

## Bioenergy and Bioproducts Fact Sheet

### VanderHaak Dairy Anaerobic Digester

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#### Quick Facts

Dairy Herd Size	~1,100 cows (tank sized for 1,500 wet cow equivalents)
Type of Dairy Operation	Confined year round – Scraped manure
Other feedstocks	Food waste (3% influent by mass)
Manure Transportation	1.5 mile pipe
Digester Type	Two stage – modified mixed plug flow (GHD design)
Digester Volume/Tank size	162,361 ft <sup>3</sup> (144,000 ft <sup>3</sup> manure, remainder gas)
Flow Rate	Sized for 45,000 gallons input / day
Digester Temperature	100 degrees F – Mesophilic
Time for Digestion	25.4 day Hydraulic Retention Time (HRT) (designed for 22 day HRT)
Methane production	1.32 tons / day (preliminary results), % content varies from 55 – 65%
Prime Mover for Power Production	Modified G 398 Caterpillar Engine – Reciprocating, generator efficiency ~ 25%, 300 kWc and 285 kW net energy - can be expanded with turbocharger to 450 kWc
Generator run-time	Estimated 95%
Electrical production capacity	5,510 ±383 kwh/day (preliminary results), 231 KW (80% of capacity), 0.21 ±0.015 kw/cow
Greenhouse gas reduction	9.47 tons/cow/year CO <sub>2</sub> equivalent,
Waste heat used to heat manure	30 – 60 %
Interconnection	Currently single phase to Puget Sound Energy lines. Engineering study to triple phase
Pathogen control	99% fecal coliform reduction as an indicator organism for pathogen control

#### Background – Anaerobic Digestion for Dairies – A solution that leads to more solutions

Washington State has approximately 600 operating dairy farms that manage nearly 250,000 dairy cows. These dairies are often identified as sources of odor, water and air pollution, and are under increasing public and regulatory pressure to control these problems. As a result, effectively managing animal wastes is a critical component of dairy operations and can make a difference in the dairy's overall success. Most modern dairies utilize a lagoon system for animal waste storage, a practice that often results in odor problems due to ammonia and volatile organic compounds (VOCs) and can lead to potential water quality concerns due to nutrient (nitrogen and phosphorous) over application or surface runoff when manure is land applied. A lagoon system

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can also be a large source for atmospheric methane and nitrous oxide emissions, both of which are greenhouse gases that contribute to global climate change. The Intergovernmental Panel on Climate Change (2001) estimates that the concentration of the three key greenhouse gases, methane, carbon dioxide, and nitrous oxide, in the atmosphere has increased by more than 150%, 31%, and 16% respectively in the last 250 years.

A growing number of dairy farmers are considering anaerobic digesters as an alternative method for managing animal manure. Ideally, these systems mitigate odor problems; protect water quality; reduce greenhouse gas emissions; improve the handling of manure nutrients; control most pathogens; and generate biogas (a low-grade natural gas) that can either be used to co-generate heat and electrical power or it can be scrubbed (separated into purified streams of the gases methane, CO<sub>2</sub>, and H<sub>2</sub>S) and compressed into a liquid fuel or used like natural gas as a base for any number of high-value products (ie. hydrogen, anhydrous ammonia, plastics, etc.). In addition to biogas, anaerobic digesters produce two raw material by-product streams, fiber and nutrient-rich liquid, that can be refined into higher value products creating new revenue streams for dairy farms. In addition there are opportunities for tipping fees to manage additional organic waste streams such as food waste. While these benefits are attractive a successful digester project requires a substantial financial and management commitment.

