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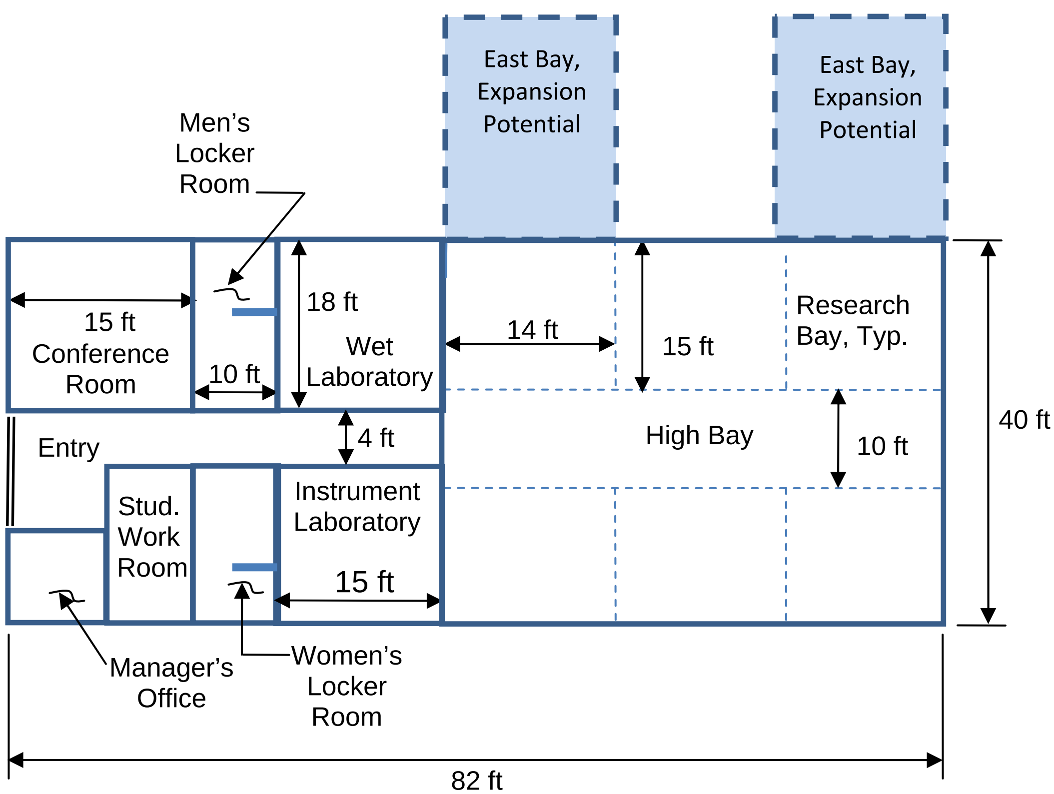
Background: MSU Anaerobic Digestion Research and Education Center

The planned Michigan State University Anaerobic Digestion Research and Education Center will be the central facility for ongoing and future waste-to-resource projects involving anaerobic digestion. Currently, research projects involving analytical instrumentation and laboratory, bench and pilot-scale equipment are spread out across the campus.

These will be consolidated at the ADRE Center, allowing a more cohesive and effective R&D program. This umbrella role of the ADRE Center allows faculty, staff, extension educators and students to tap the resources of a centralized facility and management structure, resulting in efficiencies and interdisciplinary learning opportunities. As a result, proposals relating to anaerobic digestion will be substantially more competitive.

