
# TECHNOLOGY FOR TOMORROW'S ENERGY

With national attention focused on promoting biofuels production, strengthening rural economies, reducing dependence on overseas oil, and taking actions to utilize $CO_2$ emissions, the Sunflower Integrated Bioenergy Center is being developed on the site of Sunflower Electric Power Corporation's Holcomb Station, a 360 megawatt (MW) coal-based power plant located in Finney County, Kansas.

The location of the Center in southwest Kansas on the 10,000 acres surrounding Sunflower Electric's power plant is advantaged by a strong livestock and agriculture industry, excellent transportation infrastructure, reasonable energy prices, and a rural work ethic that is combined with the pioneering spirit of the region.

The Center will integrate several commercial businesses and near-commercial bioenergy technologies. The subsystems include an ethanol plant, a biodiesel plant, a dairy, an anaerobic digester, an algae reactor, and a coal-based power plant. The integrated nature of the system will result in better economics as the biofuels industry weathers uncertain times.

Each subsystem will benefit from the efficiencies of integration like the re-use of water, consumption of co-products, roads, railways, shared human resources, and the utilization of power plant flue gas. The reduction of transportation and disposal costs for co-products will further add to the cost effectiveness of each individual subsystem.

## LEADERSHIP THROUGH COOPERATION

The National Institute of Strategic Technology Acquisition and Commercialization (NISTAC) and Sunflower Electric Power Corporation formed the Sunflower Integrated Bioenergy, LLC, to lead the development of the project. Sunflower Electric's interest in rural development and responsible energy production has been an excellent fit with the technology commercialization and project development work of NISTAC.

NISTAC and Sunflower Electric have been aided by the Kansas Bioscience Authority, which has committed resources and expertise as part of its role to promote the bioscience industry throughout the state.

Local, state, and national political support have been essential to the project. Leadership by the Kansas Legislature and the Governor's office resulted in beneficial bioenergy legislation for Kansas in 2007. Senators Roberts and Brownback and Congressman Moran have been very helpful and supportive of development efforts.

The founders of the Center also believe that similar synergies or subsets of the design of the Center will be replicated elsewhere as the Sunflower Integrated Bioenergy, LLC, is already pursuing requests to develop projects around other power plant locations.

For more information about the Sunflower Integrated Bioenergy Center contact

NISTAC

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"When this project is completed, it will facilitate the production of renewable energy that benefits our agricultural producers in central and western Kansas"
-- Earl Watkins, Sunflower president and CEO

## ENGINEERING & FEASIBILITY STUDIES

Black & Veatch Corporation completed a review of the Center model and a study of the integration among the Center's subsystems. Black & Veatch is a leading developer of coal-based power plants and brings a wealth of engineering expertise to the project.

