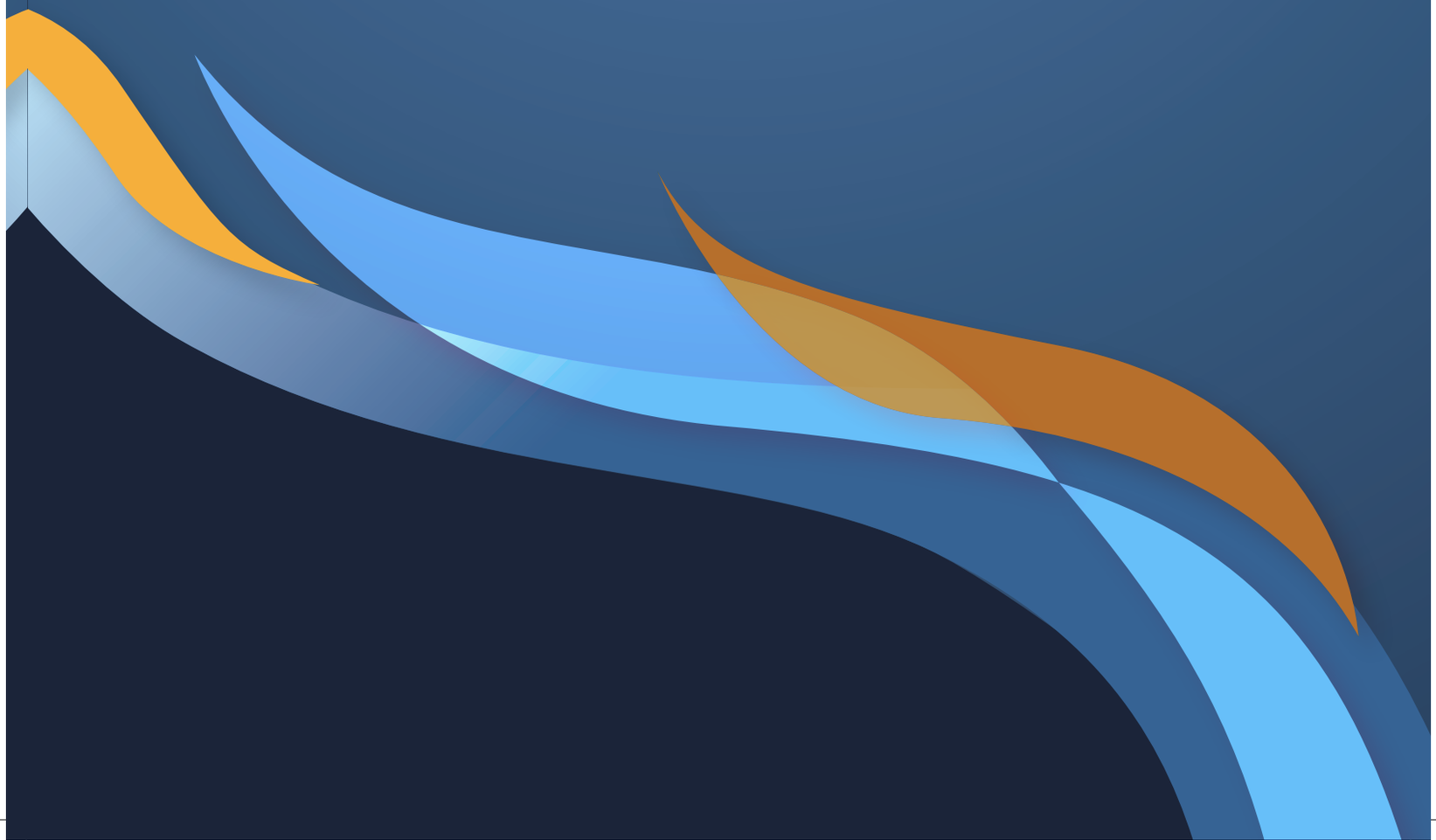
Educating Biofuels Production and Analysis Technicians

for Future Industry Needs

The Report from the Biofuels Workforce Summit

May 23-24, 2013



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Acknowledgements

We appreciate the National Science Foundation's forward thinking. Its support of this meeting will help community colleges structure their programs to prepare technicians for careers in the emerging biofuels industry.

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The NBC2 Co-Principal Investigators and Hub Directors from across the nation bring passion and expertise to the center's goal of developing a world-class biomanufacturing workforce to improve the quality of life. We are grateful to the following NBC2 Hub Directors for their invaluable input on the Biofuels Workforce Summit: Jim Hewlett at Finger Lakes Community College for Upstate New York; Lara Dowland at Mount Wachusett Community College, represented by Tom Montagno at the summit, for New England; Maggie Bryans at Montgomery County Community College and Linda Rehfuss at Bucks County Community College for BigPharma; Bill Woodruff at Alamance Community College for the South; Sengyong Lee at Ivy Tech Community College for the Midwest; and Mike Fino at MiraCosta College for the West.

