FUELING THE FUTURE

Biofuels grow as viable alternatives

By Eric Gold

Many of us have driven up to a favorite fast-food restaurant to order some golden french fries or an apple pie. When a SeQuential Pacific Biodiesel truck pulls into a fast-food parking lot, the driver usually isn't there for lunch—instead, the truck comes for the restaurant's used fryer oil. In 2013, SeQuential turned the oil from 7,000 restaurants into 6 million gallons of biodiesel, a biomass-based substitute for ordinary petroleum diesel. The production figure was an increase from 5 million gallons of fuel in 2012.

COURTESY: SEQUENTIAL PACIFIC BIODIESEL

SeQuential Pacific Biodiesel gathers used cooking oil from restaurants and businesses in trucks such as this one. The company converts the oil to fuel at its Salem, Oregon, plant.

SeQuential's story is one of growth—and is reflective of the potential for the broader biofuels industry. CEO Tyson Keever started out by forming a college club with several University of Oregon classmates in the early 2000s, making biodiesel from used cooking oil and selling it on the streets of Eugene. The club evolved into a company called SeQuential Biofuels. Then a 2008 partnership with Honolulu, Hawai'i–based Pacific Biodiesel led to the company's current name as well as the creation of Oregon's first commercial biodiesel production facility, located in Salem.

Today, the company sells its fuel at its two retail stations in Eugene, through a network of partners with stations in Portland and Seattle, and to vehicle fleets such as the city of Portland's, as well as to oil distributors for blending with petroleum fuel. In addition to transportation biofuel, SeQuential provides oils for home-heating blends. With nearly 100 employees and support from big-name investors such as musician Willie Nelson, the company is aiming to produce 7 million gallons of fuel in 2014, says marketing manager Rachel Shaver.

Today a fleet of about 40 pump trucks, running on the company's fuel, brings fryer oil to SeQuential's Salem, Oregon, plant—from oil producers such as the Burgerville chain's 39 Portland-area restaurants, the Nike campus in Beaverton, Kettle Chips' factory in Salem, Dick's Drive-Ins in Seattle, the University of Washington and the University of Oregon. At the SeQuential plant, heat and a catalyst such as lye break the oil molecules into biodiesel and glycerin, an industrial cleaning by-product the company also sells. Providers don't pay to have SeQuential pick up the oil, which would otherwise go to a landfill. And SeQuential offers an incentive to large suppliers who keep their oil free of debris.

A big part of the impetus for SeQuential's growth is increased demand for fuels that burn cleaner—perhaps from an increasing number of customers hoping to reach the drive-through windows on the same fuels that crisp their taters. A National Renewable Energy Laboratory study shows that greenhouse gas emissions could be more than 52 percent lower for biodiesel than for petroleum diesel over its lifetime, from production through consumption. And SeQuential reports say that its biodiesel emits up to 78 percent less carbon dioxide at the tailpipe than a conventional petroleum-based diesel does.

SeQuential's leaders acknowledge that biodiesel from used cooking oil can't replace petroleum by itself—no matter how much Americans love chicken nuggets. And yet, the development of this fuel—in concert with other environmentally friendly practices—is a great place to start.

"Our motto is walk, then bus, then biodiesel," says Tyson Keever. "But the product we produce is a very good solution as we work toward looking at the system as a whole."

An Industry Advances

Once limited to the efforts of hobbyists and environmental activists, the production of biofuels—fuels made from biological sources such as plant oils or animal fats—is now a maturing U.S. industry. Biodiesel is just one of many biofuels on the market or in development, and used cooking oil is just one possible biofuel "feedstock"—the industry's term for the raw material used to make a fuel.

Companies such as Imperium Renewables Inc., in Washington state, make biodiesel from crops such as canola (others use soy). The most common biofuel is ethanol—an alcohol made from corn, sugar cane or other sources—which is now blended into almost all gasoline sold in America. Pacific Ethanol Inc., with operations in California, Oregon and Idaho, is a large western-state ethanol producer. And companies such as San Diego–based Sapphire Energy Inc. are developing new biofuels from a variety of feedstocks and processes. Some of these, such as Sapphire's algae-derived "green crude," mimic petroleum at the molecular level.

