

IMUS: Integrated Manure Utilization System

The Alberta Research Council and Highmark Renewables partnered to develop the Integrated Manure Utilization System (IMUS) and address the challenging problems surrounding the livestock industry, particularly involving feedlots. This project aims to add to the sustainability of the livestock industry by utilizing manure as a resource to provide a renewable energy source, plus other marketable products, such as heat, bio-based fertilizer and reusable water. The Alberta Research Council initiated the project through their research facilities under the guidance of Dr. Xiaomei Li, and subsequently partnered with a feedlot business which understood the importance of developing a viable solution for manure management problems facing the industry. The demonstration plant is located on Highmark Feeders land, north of Vegreville, Alberta, 140 km northeast of Edmonton.

The IMUS project is driven by a need for manure management solutions that provide the livestock producer with a viable resolution to waste challenges and additional economic benefits through valuable end products such as energy production (electrical and thermal), fertilizer and reusable water. *Specifically, the unique advantage of IMUS is the ability to handle high-solids biomass.* Some concerns facing livestock operations were identified as contamination of soil, surface water and ground water, including the risk of pathogens and excess nutrients; odours from production facilities or manure disposal sites; and other social issues regarding traffic, roadway maintenance and perception.

The Partners

The Alberta Research Council (ARC) is an Edmonton based applied research corporation that develops and commercializes technology, converting early stage ideas into marketable technology products and services. Dr. Xiaomei Li's vision included developing an innovative method of extracting the valuable nutrients from the anaerobic digestion process, which would be a marketable agriculture product.

Highmark Renewables is part owner of the IMUS technology. It has an operating agreement with Highland Feeders of Vegreville, the sixth largest feedlot in Canada. The feedlot is the recipient of several national and regional entrepreneurial and environmental stewardship awards over the past 20 years. It is co-owned by Mike and Bern Kotelko, who manage the 36,000 standing capacity operation. The company was particularly interested in partnering with ARC in the building of IMUS as their environmental background and interest saw a solution for their operation, as well as an opportunity to provide similar opportunities to other livestock producers faced with growing environmental and economic issues with manure management challenges.

This IMUS demonstration project was supported by several other stakeholders who encouraged the vision to build a biogas plant which provided a manure management solution; reduced Greenhouse Gas emissions such as methane, carbon dioxide and nitrous oxide; and provided valuable end products (including "green" energy). Several government agencies provided funding, technical expertise and encouragement, with additional support from industry players.

The Process

IMUS technology utilizes biogas production. This is achieved through anaerobic digestion, with adjustments to temperature, pH and the solid/liquid ratio to create optimal thermophilic bacterial growth. The IMUS process results in a shortened hydraulic retention time, over 99 % destruction of pathogens and maximization of biogas production. The process includes a power generation unit and a heat exchanger system. The system delivers waste heat to fuel the pre-digestion steps, the digester and the fertilizer production system.

To date, the IMUS project has not achieved construction and operation of the fertilizer production system. The IMUS plant presently processes only a portion of Highmark's manure as the facility accommodates that of approximately 7,500 cattle. Cattle produce approximately 1.2 Tonnes of manure per animal per year, dry weight. (Note: The IMUS site has an average annual temperature of 2.3° C.)

Step One: Collection of the manure feedstock

The feedlot pens are built on a 2.5 % slope on clay pack to optimize drainage. The manure is collected by tractors/trucks from the pens at least once a week, depending on weather conditions, and is transported to a storage pad at the IMUS plant (less than 1 km distance) and stockpiled. IMUS ensures that there is an adequate stockpile for production, keeping in mind the risk that delivery may be interrupted because of weather conditions from time to time.

The initial step of the IMUS system is a two-stage process. The first stage includes the weighing and processing of the manure using a processing bucket attached to a wheel loader. This step sorts out foreign objects larger than two to three inches in size before dropping the material into a dry hopper which conveys the manure to the wet hopper. The weight captured in the processing bucket is communicated to an automated system via a wireless network which calculates how much water is to be added to the manure in the second stage wet hopper.

The wet hopper was developed at ARC and is equipped to adjust temperature, pH and the solid/liquid ratio of the manure to a predetermined level. The water added in this step is heated by the waste heat from the generating system. This process is done for approximately eight hours per day.