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Sonia Wallman

Principal Investigator and Executive Director of NBC2

The NSF ATE Biomanufacturing Center and Collaborative

September 2013

Executive Summary

Panel presentations and formal discussions focused on trends in the development of biofuels and how best to educate technicians for careers in this emerging industry during the two-day Biofuels Workforce Summit. The summit was convened May 23 and 24, 2013, at Kapi'olani Community College in Honolulu, Hawai'i, by the Northeast Biomanufacturing Center and Collaborative (NBC2) with support from the National Science Foundation's Advanced Technological Education program. NBC2 is an NSF Advanced Technological Education center that coordinates local and regional efforts into a national biomanufacturing education and training system to promote, create, and sustain a qualified biomanufacturing workforce

Eighty-three individuals who are involved in either the biofuels industry or biofuels education attended the summit to identify the skills, knowledge, and attributes that biofuels technicians will need to succeed in the workforce. Currently, only a few community colleges scattered across the nation offer specific programs to prepare biofuels technicians. Representatives of these biofuels programs and well-established biotechnology programs were among the educators who participated in the summit. Several biofuels industry pioneers were among the business people who shared their perspectives on the industry's future.

From the panel presentations and discussions it is clear that the biofuels technicians who enter the workforce in the next few years will be part of teams tackling the technical issues that must be overcome to reduce the cost of biofuels. Lower costs to customers and increased profits for producers will influence the wider use of biofuels, summit participants agreed. The United States military's search for ways to lower its energy costs is a key mechanism priming the pump for biofuels.

There was consensus among the participants that biofuels technicians will need core technical skills and knowledge similar to what is already being taught in community college biomanufacturing courses. The summit participants recommended that community colleges use modules to teach the advanced technical skills that technicians will need to work with biofuels. It was suggested that modules be added to existing biomanufacturing curricula and tailored to local industry. The modular approach, rather than distinct degree programs for particular types of biofuels, is expected to provide students with the broad skills they need to enter the biofuels workforce. This approach also gives community colleges flexibility within their curricula as the biofuels industry evolves and grows.

The draft occupational, technical, and educational skill standards for biofuels technicians, which the summit participants developed, are part of the summit report and posted on NBC2's website http://www.biomanufacturing.org. NBC2 hopes to gather input from more industry professionals in 2014 as part of its process for finalizing the skill standards.

Introduction

As part of its mission to prepare technicians for advanced technology fields that are important to the nation's security, the Northeast Biomanufacturing Center and Collaborative (NBC2) convened the Biofuels Workforce Summit with support from the National Science Foundation.

Biofuels currently account for a small portion of the transportation fuels used in the United States. Advances in biofuels technologies, as well as concerns about climate change and fuel security, are prompting broader interest in biofuels.

Given the potential for a vast increase in the use of biofuels, NBC2 received a supplemental grant from the National Science Foundation's Advanced Technological Education program to have 83 individuals from either the biofuels industry or biofuels education participate in the Biofuels Workforce Summit in Honolulu, Hawai'i. The summit participants' task was to identify the skills, knowledge, and attributes that technicians—individuals who earn certificates or associate degrees—will need to support the development, production, and analysis of biofuels.

"We're a bit like Wayne Gretzky skating ahead of the puck," said Sonia Wallman, NBC2 principal investigator and executive director.

The students that community colleges prepare to be biofuels technicians in the next few years will be employed on teams tackling the technical issues that must be overcome to reduce the cost and increase production of biofuels. Industry observers consider lower costs to biofuels customers and greater profits for biofuels producers as critical factors for the increased use of biofuels.

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> and Executive Director

"In order to meet the anticipated need for technicians to support the development and growth of the biofuels industry, we convened the meeting to determine the specific skills for technical careers in biofuels. Community colleges that already have biotech and biomanufacturing programs are in a position to offer modules and courses in biofuels by repurposing existing lab equipment," Wallman said.

Unlike the biopharmaceutical industry, which has established skill standards and curricula to support technician training for making these products, the biofuels industry is under development and needs skill standards to guide the education of the advanced technology technicians who will support its growth. The processes for creating biofuels are in flux and vary depending on the feedstock. Ethanol from corn, for instance, has standardized operating procedures. The mass production of biodiesel from waste cooking oil is in the process of becoming standardized. However, the processes for cultivating algae to make green crude oil and refining algae for biodiesel and jet fuel are still under development.