The conventional petroleum industry still dwarfs the output and impact of all biofuels combined. And

yet, with the variety of companies and researchers exploring biofuels, as well as the potential for environmental benefits from even incremental changes, today's biofuel industry is an exciting field to follow.

Building Alternatives

The Energy Independence and Security Act of 2007 targets a domestic production of 36 billion gallons of renewable fuel per year by the year 2022. For 2012, though, the U.S. Energy Information Administration (the statistical and analytical arm of the U.S. Department of Energy) reported that the two main components of biofuel production still added up to less than 15 billion gallons, with U.S. production of fuel ethanol at 13.30 billion gallons and production of biodiesel at 0.97 billion gallons.

Meanwhile, the United States consumed about 133 billion gallons of gasoline in 2012 and 134 billion gallons in 2013, according to U.S. EIA.

And the nation had net *imports* of about 95 billion gallons of crude oil and petroleum in 2013. Importing so much oil means that billions of dollars leave the American economy annually. Dependence on foreign oil can also expose the country to price spikes and supply disruption. Meanwhile, again according to U.S. EIA data, each gallon of gasoline (unblended with ethanol) burned adds 19.64 pounds of carbon dioxide to the atmosphere. Environmental, energy-security and economic concerns form the basis of biofuels' appeal for advocates of alternative-energy sources.

COURTESY: PACIFIC ETHANOL INC.

Pacific Ethanol Inc. can produce 60 million gallons of fuel per year at this facility in Stockton, California.

One of these advocates is Mary Solecki, who runs the Clean Fuels Program at Environmental Entrepreneurs, an organization based in New York that describes itself as a national community of business leaders who pro-

BIOFUELS TAKE FLIGHT

In July 2013, Hawai'i BioEnergy—formed as a consortium of three of the state's biggest landowners and other investors—announced an agreement with Alaska Airlines to supply locally sourced aviation biofuels for its Hawai'i flights within five years of regulatory approval, starting as soon as fall 2018. The agreement represents one part of a broad-based commitment to sustainability by Alaska Air Group, which in 2013 was ranked No. 1 in fuel efficiency among U.S. airlines by the International Council on Clean Transportation, and has reduced its overall carbon footprint intensity by 30 percent since 2004.

The continuing commitment to sustainable-fuel development is a key facet of the Alaska Air Group efforts. In 2011, Alaska Airlines and Horizon Air were the first U.S. airlines to fly multiple passenger flights powered by a blend of conventional fuels and biofuels, when they operated 75 flights on 20 percent biofuel. Prior to this, Alaska Air Group took part in the Sustainable Aviation Fuels Northwest study, the results of which were published in May 2010. More recently, in September 2013, Alaska Airlines was named as an industry partner for the Center of Excellence in Alternative Jet Fuels and Environment, a new national research center due to be created by the Federal Aviation Administration at Washington State University in Richland, Washington.

Development of a sustainable fuel source in Hawai'i is of particular interest for the airlines as well as for the Aloha State. Isolated from the mainland, Hawai'i depends on imported oil not only for transportation fuel but for much of its electricity production. Oil price fluctuations can mean not just more expensive gas but higher food prices in Hawai'i.

Hawai'i BioEnergy's goal is to develop biofuels from sources such as eucalyptus, an attractive feedstock because it grows quickly and is already present on the islands. Executive Vice President and COO Joel Matsunaga foresees the production of an array of fuels, from oil for power generation to gasoline and diesel to jet fuel. (In late 2013, Hawai'i BioEnergy also received regulatory approval for its contract with Hawaiian Electric Company to supply biofuels for electricity.)

"When you spend so much money on imported oil," Matsunaga says, "that's a lot of your economy leaving your state. Hawai'i's solution to its energy demand is a quilt of different sources, [including] wind, solar and wave [power]. But at some point you need liquid fuels, too."

Alaska Air Group Executive Vice President Keith Loveless agrees, seeing benefits for the state as well as for business.

"Beyond the environmental advantages," he says, "it improves the fuel-supply integrity in the state of Hawai'i, which will allow for the further growth of our airline operations throughout the islands." —*E.G.*

COURTESY: SAPPHIRE ENERGY INC. (3)

San Diego–based Sapphire Energy operates a facility in New Mexico (top left) where it cultivates and harvests algae (top right) that it then converts to a "green crude" that resembles petroleum (above).

mote sound environmental policy and economic growth.

