to maximize the amount of energy harvested from the AD. According to the U.S. EPA, roughly 140 wastewater biogas plants in California have 15-33% excess capacity on average. This is important, considering that wastewater treatment facilities often accrue excess capacity when utility districts overestimate development or when large industries leave an area, resulting in fewer sewage discharges.

As part of this collaboration, the U.S. EPA developed the Co-Digestion Economic Analysis Tool (CoEAT) to assess the initial feasibility of food waste co-digestion at wastewater treatment plants for the purpose of biogas production. Co-EAT is designed for decision-makers with significant technical experience, including municipal managers, engineers, and wastewater treatment plant managers. It can be found as a Microsoft Excel Spreadsheet at: http://www.epa.gov/region9/organics/coeat/index.html

Input

Co-digestion of this type is an emerging process in the United States. Under this model, waste haulers collect post-consumer food waste from local restaurants, grocery stores, and food handling facilities and transport it to the EBMUD wastewater treatment facility. The mixture is then added to less energy-rich organic waste and co-digested. This approach allows facilities with excess digester capacity to maximize electricity production as well as profitability.

Output

Increased electricity production at AD's sited at wastewater treatment facilities.

Economic Benefits

Payback period can be as little as three years depending on existing infrastructure. Operating facilities earn multiple revenue streams under this model: (i) tipping fees charged to waste haulers, (ii) revenue from electricity sales, and (iii) savings from offsetting energy use. While earnings are most efficient where AD infrastructure exists, the above Co-EAT tool allows decision-makers to better understand these revenue streams even when pre-existing digesters are not present.

Multiple financing mechanisms exist for this strategy. First and foremost, the U.S. EPA promotes *Performance Based Contracting* as an effective first strategy to evaluate. Under this model, a municipality hires a private company (or "performance contractor") to build the project. The performance contractor then studies the potential energy savings or electricity sales that would accrue from the increased biogas production. Based on these conclusions, the performance contractor provides the upfront capital needed to invest in the new infrastructure and installation costs. They are then paid back through the energy savings of the municipality. After paid in full, the performance contractor steps away, allowing the municipality to gain from its energy income.

Alternatively, a variety of grants, loans, venture capitalist money, R&D budgets, carbon credits, and state funds promoting renewable energy are used to fill in financial gaps. While there are obvious differences between the U.S. and India in this respect, it is worthy to note that these tools are used in a variety of different mixtures depending on the project. As the following case study will note, some private companies in the US anticipate that public subsidies will be less necessary in the near-term as this technology steadily progresses towards economic competitiveness.