The task for the Biofuels Workforce Summit participants was to identify the academic knowledge along with the technical and occupational skills that should be included in skill standards. The skill standards are intended to guide two-year colleges and other educational institutions as they develop new programs or revise existing biomanufacturing education programs to include biofuels.

Sustainable Environmental Practices Highlighted at Summit

Sustainable environmental practices were highlighted throughout the summit. As Sonia Wallman, NBC2 principal investigator and executive director noted, "Biofuels won't mean much without a consciousness of sustainability."

Kapi'olani Community College, where the summit was held, teaches sustainability—economic, environmental, cultural, and social—in its Hospitality and Tourism Associate Degree programs. The college has also adopted sustainability practices for its facility operations.

Prior to the formal meeting, summit participants toured the waste oil processing facility of Pacific Biodiesel Technologies, LLC, in Honolulu, and the campus of Brigham Young University-Hawai'i in Laie.

At Pacific Biodiesel, summit participants learned about the company's community-based biodiesel business practices, which are considered a national model. The company built its Honolulu facility to convert the waste cooking oil it collects from restaurants into fuel that it sells to private motorists, other businesses, and government agencies.

At Brigham Young University-Hawai'i, the summit participants learned about the measures the university has taken recently to conserve energy and teach sustainable environmental practices to its international student population. From their academic programs, students demonstrated several bioenergy production processes. These included fuel oil grown from microalgae; fuel oil extracted from jatropha seeds using a screw press; biodiesel refined from used cooking oil; and electricity from hydrogen fuel cells generated by the chemical interaction of glucose and a dye.

Why Hawai'i?

Hawai'i leads the nation in the use of biofuels. Its remote location, unique ecosystem, and extreme dependence on imported fossil fuels have instigated a variety of commercial biofuels enterprises.

The United States military's search for ways to lower its energy costs and reduce its reliance on fossil fuels is also priming the pump for the expanded use of biofuels in Hawai'i and elsewhere. The U.S. military is the largest consumer of petroleum in the world. The leadership of the U.S. Navy has set several ambitious energy goals, including the aspiration to have 50 percent of its energy consumption come from alternative sources by 2020.

Priming the Pump

The opening session provided Biofuels Workforce Summit participants with an overview of the U.S. military's interest in biofuels, a biofuels producer's innovative business, and a university's quest to develop 100% bio-based jet fuel.

This session and the other panel presentations informed summit participants' deliberations on skill standards for biofuels technicians. Summit participants worked in small groups to achieve consensus about the skills and knowledge that biofuels technicians will need to support the development, production, and analysis of biofuels. The participants' many suggestions were incorporated into the Draft Skill Standards that appear in the appendix at the back of this report. At NBC2's invitation a cross-section of industry representatives will provide their formal input on the skill standards at a subsequent meeting.

The Great Green Fleet

As the single largest consumer of oil in the world, the U.S. Department of Defense (DoD) is pursuing several strategies to reduce its dependence on fossil fuels as a matter of national security and fiscal responsibility.

The U.S. Navy's plan for 50 percent of its energy consumption to come from alternative sources by 2020 is the most aggressive of these strategic goals. The 2012 pilot test of the "Great Green Fleet" in the Pacific involved the purchase of 450,000 gallons of biofuels. At the time it was the largest single purchase of biofuels in history. The biofuels (mostly from waste cooking oil, but about one-tenth from algae) were blended with petroleum. The Navy reported that dozens of jets, two destroyers, and a guided-missile cruiser operated safely and effectively with the blended fuel during the test.

At the Biofuels Workforce Summit, Joelle Simonpietri, a senior energy analyst with the U.S. Pacific Command's Innovation and Experimentation Division, noted that corn-based ethanol for transportation is currently the most commonly used biofuel in the U.S. However, ethanol and other alternative fuels must contend with inefficiencies similar to those involved with fossil fuels. The Hawaiian Electric Company, for instance, uses soy-based biodiesel that must be shipped from the Midwest to the islands.

The breadth of the search for next-generation biofuels is evident in the Commercial Aviation Alternative Fuels Initiative (CAAFI) and its tests of biofuels in passenger aircraft. The DoD is cooperating with this effort by the commercial aviation industry and Federal Aviation Administration to find alternative jet fuels.

Reducing the cost of biofuels to a per-gallon price comparable to petroleum is the next critical step, according to Simonpietri. "The government has no intention for ongoing subsidy of biofuels," she said, predicting that "hard, slogging work" will be necessary for the technical breakthroughs that will lead to lower prices. She also pointed out workforce skill gaps that need to be addressed "to reduce cost, increase scale, and improve integration" of biofuels.