There are dozens of digester designs, but the high-solids characteristics of dairy manure limit the applicability of most of these designs. The three most common designs for dairy manure are covered lagoon, complete mix, and plug-flow. There are also three levels of temperature operating with different bacteria: 1) Psychrophilic (75 – 95 degrees F); 2) Mesophilic (95-105 degrees F); and 3) Thermophilic (125-135 degrees F). Scrape dairies and flush dairies generally require different specific technologies to do anaerobic digestion. While these systems differ in design, cost, and performance, they all follow the same basic principle where the manure is digested by anaerobic bacteria and converted into a stable effluent and biogas. The biogas generated by the digester contains about 50 to 70 percent methane (600 BTUs per standard cubic foot). Preliminary data from the VanderHaak digester, co-digesting manure with limited additional food waste feedstocks, indicates an electrical capacity of 0.21 ±0.015 kw/cow. Other types of digester systems, generator sets, operating temperatures and types of animals/feedstock will produce different results. In Washington State alone using the digester systems such as the VanderHaak dairy, if half of the 250,000 dairy cows were on a farm with anaerobic digestion (AD), as much as 25 MWh of renewable “green” electricity could be generated annually. In addition, as much as 110 million pounds of methane could be captured each year (1,183,750 tons CO<sub>2</sub> equivalent), providing a significant reduction in greenhouse gas emissions. **(Note: calculating actual greenhouse gas reductions are more complicated than presented)**

**Bioproducts & Making Economic and Business Sense**

Single purpose bioenergy projects (biopower or biofuels) in the Pacific Northwest rarely make business or economic sense on a stand alone basis. Multiple products with multiple revenue streams (including cost offsets) are the key to business and economic success in our region. In this setting, the development of bioproducts assumes major importance. The VanderHaak dairy is no exception. The following is a table of current products, buyers and prices.

Electricity produced – base price	Puget Sound Energy	\$.035 / kwh, locked, long-term contract
Green power (Green Tag) adder	Puget Sound Energy	\$.015 / kwh
Bedding (digested fiber)	Used by the dairies (40-60 % of total solid effluent)	Offsets sawdust @ ~\$12/ton
Composted digested fiber	Various buyers	~\$6 – 24 / ton
Liquid fertilizer	Used by dairies	Substitutes for manure application
Carbon credits	Aggregated by Environmental	Variable – rates determined

	Credit Corporation	through Chicago Climate Exchange
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The following is a table of future products, product development leadership and potential value of the product.

Nursery quality digested fiber (in place of peat moss)	WSU Whatcom County Extension	Peat moss from Canada sells to the nursery industry @ \$24+
Slow-release phosphorous fertilizer	WSU Center for Bioproducts & Bioenergy	Potential value TBD
Ammonia-based fertilizer	WSU Center for Bioproducts & Bioenergy	Subject to market prices for Natural Gas . . . recent N prices have ranged well over \$.30/ lb N.

Other products could be developed. For example, 40-70% of the heat produced by the engine is currently under-utilized and could be used for such things as heating parlors, barns, shops, homes, greenhouses, aquaculture systems, etc. In addition, digesters help resolve manure management and odor issues, which in turn can enable larger herd sizes.

Transportation of manure from lagoons to the digester is an extremely important economic consideration, particularly for central digesters collecting manure from multiple farms. The economical distance for trucking manure is highly variable and dependent on the price of diesel, but generally it is not economical to transport manure more than 2 miles. Piping the manure can reduce operating costs, but there are effective economical limits to the distance for piping manure as well.