Solecki acknowledges that biofuel producers have a long way to go to reach any significant scale relative to the well-established petroleum industry. But she views the expansion of biofuels as important for the nation.

"We Americans are going from one feedstock and one fuel—petroleum in the ground used to make gasoline and diesel fuel—to two- or three-dozen feedstocks and technologies," says Solecki. "That diversified approach has very good implications for our energy security in the future."

Scaling Up

By early 2004, Seattle resident John Plaza had left his job as a commercial airline pilot, taken out a second mortgage, cashed in his 401(k) and sold other assets to begin a new career in biofuel development.

"I sold my motorcycle and my sports car," recalls Plaza, "and started Seattle Biodiesel."

A partner helped Plaza build a facility able to produce 5 million gallons of biodiesel a year. By 2007, the company had 125 employees and had raised $135 million in private equity and $100 million in debt financing. The capital allowed the company, now known as Imperium Renewables, to build a 100 million-gallon-a-year plant in Grays Harbor, Washington—among the largest such facilities in the country, according to Plaza.

Imperium uses mostly canola oil to make its fuel. Much of the canola is grown in Canada, but some is from Washington and other states. Canola's crushed seed yields 60 percent of its mass as high-protein meal sold as livestock feed. The other 40 percent is oil. Imperium refines the oil into biodiesel through a proprietary process and sells much of it to major oil companies, such as Shell, for blending.

"We don't see the oil industry as our nemesis," Plaza says. "They're [the] industry that we sell to. We need them to be supportive and successful, and for policymakers to recognize the synergies [between the petroleum and biofuels industries]."

Imperium is also working on renewable jet fuel. "I haven't lost my love for all things aviation," says former pilot Plaza. His company won a demonstration project for Boeing to produce what he calls a first-generation bio-based jet fuel. Today, Imperium is developing jet fuel from sources such as municipal waste, wood slash piles (from the timber industry) and other feedstocks. While the company is a few years from commercial production, Plaza sees a great opportunity. Global demand for jet fuel is about 80 billion gallons a year, and Plaza says as much as 250 million gallons of jet fuel per year could be made from Seattle's trash alone—despite the city's robust recycling program that diverts much of the municipal waste.

As a young industry, biofuels need federal support, Plaza says. "Not pockets of innovation—national innovation. Biofuel

has seen tremendous instability of policy. I like to remind people that the petroleum industry is 120 years old, and is still heavily subsidized today," he says. "We're offering a good solution to produce energy at home, and a pathway to the reduction of greenhouse gases. In future decades, we're not going to be given the luxury of ignoring those consequences and costs."

Distilled Energy

While companies such as SeQuential and Imperium are contributing to the growth of biodiesel, ethanol is still the king of biofuels. Almost all gasoline sold in the U.S. today contains this alcohol at levels up to 10 percent—a mixture known as E10. Corn from the Midwest is America's go-to source for ethanol (as sugar cane is in Brazil), though some biofuel critics suggest that we may be unwisely trading food for fuel. Ethanol can be made from many other feedstocks, including corn stover (the inedible parts of a corn plant), wood or even municipal waste. According to a 2007 Department of Energy study, the combined production and use of corn-based ethanol instead of gasoline reduces greenhouse gas emissions by 19 to 52 percent, depending on the source of energy used to make the ethanol. The production and use of cellulosic ethanols—ethanols made from non-food-based feedstocks such as crop residues, wood residues and other wastes—could reduce greenhouse gases by up to 86 percent.

Sacramento-based Pacific Ethanol Inc. makes its product from a variety of feedstocks—including corn as well as winery wastes, surplus beet sugars and sorghum (a crop with a lower carbon footprint than corn). Paul Koehler, who lives in Portland, founded the company with his brothers Neil—who had already been in the ethanol business for 20 years—and Tom, as well as former California Secretary of State Bill Jones. Two years later, Pacific Ethanol went public; it is now traded on the NASDAQ.