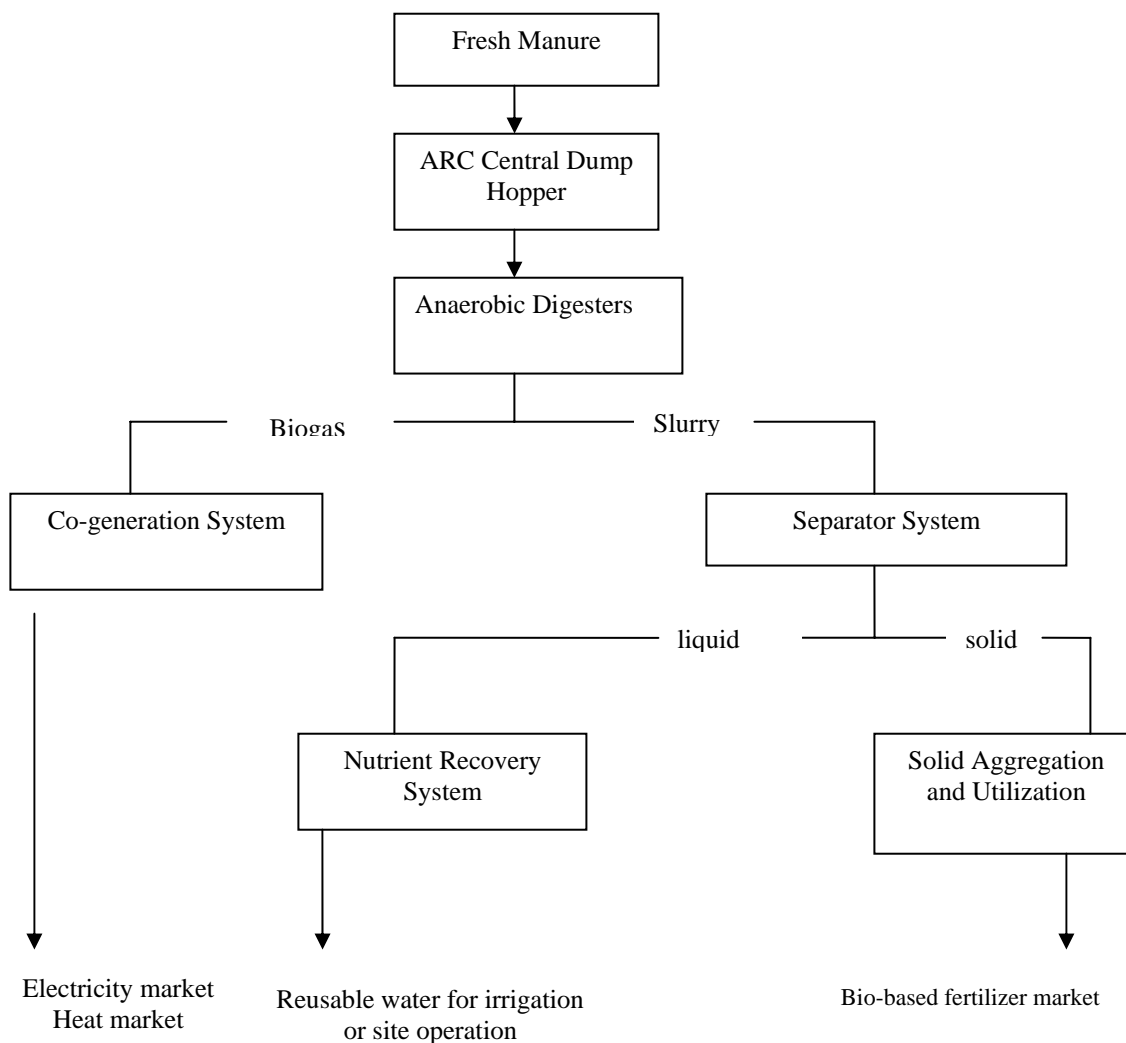
The mixture is pumped through a masterator and piped through insulated pipes to one of two digester tanks. Due to extreme cold five months of the year, it is necessary to insulate all systems.

Step Two: Bio-digestion

The next stage is anaerobic bio-digestion which takes place in two above-ground insulated concrete tanks with a 1,800 cubic metre capacity and working levels of about 1600. The tanks are 15 metres in diameter and stand 11.2 metres high. The tanks are capped with a heavy rubberized material. The temperature is maintained at 55° C in order to create optimal thermophilic bacterial growth. These conditions provide a shortened retention time (14 days), and optimum biogas production. This process destroys over 99 % of the pathogens in the raw material.