### **Vander Haak Dairy**

The VanderHaak Dairy is a family run farm operating in Lynden, Washington since 1968, and became the first dairy in Washington State to install a commercial anaerobic digester. The system utilizes a patented modified, two-stage, mesophilic plug flow digester with axial dispersion, designed by GHD Incorporated of Wisconsin, which handles manure from 3 dairies and up to 1500 dairy cows (as currently configured). In general, plug-flow digesters have few moving parts and work well with dairies, like VanderHaak, that collect cow manure by scraping instead of flushing the manure with water (adaptations can be made for flush dairies, too) The unprocessed manure is collected in a receiving pit and pumped directly into the anaerobic digester vessel where it undergoes a two-stage digestion process. In the first stage (the “acid chamber”) raw manure is mixed and heated to 100<sup>0</sup>F, using the reclaimed waste heat from the engine/generator set. This first chamber is designed to facilitate the growth and metabolism of acid growing bacteria that break down the raw manure into simpler volatile fatty acids and acetic acid. The slurry then gravity feeds into the second stage of the digester where methanogenic bacteria convert the volatile fatty acids into biogas. The second stage of the digester process is designed to take about 20 days, as the manure is pushed through as a semi-solid “plug” as each new batch of influent is loaded into the digester. In the GHD modified, plug flow digester, biogas is recirculated through the second stage through port valves along the wall of the tank which facilitate mixing in the axial direction (the plug “corkscrews” through the length of the tank. The methanogenic activity is maintained by recycling some of the sludge from the end of the process to inoculate the manure being added in the beginning. At the end of the second stage, the remaining materials flow into an effluent collection pit. The design and loading process is vital to facilitate the delicate and synergistic balance between the active acid bacteria from the first stage and the methane forming bacteria in the second stage. Performance evaluations of the VanderHaak digester are examining the role and effects of co-digestion of different feedstocks with dairy manure.

The biogas generated in the digester is collected and burned in a natural gas fueled reciprocating engine set modified to burn biogas. Heat from the engine set is recovered and used to heat the digesters (30 to 60% is used depending on air temperature), and some of the remaining heat is currently being used to heat a house and dry the bedding fiber. More heat is available to meet other thermal needs of the dairy or new enterprises. The engine

genset has the capacity to produce about 285 net kw of electricity (parasitic load is 15 kw) for sale to the power grid. This is enough electricity to serve approximately 180 average homes. The remaining digester effluent is separated into a solid and liquid stream for further processing. The separated solids are currently used as bedding material or sold as a bulk amendment for composting. Research is underway at WSU to refine a process for converting the material into plant growth media for sale to commercial nurseries as a replacement to peat moss. The liquid stream from the digester is land-applied as a fertilizer, and research is ongoing to extract excess phosphorous and nitrogen from the liquid to export it off the farm as another value-added co-product.

### **Financial Structure at a Glance**

A number of financial pieces came together to build and operate the Vander Haak digester. Here is a summary table.

Total cost	\$1.2 million*
USDA 9006 grant funds	\$272,000
Vander Haak Dairy, LLC. Private financing	\$768,000
WSU Center for Sustaining Agriculture & Natural Resources; Climate Friendly Farming Project	\$160,000
Did the bank accept the digester system as collateral?	No
Annual Return on Investment (ROI)	Estimated ~8% (average years 1 – 10); ~22% (average years 11+)
*Cost for physical plant / engine-generator set only. Additional costs were incurred for installing piping to transport manure, etc.	

### **Key partners and contacts for the Vander Haak Digester Project:**

VanderHaak Dairy, LLC; Andgar Corporation; Whatcom County Extension / Whatcom Dairy Biogas Team; Port of Bellingham; Whatcom Conservation District; Whatcom County PUD #1; Puget Sound Energy; USDA Rural Development; WSU’s CSANR & Climate Friendly Farming Project (funded by the Paul G. Allen Family Foundation)

### **Websites for more information:**

WSU Center for Sustaining Agriculture & Natural Resources: <http://csanr.wsu.edu/index.htm>

Climate Friendly Farming™ Project: <http://cff.wsu.edu/>

Anaerobic Digestion Research, Demonstration and Outreach Activities at WSU:  
[http://cff.wsu.edu/Publications/WSU AD activities.pdf](http://cff.wsu.edu/Publications/WSU_AD_activities.pdf)

WSU Extension Energy Program (Renewables): <http://www.energy.wsu.edu/projects/renewables/>

Pacific Regional Biomass Energy Partnership: <http://pacificbiomass.org/>

Agri-Environmental and Bioproducts Engineering Research Group: <http://c100.bsyse.wsu.edu/aebe/index.asp>