The locations of the company's four biorefineries—one in Oregon, one in Idaho and two in California—are part of its "destination strategy," a model Koehler says sets Pacific Ethanol apart from Mid-

west producers. The strategy is to have facilities near the destinations of their products rather than their fuel feedstocks. Unlike Midwest ethanol companies located near corn, Pacific Ethanol's facilities, Koehler says, are near *cars*—in major fuel markets such as San Francisco, Portland and Boise—and near *cows* (on dairies or ranches that purchase coproduct animal feed from the company).

Koehler says that Pacific Ethanol's coproducts—animal feed and corn oil—account for about a third of the company's revenues. Koehler points to the animal feed his company markets as evidence that the "food versus fuel" criticism of corn-based biofuels is overblown. Much of the nation's corn, he says, is already grown for animal feed, and his company's process still produces that feed along with the ethanol.

The feed Pacific Ethanol produces, at about 70 percent moisture, is heavy. Being close to the cows saves shipping costs and energy—the company doesn't have to dry the feed for shipment. That and production efficiencies, Koehler says, mean that the company uses about one-third less natural gas than other fuel producers. Overall, Pacific Ethanol claims to have among the lowest-carbon ethanol of any commercially available transportation fuel.

In terms of incentives, Pacific Ethanol is again aided by location—and by government policy. California's Low Carbon Fuel Standard creates economic benefits for emission reductions. It requires producers of petroleum-based fuels to reduce the carbon intensity of their fuels or purchase credits from companies such as Pacific Ethanol that produce low-carbon fuel alternatives. The governors of Oregon and Washington—along with leaders in British Columbia—have agreed to align policies with California's, though it's too soon to know what form that alignment will take.

Going forward, Koehler says, the company is exploring operations efficiencies as well as new materials and methods. "It's very much an organic process," he says. Fine-tuning the sometimes unpredictable process of turning crops into ethanol is one opportunity to improve Pacific Ethanol's product and bottom line. The company is

also looking at new ways to make fuel.

Koehler looks forward to the day when more of the gas sold in the United States exceeds the 10 percent blend. He feels that widespread use of a 15 percent ethanol blend is possible now, though some lobbying groups and car manufacturers oppose this, citing concerns about engine failures. "It's probably the most tested fuel on the planet, the E15," says Koehler. "The cars can handle it."

Mimicking Molecules

Ethanol and biodiesel have made inroads into world markets for transportation fuels, with plenty of room for growth. At the same time, companies and researchers are investigating ways to make biofuels more chemically similar to petroleum—in a category known as renewable hydrocarbons. One such fuel is "green crude," being developed by San Diego's Sapphire Energy. This oil made from algae is virtually identical on a molecular level to the petroleum pumped out of the ground. This means it can be used for all the same applications as petroleum and has the same energy density—the amount of energy stored within a given volume or mass—as crude from an oil well.

Tim Zenk, Sapphire's vice president of corporate affairs, says there is a simple reason for the similarity between his company's algae oil and petroleum crude: In prehistoric times, petroleum was often some form of algae.

"We validated that we can take the algae we know today and turn it into a pure hydrocarbon, much like Mother Nature did over 300 million years," says Zenk. The difference, of course, is that Sapphire's process is quite a bit faster.

The company, which was founded in 2007, operates a 100-acre algae farm near Columbus, New Mexico—the world's largest demonstration of algal crude-oil production. There, on land that has been fallow since the 1970s because of brackish water, Sapphire grows algae in open pools. At this location, the algae oil production doesn't compete with other land and water uses because the salty, alkaline water is not potable, nor is it CONTINUED ON PAGE 181

FROM PAGE 166 model of its Leaf electric car to compete more directly with the compliance-car deals. While manufacturers of more expensive EVs such as the BMW i3 and Tesla Model S have been impacted little by the newer electric entries, the additional EV options available are certainly an advantage for shoppers.

If you're lucky to live where these vehicles are available, you'll find that they provide some interesting opportunities for a second or third car in the household. Most Americans drive only about 35 miles per day on their daily commute. That's well within the comfortable driving range of any of these models, even when you're running the heating or air conditioning.

By the way, this niche market isn't cooling off anytime soon. In fact, there's a second generation of all-electric models on the way, including the Kia Soul EV and Volkswagen e-Golf—both slated to arrive later this year. Kia has already said that the Soul EV will be able to go 80 to 100 miles on a charge, while VW claims a range of about 100 miles for the e-Golf.