Location and layout

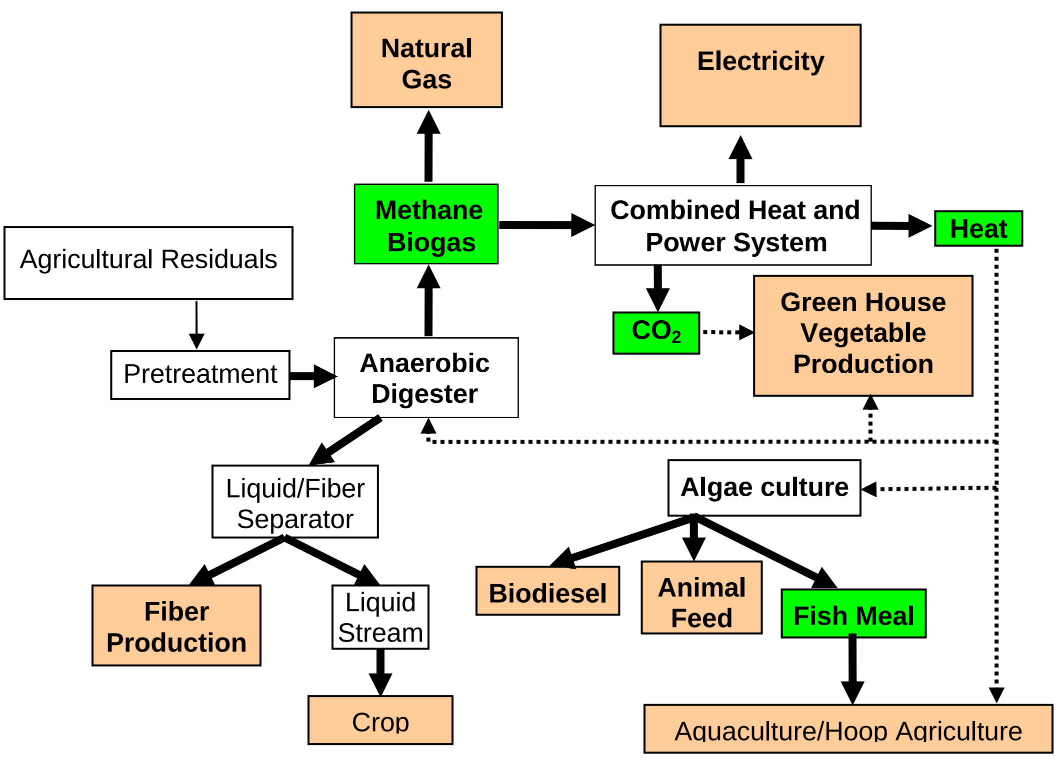
The MSU ADRE Center will be part of a planned research complex located near MSU's Dairy Cattle Teaching and Research Center south of campus on College Road, between Forest and Jolly roads. It will be next to the Animal Air Quality Research Center, where researchers study the impact of diet and dietary supplements on the animal emissions and manure, making this a one-of-a-kind complex for applied research on animal agricultural sustainability.



The center is designed for maximum flexibility. Each research bay will have electrical service suspended from the ceiling. Potable water service and sanitary drains will be available at multiple locations. The high bay will be ventilated by exhaust fans and heated in winter. One of the bays will be used for two of the existing four 200-liter bench-scale digester units. These digesters will be configured as an anaerobic membrane bioreactor for proof-of-concept experimentation.

Two existing 100-liter reactors will occupy another bay, allowing for bench-scale optimization research. The existing respirometers, used to conduct lab-scale anaerobic biogas-potential assays, will be placed in a bay so assays can be routinely and conveniently run. The remaining three bays provide the flexibility for diverse projects. The building will be designed for expansion out the east side when needed. Included can be the installation of greenhouses, algal bioreactors or additional high bays. Research on feedstock blending, including mixing manure from different animals and with residuals from the food processing and ethanol industries, also is possible.

The laboratories will be equipped to monitor and evaluate the performance of units being researched and evaluated. Locker rooms are needed so that researchers can practice proper safety procedures. All of these features will result in a safe and comfortable environment for the researchers, who are anticipated to be stationed at the ADRE Center full time.



Extracting energy and other products from waste using anaerobic digestion

The anaerobic digestion process

The flow chart on page two tracks the waste stream from the agricultural residues through possible byproducts, including growing algae culture on AD effluent. That is an important component of one of the projects supported by the Michigan Public Service Commission. Algae can live on environmentally harmful substances such as phosphorous, ammonia and carbon dioxide. Algal biomass is rich in omega-3 fatty acids, starch and protein that can be converted to animal feed and vegetable oil for biodiesel. Due to the tolerance to phosphorous and ammonia and high oil content, algae cultures could be the focus of one of the post-AD processes to utilize the remaining nutrients and carbon dioxide to reduce pollution and generate value-added products.