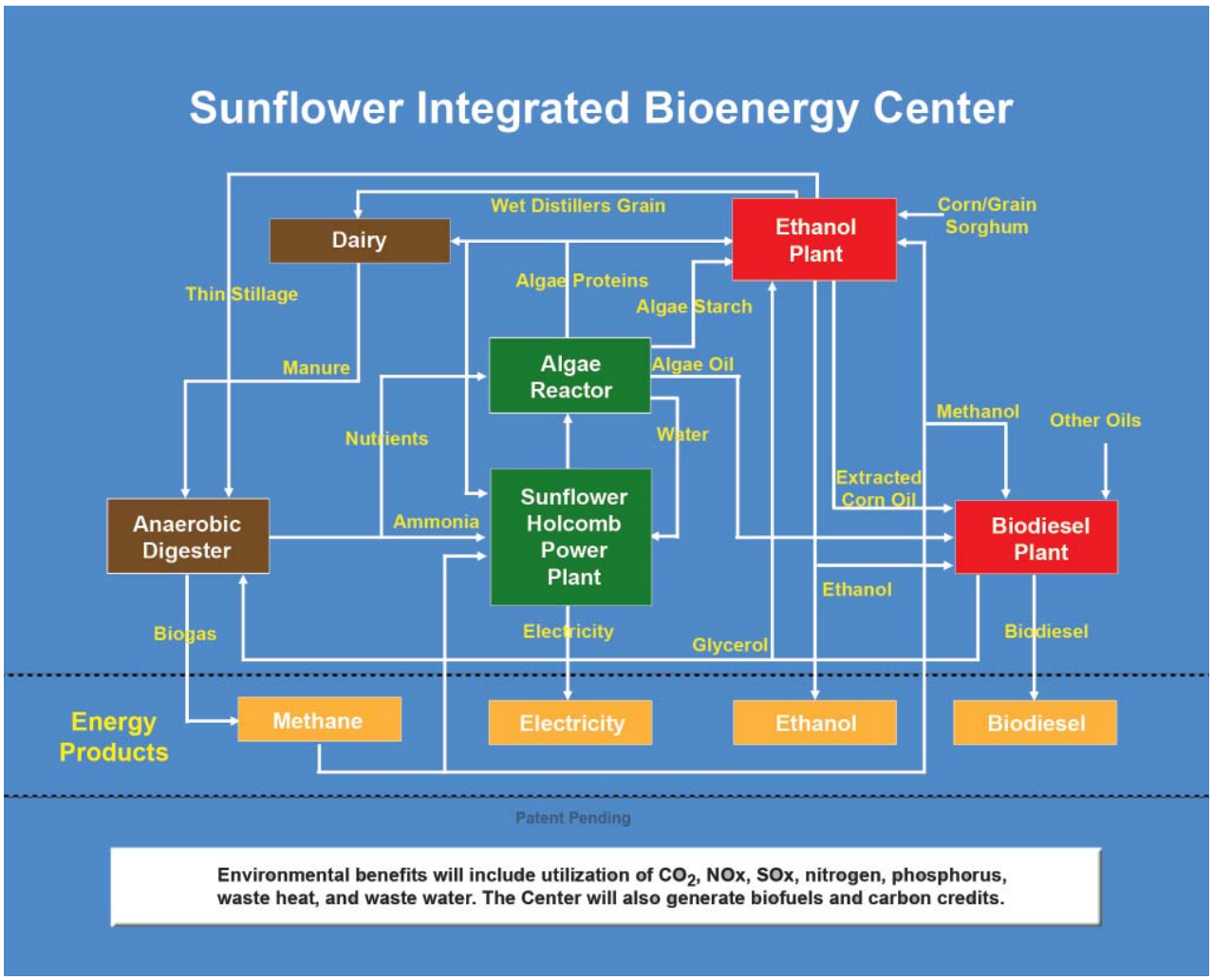
Ascendant Partners developed a financial and technical review of the model and made recommendations about the order of deployment for the subsystems.

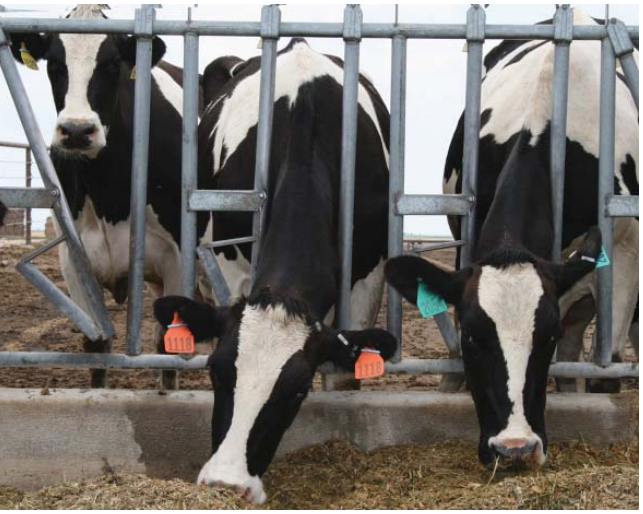
Because of the timing of the subsystem construction, integration will possibly occur in stages as the portfolio of technologies is assimilated into the ending model.

## DEVELOPMENT SCHEDULE

A study has been completed by GreenFuel Technologies to determine which species of algae are most appropriate to grow in the southwest Kansas climate. The studies also tested the algae strains with varying levels of $CO_2$ and different types of water, including ground water and water from an ethanol plant cooling tower. The study was funded by Holcomb Expansion Project participants Sunflower Electric Power Corporation and Tri-State Generation & Transmission Association, Inc.

The Center developers and the Holcomb Expansion Project participants are also working with the city of Holcomb and Finney County to plan for area traffic impacts resulting from the Center's development activities. Current project estimates reflect an expected capital investment of $399 million, which will result in the creation of 161 full-time jobs after construction is completed. The table on page 4 reflects the projected employment and investment by subsystem component.







## SUBSYSTEM INTEGRATION
## How They Work Together

### Algae Reactor

The cultivation of microalgae in the algae bioreactor system provides prospects for renewable energy production. Microalgae are the most primitive plant form—typically a single-cell plant. Because of this simple structure, algae are very efficient in converting sunlight, carbon dioxide, and nutrients into oil (for biodiesel) and starch (for ethanol).

