Algae R & D Tools

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The world's dependence on finite, nonrenewable petroleum is at the heart of many of the environmental and energy challenges we face today. Additionally, transportation fuel use is a major contributor to global warming: more than 30 percent of the CO2 emissions in the United States come from the burning of petroleum fuel for transportation.[1] [1]

Efforts are underway around the world to develop an economically viable and scalable alternative fuel source that will reduce the net emissions of CO2 in the atmosphere.

Biofuels can provide an alternative to petroleum-based fuel and also reduce total CO2 emissions. By definition, a biofuel [2] is a solid, liquid, or gaseous fuel derived from recently deceased biological material. For photosynthetic organisms, such as corn or soybeans, the plants use the energy of sunlight to convert available CO2 into hydrocarbons, creating stored chemical energy. Fuel is produced and CO2 is consumed, thereby addressing both the fuel supply and global warming challenges.

Biofuels can be produced from any biological carbon source, and a variety of crops are currently used for biofuel production in the United States and around the world. These crops include corn with sugars typically used as a feedstock for ethanol, and soy, canola, and palm with oils typically used as feedstock for biodiesel. Unfortunately, growing these crops typically requires good quality agricultural land, which increases the overall demand for cropland. Other resources, such as water for irrigation and petroleum for fertilizer, are also consumed in the production of crop-based biofuels.

The Benefits Of Using Algae Because Algae grows 50 to 100 times faster than conventional food crops, biofuels produced from algae have the potential to become a scalable alternative energy solution that could one day replace petroleum-based fuels. Additionally, algae are single-cell organisms that do not require freshwater resources or soil for growth.

Algae can grow in aqueous suspension in many nonpotable and saline water sources. By growing algae in areas that are not suitable for food crop production, more land and water can be made available for growing food.

In 1978, the U.S. Department of Energy (DOE) launched the Aquatic Species Program to research the production of energy and biodiesel from algae. However, as crude oil prices continued to decline in the mid-1990s and the DOE aimed to cut costs, the program was discontinued in 1996.

While this study showed algae can achieve the desired production yields, researchers concluded that the solution could not be cost-effective unless the price of oil doubled.

In 2006, with oil prices nearly triple what they were the previous decade and still rising, along with concerns over greenhouse gas emissions, it was time for a fresh look at algae as an energy source.

The Engines and Energy Conversion Laboratory (EECL) at Colorado State University focuses on developing technological and entrepreneurial solutions to pressing energy and environmental challenges.

EECL worked with entrepreneurs who saw the potential of the DOE research, and Solix Biofuels [4] was formed with the goal of delivering scalable, cost-effective technology to produce biofuels from algae. In the three years since its foundation, Solix Biofuels has refined multiple generations of the Algal Growth System (AGS) technology now operating at the Coyote Gulch Demonstration Facility in southwestern Colorado.

The Solix Vision Algae can be cultivated in two ways — in an open pond system (either naturally occurring or engineered) or in an engineered closed system. Algae must be hardy and resistant to competitors when grown in open pond systems where environmental conditions cannot easily be controlled.

Without controlled conditions, it can be difficult to sustain desired species of algae or grow them at optimal rates for biomass or fuel production. We focused on developing closed growth systems. In addition to supporting the cultivation of specific target cultures, a closed growth system can feed CO2 from industrial processes directly to the algae at high concentrations and in a controlled manner, thereby tailoring growth conditions and maximizing the amount of CO2 captured.

In August 2006, we deployed the first closed-system prototype of our AGS. For the last three years, we have continued to refine our technology and expand our area under algae cultivation. In July 2009, we commissioned a large-scale growth system for the production of biofuels at our Coyote Gulch Demonstration Facility.

Automation Systems The challenge for our AGS automation system was to develop data acquisition and controls to manage and control the growth process. We wanted a single technology platform that would support both R&D experimentation and industrial operation, thereby accelerating the transition of this new technology from the laboratory to the demonstration plant.

For R&D, the platform must be flexible for the engineers and scientists who conduct experiments on separate test systems at our labs. A variety of chemical and physical sensors and flow actuators can be used. For plant operations in an industrial environment, the platform must be stable, reliable and straightforward, and it must interface with industrial-scale instrumentation and controls. In addition, all data needs to be collected in a central repository and presented in a variety of formats that are accessible and useful to all stakeholders, including managers, operators and R&D personnel.

Control Solution Using LabVIEW [5], we developed the entire Supervisory Control and Data Acquisition (SCADA) system for our AGS, including the operators' user interface and data logging and Compact FieldPoint [6] code that monitors and controls the algal growth process.

Our pilot plant includes a variety of systems for delivering gas and liquid flows to the AGS, growing the algae, harvesting the algae, and processing the harvested algae into products such as feedstock for fuel.

When developing our control solution, we had several possibilities to choose from including designing a large distributed control system (DCS) or using low-end programmable logic controllers (PLCs). We selected LabVIEW and NI programmable automation controllers (PACs) [7] for our application because of the possibility to integrate simulation, control, SCADA and Web reporting into a single software solution. By using NI products, we have the flexibility of a custom measurement and analysis system and the capabilities of a DCS.

Compact FieldPoint systems gather all the required input data from sensors and execute proprietary control algorithms to deliver the required nutrients to the algae as it grows. In addition, critical process parameters are displayed in a LabVIEW GUI that plant operators regularly monitor to keep track of the plant operation. Data is automatically stored in the LabVIEW DSC Module [8] Citadel database for later retrieval and processing. If the values of critical parameters are outside safe ranges, operators are notified with local warning alarms, alerts on the operator interface screen and text messages to cell phones and pagers.

With LabVIEW, we can collect data from both small- and large-scale process tests and profile the response of different types of algae to varying atmospheric variations. In addition to controlling the algae-based biofuel production process, LabVIEW and NI hardware also log a range of measurements during each test, providing our researchers and control engineers with valuable data.

Then we perform postdata analysis with DIAdem [9]. Using this feedback in our research, we can determine the levels of CO2 and other nutrients that need to be present in the AGS under specific conditions to achieve optimal production.

Scaling Up Data Acquisition & Control At our Coyote Gulch Demonstration Facility, we are currently monitoring and controlling our AGS using Compact FieldPoint devices. Because our facility deployments will expand to cover larger areas, we must significantly reduce the cost per control point, which has driven us to research alternative control solutions.

As we plan to transition to lower-cost devices, we are considering both NI Single-Board RIO and the NI wireless sensor network (WSN) platform [10]. These products may better fit our future needs, and we can combine them with our integrated system of hardware and software components from NI.

Algae-based biofuel is poised to revolutionize the energy industry and play a leading role in addressing greenhouse gas emissions.

NI has provided the products, tools, and ongoing technical support that we use to quickly develop and deploy our technology for growing algae to produce fuel. We expect our strategic partnership with NI will continue to support our expansion as we deploy our systems on an increasingly large scale.

[1] [11] *2009 US Greenhouse Gas Inventory Report. United States Environmental Protection Agency.*
http://www.epa.gov/climatechange/emissions/downloads09/ExecutiveSummary.pdf
[12]

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