The circulating system utilized is a hydraulic/jet nozzle mixing system. The tanks have a radiant heating system in the concrete tank walls and bottom. Retaining heat is not an issue, and with the insulation on the outside of the tanks, IMUS has found there are no problems even in the coldest weather. The system is a batch continuous process with approximately 5 % new manure added to the system each day, and 5 % digestate removed.

The IMUS Process



The digestate flows through a separation process including a screw press where the solids are removed. The liquid is pumped to a large lagoon (32 million gallon capacity) to be re-used in the IMUS process at the hopper stage, and used for the farm’s irrigation pivots. The solids separated out with the press are stockpiled and then spread on the land base.

The IMUS plant is not yet complete. The company intends to install a Nutrient Removal Process within the next 12 – 18 months, where the digestate would be processed to take out all the phosphorous and ammonia, resulting in cleaner irrigation water and a valuable “bio-fertilizer product.” The vision for the future use of the separated solids is to market this dry material in a pelletized form for easy application and provide nutrients and stability back to the land.

Step Three: Biogas

The biogas is collected under the rubber roof and is treated to take out a percentage of the moisture and reduce the amount of H₂S and heat before being fed to a Jenbacher one-megawatt co-generation system. Presently the average production from the biogas is about 760 kW. The plant and the feedlot utilize about ¼ of the production, with the remainder sold to the neighbouring grid. Average revenue from the sale to the grid is about nine cents per kilowatt. (Spot price monthly averages between \$.035 to .19).

The plant augments electrical production in peak usage times with natural gas (a 15 % natural gas: 85 % biogas mix) to maximize the economic return of the plant. The generator used in the IMUS demonstration project is sized to accommodate this extra electricity production. Future plants may be sized to run solely on biogas.

The heat produced is presently utilized only by the IMUS plant to heat the water and digester. Additional thermal energy is available.

IMUS made adjustments and modifications to their system over the past months to correct or improve operational optimization. The technical hurdles and changes proposed for subsequent plants are listed in the Appendix.

A Full-sized Economically Viable Project

IMUS plans to market their system to accommodate any type of livestock producer or food processing plants with the following needs/benefits and market abilities. The “viability” parameters include a Return on Assets of up to 18 % and a Return on Equity of over 30 % to equity shareholders (based on investment of ½ equity, and ½ debt), and debt repayment (at 6.5 % interest rate) of less than 10 years. To fulfill the “viability” parameters the following must be in place:

- If a feedlot, the size needs to be 30,000 animals (or equivalent bio-gas production ability from other animals/waste). Total cost is \$11M. (This size is based on the ability to produce sufficient biogas and electricity for optimal use of generator capacity and, therefore, profitability.)
- Ability to sell approximately 3 MW of power at a contracted price of \$.13/kWh (projections include a range from .09 to .13).
- Ability to provide replacement electricity to plant and feedlot at \$.10/kWh.
- Benefit from a reduced manure handling cost of \$4/animal (or tipping fees).
- Need to ensure/contract a market for over 20,000 Tonnes of bio-fertilizer per year at a price of \$50/T.
- Be able to sell (contract) the excess heat/thermal power available from the process.
- Have the management and technical expertise in place for a full scale business.

Economics and Financial

IMUS/Highmark is a demonstration project with the owners’ intentions to build larger and economically viable full sized manure/waste management systems, and most likely food processing or integrated feedlot/energy intensive process plants, like a feedlot/ethanol/biogas facility. All products require a financial return for the facility to be optimally viable. The IMUS

process can be adapted to accommodate other livestock producers or food processing plants and their waste management needs. Note: no green credits are applied for as yet, and any possible future revenue from the sale of green credits is not used in financial projections.

Financing of IMUS Demonstration and Future Project

Project Funding Source (CAD)	For Demo Project (7500 head)	Future Full-sized Economically Viable Project (30,000 head)
Plant Price	\$6,805,000	\$11,000,000
Equity Partners	\$1,950,000	\$ 5,500,000
Government Grants	\$3,254,675	0
Lenders (@6.5 %)	\$1,600,000	\$ 5,500,000
Expected Payback for Lenders and Shareholder Investment	15 years	~ 6 years
Expected revenues (including electricity, heat, biofertilizer, water)		Between \$3M to \$3.8M
Expected expenses (including G&A, maintenance, taxes, interest)		\$1.8M
<i>NOTE: expected revenues based on electrical prices of \$.09/kwh</i>		<i>\$1.9 M</i>
<i>NOTE: expected revenues based on electrical prices of \$.13/kwh</i>		<i>\$2.8M</i>
NOTE: Payback for demonstration project is based on the lenders' needs; the government grants require no payback. The demonstration project does not provide for any sales of fertilizer or heat/thermal power.		