The algae reactor will utilize water acquired from the anaerobic digester, which contains micro-nutrients, and process water from the coal plant. To grow, the algae will use the micro-nutrients from the digesters, along with carbon and nitrogen from the coal plant. A portion of the carbon dioxide and nitrogen oxides from the power plant flue gas are consumed in the bioreactor by algae through photosynthesis. Algae will be harvested daily, sent through a dewatering process, and then processed into co-products including solids and oils.

The outputs from the algae reactor are numerous. The lipid oils in the algae can be processed into biodiesel, carbohydrates fermented into ethanol, and proteins can be used in the production of feed and fertilizers for crops. The carbon-enriched algae biomass can be dried and fed back into the power plant as renewable fuel or further processed to produce transportation fuels and other high-value products. Most of the water can be recycled and used in the coal plant cooling system or returned to the reactor for additional algae growth.

Algae systems have been researched for decades, most notably by the National Renewable Energy Laboratory and NASA. Production was found to be viable, but most work was done when fuel prices were much lower than they are today. The first large-scale algae reactor is currently under construction in Spain. Because of the tremendous potential for biofuel production and $CO_2$ utilization, significant venture capital investment has been made recently into several algae companies to develop this technology.

### Anaerobic Digestion

An anaerobic digester, a system that harnesses the naturally occurring process of decomposition, is used to process waste and produce biogas and other co-products. The digester will process wastewater and manure from the dairy, thin stillage from the ethanol plant, and possibly glycerol from the biodiesel plant. Bacteria in the digester will produce methane that can be used by the ethanol and/or the power plant. Other co-products from the digester could include ammonia, water and nutrients (nitrogen and phosphorus) for the algae reactor, water for the power plant, and treated sludge that can be used as fertilizer.

Digesters have been used throughout the world for many decades, but they have recently gained popularity because of advances in anaerobic microbiology, reactor technology, and the potential to generate value-added end products.

"This project is based on the cutting edge of integration; I know of no other place in the world where renewable energy technologies will be efficiently utilized like our goal is for this project."
-- Kent Glasscock, NISTAC president and CEO

## Biodiesel Plant

Biodiesel is a fuel that has many of the same characteristics as normal petroleum diesel, including similar energy content, improved lubricity, and higher flash points. Biodiesel is derived from "cutting" triglycerides found in vegetable oils and animal fat, using simple alcohol in the presence of an alkali catalyst (transesterification). The biodiesel plant will be a multi-feedstock facility and will receive shipments of vegetable oil (including soy), animal fat, possibly extracted corn oil from the ethanol plant, and eventually algae oil from the algae reactor.

Although the use of biodiesel as a fuel for machinery dates back to the 1930s, the awareness in biodiesel as an alternative fuel has grown dramatically over the past several years. Some experts believe that growth in the biodiesel industry may be limited by the access to or cost of oil sources. Many of the crops that produce oil require large acreages to produce a significant volume of oil. Soybeans, for example, produce around 50 gallons (depending on location) of biodiesel per acre per year. In contrast, one acre of algae could produce 8,000 gallons of biodiesel per year.

## Coal-Based Power Plant

The Holcomb site offers several resources for an integrated bioenergy facility. These include access to land, water, rail, natural gas, carbon dioxide and heat from power plant emissions. The emissions produced by the power plant, when passed through the algae reactor, optimize algae growth by utilizing the warm flue gas that includes carbon dioxide.

## Dairy

The dairy brings important components to the Center, and southwest Kansas has characteristics that allow for a growing dairy population. The dairy will provide manure and wastewater to an anaerobic digester where it will be converted to methane. The starch and wet distillers grain from the ethanol plant and possibly solids from the algae reactor will be used by the dairy for cattle feed.

## Ethanol Plant

Ethanol is a high octane, clean-burning, renewable fuel that is produced by converting cereal starches found in grain into sugar. The sugar is then converted to ethanol through fermentation. The ethanol plant will consume local corn and milo as well as grain railed from other parts of the country, possibly starch from the algae reactor, and methane (displacing natural gas) from the anaerobic digester. Co-products that will likely be provided include extracted corn oil to the biodiesel plant, thin stillage to the anaerobic digester, and distillers grain to the dairy and surrounding livestock industry.

Project developers are also exploring options to power the thermal needs of the ethanol plant with over 90% renewable fuels. This achievement would enable the ethanol to qualify for additional credits under the Renewable Fuels Standard.

**Projected Impacts**

| Subsystems | New Jobs | Investment |
|---|---|---|
| Ethanol | 50 | $200M |
| Biodiesel | 25 | 66M |
| Dairy | 65 | 53M |
| Digester | 6 | 25M |
| Algae* | 15 | 55M |
| Total | 161 | $399 Million |

*with projected initial commercial build out