Although these small electric cars are available on a limited basis, they raise questions about what might happen without the incentives. They present a new kind of driving experience, and help refine our impressions of what a cost-conscious commuter car ought to be.

If you remember what we used to call economy cars—yes, the buzzy, boomy, slow small cars that sacrificed so much for efficiency—you'll understand what a game-changer these cars are. As a second or third car, exclusively for commuting or around-town errands, the latest crop of small electric cars is a nice step up.

Already, customers have lined up for some of these models, with the Fiat 500e rumored to be sold out, and reports of waiting lists for the Honda Fit EV. If automakers can continue to produce small wonders like these, and keep prices low enough once tax credits expire, the pejorative sense of an "economy car" might truly be a thing of the past. ▲

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FROM PAGE 90 useful for agriculture.

"Using freshwater to produce energy is a nonstarter," Zenk notes. "Freshwater is rarer than crude oil." The gaseous carbon dioxide Sapphire feeds its algae would float away into the atmosphere were it not for the alkaline quality of the water, which turns the CO_2 aqueous. The conditions suit Sapphire's algae.

"All the algae do is consume CO_2, multiply and divide," Zenk says. "Every hour of every day. It's agriculture. Just a new form of agriculture."

To perfect the process of generating oil from algae, Sapphire works with researchers from Seattle's Institute for Systems Biology, from the University of California at San Diego, and from dozens of labs around the country.

A peer-reviewed study conducted by scientists from the University of Virginia, the Scripps Institute of Oceanography in La Jolla, California, and other organizations (including Sapphire Energy) showed that producing and using algal fuels might lead to a 68 percent reduction in greenhouse gases when compared to the extraction and use of petroleum. This factors in the benefits of biofuels on the production end. As with other biofuel feedstocks, algae consume CO_2 as they grow, offsetting some of what is emitted at the tailpipe.

Today, Sapphire is producing three barrels (126 gallons) of green crude a day, using 20 acres of its pond facility. The next phase, to be completed next year, will increase that production to 25 barrels per day. Zenk says the company's goal is to produce at least 5,000 barrels a day by 2018. That, he says, would require a 15,000-acre algae-pool complex, comparable in size to a medium to large corn farm. While a corn farm yields about 420 gallons of ethanol per acre per year, Zenk says, algae ponds such as Sapphire's may produce 5,000 gallons of oil per acre per year (with a higher energy density to the fuel, as well). Because of the fuel's similarity to petroleum, Sapphire claims that green crude is compatible with existing infrastructure (including pipelines, distribution centers and vehicles). The company recently partnered with Phillips 66, the oil refiner, to analyze Sapphire's oil. The hope is that data from this analysis will allow refiners to process Sapphire's green crude alongside petroleum.

Sapphire may have a long way to go to have significant impact on America's transportation fuels, though a 2011 study by the Pacific Northwest National Laboratory in Richland, Washington, put the potential for oil production from American-grown algae at 21 billion gallons a year (a figure that would require a large amount of water and land use, though these needs would vary by region).

"We have the ability to produce highly dense fuels and reduce greenhouse gases all at the same time," Zenk says.

Fueling the Way Forward

Sapphire's algal crude, Pacific Ethanol's fuel, and the biodiesels of such companies as Imperium and SeQuential are just a few of the fuels in a diverse and dynamic biofuels sector. Producers around the world are making biofuels from an ever-growing array of feedstocks and processes—each with different performance, economic and environmental characteristics. Of course, these various biofuels, taken together, still represent just a small part of the world's fuel use today. Even so, developing and using more and better biofuels is a concrete way to make transportation greener and more economically secure.

For clean-fuels advocate Mary Solecki, of Environmental Entrepreneurs, biofuels' upside is big, and so are its challenges. One obstacle, she says, is the public's limited familiarity with the fuels. "So many people understand renewable energy when it comes to solar and wind," she says. "But in reality, so much more of our economy is underpinned by our use of fuels. We have only one really large option in the United States today: petroleum." The risks and rewards for biofuel producers, she says, are high. "They're going to become the next Rockefellers, but for every success, there could be some failures. That doesn't mean we should stop trying." ▲

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