In an interview after her summit presentation, Simonpietri declined to say whether she thought that the Navy's goal could be met. "A lot of smart, well-meaning people need to agree on a lot of things, and a whole lot of stuff has to happen for it to come together. That's the point of having an aspirational goal. It's not that different than putting a man on the Moon," she said.

About a week after the summit, the DoD awarded grants to three biofuels companies. These grants support the development of drop-in military biofuels from oil seed crops and waste oil. They require matching investments in the projects by the companies receiving the grants.

Hawai'i-Based Company Works on Sustainable Biofuels

"One of the first things you have to do to switch over to biodiesel is change your mind," said Kelly King, a founder of Pacific Biodiesel, Inc., and vice president of Pacific Biodiesel Technologies, LLC.

Pacific Biodiesel started in 1995 when King's husband Robert King, a diesel mechanic, convinced the operators of the Central Maui Landfill that he could convert restaurants' waste oil into diesel fuel. His solution eliminated the fires and other environmental hazards the oil was causing at the landfill. The company's community-based model quickly persuaded restaurateurs to give Pacific Biodiesel their waste cooking oil and grease trap residues rather than pay other vendors to have this material hauled away to the dump. It took more time and mechanical expertise to address some drivers' misperceptions about biodiesel. Since utility companies in Hawai'i and Honolulu government

agencies began using Pacific Biodiesel's fuel in their buses and other vehicles, more people have become willing to fill up their cars and trucks at the six gas stations in Hawai'i that the company supplies with B100 biodiesel.

At its new Big Island Biodiesel facility, the company strives to recover all useable materials from multiple feedstocks. The feedstocks include used cooking oil, grease trap residues, animal tallow, and increasingly, virgin vegetable oils pressed from locally grown oil seeds. In addition to producing biodiesel that meets stringent fuel standards, King said that the company is trying to develop markets for by-products. For example, the company is exploring the potential for press cake to be used for animal feed, soil additives, and fertilizer. Press cake is the solid material left after oil is extracted from vegetation.

Part of the company's work on its Military Biofuels Crop Project with the Army Corps of Engineers involves encouraging Hawai'i farmers to grow crops for biofuels. Since 2011, Pacific Biofuels has been testing plants such as jatropha, kukui, coconut, castor, peanut, canola, sunflower, palm, safflower, moringa, and hemp for varieties that can be harvested for oil 100 days after planting. Supplying a reliable fuel source for Hawai'i-based military units is the first goal. But, King said, identifying the crop, developing a cultivation plan, and designing a crushing facility could create jobs and generate economic and environmental benefits to farmers and residents in Hawai'i.

"Our plan is not to do everything ourselves but to work with the community and then create these jobs and create the economy around us," she said.

Washington State University Research Explores Options for Jet Fuel Production

Concerns about carbon dioxide emissions and climate change are driving Washington State University researchers' exploration of aviation fuel from biomass, oil seeds, municipal solid waste, algae, and other microbes, according to Ralph Cavalieri, associate vice president for Alternative Energy at the university.

The search for alternative fuels has fit within the land grant university's mission since the 1990s and is the focus of collaborative activities with the Boeing Company. The airlines that buy Boeing jets are particularly interested in reducing the carbon taxes they have to pay to fly into Europe. With the market for bio-based jet fuels estimated at $160 billion, the potential for profits is a strong motivator too. Cavalieri said, "It's a large market; it's worth investing in."

A fundamental challenge is getting the right mix of energy-dense and multifunctional molecules in 100% bio-based jet fuel. Because jet fuel cools, lubricates, and seals engine parts as well as provides thrust, "any drop-in fuel has to perform these functions," he said.

The university's researchers are testing lipid-producing plants, bacteria, and microalgae because they produce long carbon chain fatty acids similar to hydrocarbons needed for jet fuel. Other potential sources are oleaginous yeasts and alcohols derived from fermenting the sugar derived from cellulosic materials such as agricultural waste, fast-growing poplar trees, and switch grass.

To reduce expensive feedstock costs, researchers are trying to use forest residues. Grinding biomass in the forest makes it easier to move. The need to use diesel fuel to transport the biomass and additional energy to ferment and refine it remains an obstacle. Production costs are another hurdle. With current technologies, a ton of dry biomass is needed to generate 42 gallons of jet fuel that costs customers two to three times more than regular jet fuel.

Cavalieri suggested that mechanical engineering breakthroughs could make it possible for oil refineries to accomplish the thermochemical pyrolysis required to convert various feedstocks into jet fuel. The technology is still in development, but given the trend, Cavalieri recommends that biofuels technicians learn microbiological skills. As he pointed out, several airlines already use bio-based jet fuel on scheduled flights and are planning to move more and more to bio-based jet fuel in the future.