Five integrated components comprise the system: (1) pretreatment; (2) a high rate, short retention time completely mixed stirred reactor for the anaerobic digestion and biogas production of the liquid stream; (3) a solid-liquid separator to obtain a nutrient-rich liquid stream and fiber-rich solid stream; (4) combined heat-and-power system for generation of electricity and heat using biogas from AD; and (5) algae culture on AD effluent and carbon dioxide for biodiesel, fish meal and animal feed production.

The energy efficiency of the system will be improved with a novel combined heat-and-power cogeneration system. Various value-added products in addition to methane, such as digested fiber for soil amendment, oil-rich algae biomass for biodiesel feedstock, fish meal and animal feed will be produced from the system. In addition, the integrated system will further reduce the environmental impacts of greenhouse gas emissions, odors, pathogens and excess nutrients associated with manure.

Environmental impacts

The technology has the potential to co-produce at least two energy products, methane and biodiesel. Sustainability of animal production systems will be improved by reducing potential surface and groundwater pollution from manure application, eliminating noxious odors and reducing greenhouse gas emissions from manure lagoons.

Animal manure is of particular environmental concern due to the release of harmful greenhouse gas, odors and potential water and soil quality degradation. The U.S. Environmental Protection Agency calculates that agriculture contributed about 10 percent of the U.S. greenhouse gas emissions, primarily as methane and nitrous oxide. About 65 percent of the methane from agriculture is attributable to animal farms.

Phosphorous and nitrogen are two other major environmental impacts from animal manure. Nitrogen in the form of ammonia is volatized to the atmosphere to cause air pollution, and phosphorus can leak to the surrounding watershed to impact surface water quality. With proper treatments, those substances can be nutrient sources to offset the use of fossil fuels to produce commercial fertilizers.

Economic impacts

Small to medium-sized farms, those with fewer than 500 cows, represented approximately 53 percent of U.S. dairies in 2007, according to U.S. Department of Agriculture figures. Production from these dairies accounted for 48 percent of U.S. milk production. Michigan alone hosts approximately 2,359 dairy farms.

For such smaller farms, affordable “plug and play” AD-based technologies need to be developed because of the high cost of current technology, MSU researchers say. The U.S. Environmental Protection Agency estimated the current cost of such systems at between $200 and $700 per 1,000 pounds, and a typical cow weighs about 1,400 pounds.

The power generator portion of an AD-based system usually accounts for 30 percent to 40 percent of total capital cost, researchers say, including costly biogas purification for combustion in gas turbines. Reducing such capital and operational/maintenance costs will require novel designs of combined heat-and-power systems.

MSU researcher Wei Liao estimates that the 160 million dry tons of manure produced daily in the U.S. could generate approximately 36 billion kilowatt-hours of electricity, 50 to 70 million tons of high-quality fiber for soil amendment and animal bedding plus other value-added products.

The Great Lakes Regional Biomass Energy Program estimated in 2004 that revenue from annual electricity sales or cost offsets for operating AD systems amounted to $32 to $78 per head, depending on state and utility policies. One 1,050-head farm in Vermont realizes $200,000 annually from electricity sales, according to a Sept. 24, 2008, New York Times report, producing up to 300 kilowatts of electricity daily – enough to power up to 350 homes.

Dairies using AD also saved between $41 and $60 per head in fertilizer costs, the Great Lakes Regional Biomass Energy Program figured, thanks to improved nutrient availability in the digested manure. The savings from reduced exposure to nuisance odor complaints, MSU researchers add, are hard to quantify but still significant.

Additional revenue from other value-added products such as fish meal and animal feeds could enhance the economic performance of the system as well as diversify the income base of small animal operations. Marketing of algae biofuel products such as biodiesel and ethanol could benefit a local bio-refinery industry. MSU researchers, meanwhile, already are working on using the fiber from manure to make environmentally friendly construction products.

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