Further Analysis

Since the IMUS system was developed to utilize all the available resources from the manure management process, the research and development done till now helps to address the technical issues, as well as provide a basis for a viable business model.

As discussed, the demonstration sized plant is not economically viable, but an optimum-sized operation is determined. There are challenges to putting all the pieces together to ensure viability.

Barriers to Entry:

- A 3 MW power plant requires, in most jurisdictions, a Power Purchase Agreement, which can be challenging to obtain.

- Capital cost (\$11M) in equity and lending for the minimum-sized economically viable plant may be difficult for many producers to finance.
- Challenge will be to locate a plant which is readily available to the manure feedstock as well as adjacent to a purchaser for the heat energy.
- Markets for the bio-fertilizer will require purchase contracts in place.
- Bio-fertilizer adoption may require some education and successful demonstration for potential users.
- The return for investors may not meet expectations/needs.

Incentives to Entry:

- Changes in environmental and food/water/safety regulations in future years may encourage systems such as IMUS
- Community/industrial distributed heating systems could become more attractive as markets for both heat and electricity products.
- Ability to involve more than one waste feedstock or ability to solve more than one issue could provide sales for excess heat and water.
- Possible dead animal disposal solution.

Appendix

General Facts (as of March 2006)

	DEMONSTRATION PLANT	FUTURE PLANT
Business Proposition	Private company owned, partner with 35,000 head cattle feedlot, near Vegreville, Alberta	Large feedlot/plus other processing plant; food processors, or other large facilities
Type of Plant	1MW Jenbacher co-generator	3MW co-generator
Cost of Plant	\$6,895,000 CAD (2004)	\$11,000,000
Estimated Payback Period for Shareholder/Funders	14 years	7 years
Feedstock	Cattle manure (dry solids)	Cattle manure (dry solids), food processing waste, depending upon the plant involved
Reactor Dimensions	2 – 18,000 cu metre tanks	MORE – to be determined by design requirements
Feed Rate	105 Tonnes	420 Tonnes
Operating Temperature	55° C., thermophilic	55° C., thermophilic
Dry Matter	10 % - 14 % solids into the digester	10 % - 14 % solids into the digester (if similar feedlot manure plant)
Retention Time	14 days	14 days
Agitation	Hydraulic jet-nozzle mixing system	Hydraulic jet-nozzle mixing system with an additional

		paddle system for the tank tops
Biogas Production	8400 m ³ /day,	32000 m ³ /day
Sulphur Output	n/a	n/a
Energy Output	>5,900,000 kWh/year	>21,000,000kWh/year
Waste Heat Usage	ARC hopper and water storage unit, digester radiant heat unit	ARC hopper and water storage unit, digester radiant heat unit and possible outside markets
Waste Water Management System	Lined storage pond for field application, 3.5 million gallons	“Cleaner” water with nutrients removed for irrigation, recirculation.
Operating Personnel	Technical employees	Technical employees
Use of Digestate	Field application	Biofertilizer production and sale
Annual Savings Fertilizer/Herbicide	\$40,000/\$7,000	Revenue from sale of bio-fertilizer will over compensate for loss of manure fertilizer
Electricity Purchase Price	\$.91/kWh	Contracted purchase price of \$.13/kWh (target availability in concentrated markets such as Ontario)
CO2 – annual mitigation	5,322 Tonne/year	>20,000 Tonne/year
Total Annual Revenue Projection	\$600,000 CAD	>\$ 4,000,000

Note: Initial payback analysis for demonstration project includes shareholder and lender capital only.

Technical Hurdles/Identified Enhancements and Solutions

Initial Process	Solution Option
Stockpile Storage: Weather challenges from time to time require adequate storage for manure	Design for adequate storage – with waste material and location in mind.
Dry hopper/manure had problems with rocks and dirt	Design of hopper bottom to separate out larger foreign material
Digester mixing: Because of high straw content in manure, the hydraulic jet-nozzle mixing system didn’t adequately mix the top of the tank where the lighter material collected.	Future design would include a mechanical surface mixer, such as a paddle system for the top portion of the digester tanks. The hydraulic jet-nozzle mixing system would be retained.
At this scale the hydrolyzing process worked adequately	Would design a much larger pre-treatment area with a better settling process.
Demonstration possible at this stage with government grants.	To adequately address environmental and social issues, governments may need to provide “incentives” or “breaks” to help capitalize such projects.

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