Biofuels Industry Panelists Share Their Perspectives

Panelists' presentations about current biofuels production processes led to their analyses of possible business models as the biofuels industry grows. All speakers agreed that future workforce needs will be influenced by technological breakthroughs and market forces. The speakers pointed out that aspects of technicians' education will require tailoring for the type of biofuel they intend to work in. Proficiency in math and science, excellent lab practices, and constant attention to detail were consistently mentioned as the knowledge and skills that all biofuels manufacturers seek in technicians.

Microalgae Farmer Expects Synergistic Development

"Biofuels from algae are not easy," said Miguel Olaizola, a self-described algae farmer. As director of Production at Synthetic Genomics in San Diego, California, Olaizola tests synthetic microbes for use as biofuels and tweaks enzymes in the algae to make them more efficient. He sees promising "synergies" for biofuels using microalgae, despite the current high costs.

During his summit presentation, Olaizola pointed out that microalgae can be cultivated in sea water, in waste water, on landfills, and at power plants fueled by natural gas, petroleum, or coal. Because these production processes do not need fresh water and utilize carbon dioxide (CO_2) expended in flue gases, he thinks microalgae cultivation can be done in tandem with a variety of industrial processes.

Animal feeds offer another potential synergy. Because the amino acids and lipids from algae are the same as the amino acids and lipids in fishmeal and fish oil, scientists are exploring the possibility of using microalgae in animal feed.

Scientists are still working out how to cultivate algae in targeted and less expensive ways. For instance, at the Southern California desert facility where Olaizola

Biofuels Employers Delineate Technicians' Skills

A technician's ability to work as an effective member of a team with scientists is critical, particularly at small companies, according to Adelheid Kuehnle, chief executive officer of Kuehnle AgroSystems in Oahu, Hawai'i.

"Regardless of who we have on our team and what they do, they have to demonstrate creative thinking, the ability to be a team player, and also just understanding [of the company's scientific processes]," Kuehnle said. Her biosciences company collects microalgae, characterizes them, and optimizes them for specific traits and performance.

"The skill set of the technicians that we have is the same across the board regardless of what the end market is," Kuehnle said.

Kelly King, vice president of Pacific Biodiesel Technologies, LLC, said in a separate interview, that her primary expectations for entry-level technicians include basic technical skills and an understanding of various biofuels production processes.

"They need to know basic skills: how to use certain types of instruments; how to do measurements; how to identify standard operating procedures [and] follow them; how to write standard operating procedures; [and] things like that. And then they need some basic information; They need to know the difference between the different types of biofuels ... then they can specialize from there," she said.

During her presentation at the Biofuels Workforce Summit, Kuehnle said that in addition to mastery of lab skills such as sterile techniques, microscopy, and solution making, she expects technicians to:

- handle live, perishable products with respect and care;
- adhere to standard operating procedures in the lab, in the field, and when preparing products for shipment;
- keep accurate, detailed records;
- follow checklists;
- calibrate and operate equipment properly;
- pay attention to safety requirements;
- acknowledge mistakes when they occur and troubleshoot to find solutions; and,
- communicate clearly with customers.

"There's quality assurance across the production that has to be followed. Some people think that short cuts are OK. They are not," Kuehnle said.

Kuehnle AgroSystems has developed its own technical workforce by hiring high-performing high school and college students to do routine tasks like cleaning glassware. The company trains these individuals and when they complete their degrees they have the opportunity for promotions within the company. "Then they get to train the next dishwashers," she said.

works, the extreme variation in daytime and nighttime temperatures presents significant challenges. "How do you convince algae to be tougher?" Oliazola humorously asked summit participants as an example of the unresolved technological issues.

Bioscience Company Leader Describes Collaboration with Oil Company

Adelheid Kuehnle, chief executive officer of Kuehnle AgroSystems, described the work that technicians do to cultivate algae using recycled CO_2 and untreated waste water in a specially-designed closed system at Chevron's Hawai'i oil refinery. The algae are converted into biofuel at another facility.

The U.S. Environmental Protection Agency (EPA) has recognized Kuehnle's innovative techniques, and described them as "the nation's first connection of industrial CO_2 from an oil refinery with a working algae production site."

In a 2012 press release, U.S. EPA Regional Administrator Jared Blumenfeld, said, "This clean-tech company's work on renewable biofuels will help make Hawai'i energy self-sufficient, and it protects the quality of our air, water, and land."

Biochemist Proposes "Franchise" Business Model

Based on the research conducted by his master's degree students at the Keck Graduate Institute and his own analysis of the biofuels industry, Matthew Croughan advised community college educators to add biofuels as an option to existing biopharmaceutical manufacturing programs.

"Ideally, keep both going so students can go either way," he said, adding, "Biofuels is coming up, but don't give up on biopharmaceuticals because it's a very successful industry."

Croughan was the chief scientist at Genentech's cell culture facility in Vacaville, California, before becoming the George B. and Joy Rathmann Professor at the Keck Graduate Institute in Claremont, California. He has also directed the institute's Amgen Bioprocessing Center.

During his presentation at the summit, Croughan predicted that sometime in the future algae cultivation will dot the American landscape as fields of soybeans and corn do now. However, the uncertainty of when biofuels will achieve the economies of scale to compete with fossil fuels led to his suggestion that educators equip biofuels technicians with a flexible array of skills.

"Carbon capture professionals" for biofuels are farmers, he said, indicating that future biofuels technicians will need to understand farming techniques as well as chemical synthesis processes.

He posited that large-scale algae farming may involve licensing or franchising arrangements between agriculture-bioscience companies and farmers, who will be instructed in new crop cultivation processes or protocols. Acres of algae could be processed into biofuels at either local or regional facilities, he said.

If algae-to-oil companies follow this business model, Croughan said people will be needed to provide technical support to farmers, and to construct and operate local and regional processing facilities.

"If you are going to do this and really make a dent [in competition with oil] you are going to have thousands of these things around the planet, right, and you are going to have to support all that. Think of it more like a biopharmaceutical vendor, like a Millipore or Pall, that has a huge technical support staff to help every company around the planet use their products and troubleshoot them," he said.

Matthew Croughan Offers Advice to Community College Educators

Developing biomanufacturing curricula with the right balance of broad knowledge and specialized skills is a challenge that Matthew Croughan has experienced as an employer and academician.

"If you highly specialize, then that makes you super qualified for a particular job at a particular time. But it's a risk if that job goes away or that industry goes away. So the broader training qualifies you for a broader range of jobs, but you are a little less qualified for each one at the time," he said. In 2013, Croughan became the chief technology officer of Sapphire Energy, which produces algae-based green crude oil, after seven years as the George B. and Joy Rathmann Professor at the Keck Graduate Institute in Claremont, California.

Croughan acknowledges that there is some risk for community colleges to add biofuels to their programs due to uncertainty about how rapidly the industry will grow. However, he sees it as "a good area to go into" for both colleges and students.

Croughan offers the following advice for community college educators as they prepare students for biotech careers, in general, and biofuels employment, in particular:

- stay engaged with industry;
- keep track of what's happening with industry;
- stay connected with other biotechnology educators to share knowledge, best practices, and insights; and,
- adjust your programs as necessary.

Founder of Small, Community-Based Biofuels Company Touts Micro-Nodal Model

Lyle Estill, president of Piedmont Biofuels Industrial, LLC, described the evolution of the company since 2002, when it began with three partners making biodiesel in their backyards from virgin soybean oil. Feedstocks have changed over time due to price and availability. The company now collects waste vegetable oils from restaurants and by-products from pharmaceutical industries. "We're entirely powered by waste these days," he said. Piedmont Biofuels, Inc., the member cooperative that contracts with the LLC for services, includes 300 families who drive on 100% biodiesel known as B100, and oil companies that blend Piedmont's biodiesel with petroleum diesel.

The "mission-driven" company became profitable in 2011 with better management of the three separate "cogs" of the biodiesel business: collecting feedstocks, refining biofuels, and distributing products. The bio-refinery that Piedmont Biofuels built in Pittsboro, North Carolina, extracts an array of products. Other business practices have contributed to the company's current monetization of everything it collects, including pallets and scrap metal. "It all has to be monetized if you are going to keep your doors open in this business," he said.

In addition to constructing its own facility, Piedmont has designed and built 24 biodiesel plants for communities and other clients that utilize "anomaly" feedstocks. For instance, the facility built for the North Carolina Department of Agriculture processes grease from the state fair to power the department's vehicles.

Estill advocates a small-scale, community-based approach to biofuels. He sees a micro-nodal model of 100 little, community-focused plants as more efficient and realistic for biofuels production than large facilities that perpetuate a top-down approach to energy production.

Estill said people thinking of making their careers in biofuels should be aware of two things: it is heavy-duty work and it is affected by government policies. He described the process of turning low-value fats into high-quality biofuels as hot, heavy, dangerous, smelly work that often "wrecks your clothes." Educating people, particularly politicians, about biofuels is part of the job too. "If you are going into the energy business in this country you are going into the policy business, whether you like it or not," he said.

Estill urged educators and those contemplating careers in biofuels to consider how biofuels will be used and how business practices contribute to environmental sustainability. "Think about the entire system that we're involved in and don't plug into things that don't work," he said. He pointed out that while 1.2 billion gallons of biodiesel were produced in the U.S. in 2012, about 6 billion gallons of fuel are wasted each year by vehicles idling. "If biofuels have something to teach us, it's conservation. That is the biggest resource that we have left to get to sustainability," Estill said.

Biofuels Pioneer Vertically Integrates Businesses to Encompass All Aspects of Industry

Kelly King, vice president of Pacific Biodiesel Technologies, LLC, broadly defines community-based biofuels companies as those that rely on local feedstocks, regardless of whether they serve 200 or 200,000 people. "The ones [companies] most likely to survive are community production models because they are more likely to survive the ups and downs," she said.

Pacific Biodiesel began in 1995 to remedy the environmental problems caused by waste cooking oil dumped in the Maui landfill. The company's success as the nation's first

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> Lyle Estill,
> President of Piedmont Biofuels Industrial, LLC

commercial biodiesel refinery and first seller of biodiesel to retail customers has led to other, vertically integrated businesses. In addition to biodiesel production and retail pumps, the company's activities include construction of biodiesel facilities, collection of used cooking oil, fuel quality testing, research and development, distribution of fuel, and management contracting.

Although Pacific Biodiesel operates facilities in several states, King said she and her husband are particularly proud of bringing quality green jobs to Hawai'i. To staff the 5.5 million gallon per year Big Island Biodiesel refinery it opened in Kea'au, Hawai'i in 2012, the company hired plant operators, facility technicians, service technicians, logistics managers, and engineers. "For every dollar we bring in, 90 cents of it stays in the state of Hawai'i," she said.

With this high vacuum distillation facility, the company has dramatically increased its capacity to recycle multiple feedstocks including a variety of waste oils, animal tallow, and oilseed crops. In addition to producing biofuels that meet stringent international industry standards, the Big Island Biodiesel refinery is exploring markets for by-products such as the glycerin created in the transesterification process used in biofuels production.

She pointed to the 200-acre jatropha farm that the company has operated on the Big Island of Hawai'i for five years, as an example of the company adding to the diversity of agriculture on the islands. Jatropha, a hardy plant with oil-rich seeds, is just one of the crops the company is testing for its 100 Days from Soil to Oil project with the U.S. Army Corps of Engineers and the Hawai'i Army Garrison.

King sees the company's addition of 200 agriculture jobs to the local economy as part of a "whole sustainable community" that could revive ranching and farming in Hawai'i. Pacific Biodiesel is seeking close collaborations with local farmers rather than operating farms itself. "We know we can't grow crops just for fuel. Everybody knows that. You have to have other co-products," King said.

Conclusion

Commercial biofuels operations are a relatively new phenomenon. Even industry veterans have less than 20 years in the biofuels business. The evolving nature of the industry and its potential to reduce CO_2 emissions and alleviate the nation's dependence on foreign oil are among the motivations for those involved in biofuels. While the industry representatives who spoke at the summit did not agree on how the industry is likely to develop, they repeatedly asserted that biofuels will eventually fulfill more of the nation's energy needs in the future. This conviction was shared by all of the panelists even as they acknowledged the many unknowns about when and how this will happen.

Piedmont Biofuels Grew From Community College Classes

Piedmont Biofuels Industrial, LLC, the smallest BQ9000 accredited biodiesel producer in the world, originated during classes at Central Carolina Community College.

Aside from supplying Central North Carolina residents with 100% biodiesel and related products made from used cooking oil, the company does research, consulting, and educational programs. Its stated mission is to lead the sustainability effort in North Carolina through the development and production of clean, renewable fuels. BQ9000 is a voluntary quality control standard of the National Biodiesel Accreditation Program.

As Lyle Estill explains it, Piedmont Biofuels and green energy programs at the Pittsboro, North Carolina community college "have grown up together."

In 2001, Estill was already making biodiesel in his backyard when he enrolled in a biodiesel course taught by Rachael Burton and Leif Forer at Central Carolina Community College. When the semester ended Estill, Burton, and Forer continued working together in Estill's shop. Burton was a college faculty member; Forer taught part time; and for a few years Estill taught a renewable energy class.

"As an economic construct we completely emerged from the community college system. And our project, and Central Carolina's extensive green building, biofuels, and renewable energy programs grew up together. For years Piedmont staffers have taught at the college. The college brings classes for tours. And we send new employees to the college for training," Estill explained after the conference.

Piedmont Biofuels and the college have collaborated on conferences, equipment, and grants. Estill serves on an industry advisory board for the college. The college performs regular testing for Piedmont Biofuels. The company provides the college with fuel and hauls away the co-products from the biodiesel that students produce in classes.

Estill, president of the company and the author of three books on sustainable environment practices, wrote the following about Piedmont Biofuels' relationship with its local community college: "Our relationship with Central Carolina Community College is exactly as it should be: the academy provides ideas and test beds for thinking, which spawns industry. Industry then feeds back to the college with funding, and teaching support, and training requirements, which the college provides.

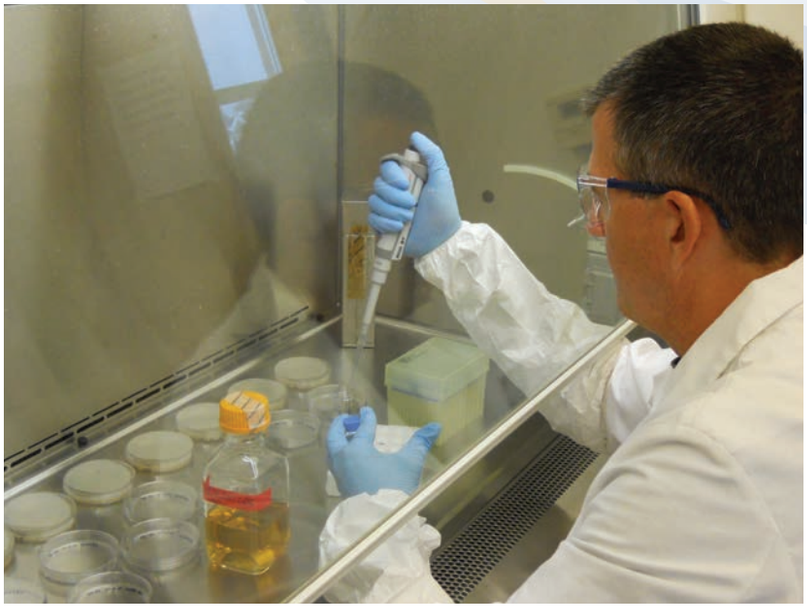
"Both the college and Piedmont fill unique ecological niches in the community, and our relationship is symbiotic."

Community College Educators Describe Unique Aspects of Their Biofuels Programs

During the Biofuels Workforce Summit, community college biomanufacturing educators shared information about the modules, courses, and certificate and degree programs that they have created with industry input to prepare technicians for careers in biofuels.

Lone Star College Uses Projects to Teach Workplace Skills

Daniel Kainer, a biotechnology professor at Lone Star College-Montgomery, directs the Lone Star College Biotechnology Institute in Houston, Texas. At the summit he described a recent collaboration between biotechnology and engineering technology students to disconnect the college's pilot-scale biorefinery from the electric grid. The two groups of students collaborated on building and installing two windmills and 24 solar panels for the biorefinery, which produces algal oil. The biodiesel created by the students is also used to run the electric generator that serves as the biorefinery's back-up power source.



For several years, Lone Star biotechnology students have worked with businesses and independently on research projects that focus on questions about algal oil-to-biodiesel processes, water remediation, and microbial fuel cells. Some students "adopt" algae species for long-term studies, other students "tinker" with bioreactor configurations, while others test open pond harvesting techniques. Students have also been involved in the construction of a greenhouse and solar dehydrator.

In general, the optional research activities give students opportunities to gain additional workplace skills. For instance, Kainer said, he added instruction in flow cytometry for students engaged in research because an industry advisory board member told him, "This skill alone will get students jobs."

Undergraduate Research Leader Utilizes Biofuels as Source for Students' Projects

James A. Hewlett, a biology professor at Finger Lakes Community College, Canandaigua, New York, has added biofuels modules to his college's biomanufacturing curriculum based on what he and Rochester Institute of Technology faculty learned from industry about their future technical workforce needs. Their study found that even an ethanol production facility with 100 employees required only three or four technicians. "We didn't see a huge need to develop whole degree programs ... but there was a need to introduce students to concepts within current programs. So,that is where we decided to go to a module level," he said.

Biofuels provide "rich opportunities" for undergraduate research at two-year colleges, Hewlett said. Questions about biofuels are ideal for semester-long undergraduate projects because they are not too instrument intensive nor do they require expensive equipment. Students with one year of college science courses can tackle them, and in subsequent semesters other students can build on initial findings. "It fits what we know works, if you want to be doing undergraduate research," he said.

Hewlett leads the Community College Undergraduate Research Initiative that is helping 29 community colleges around the nation incorporate undergraduate research into their biology curricula. The initiative received a $2.6 million grant from the National Science Foundation's Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics (TUES) program. Hewlett and his students are currently working with a Cornell University research professor and DuPont scientists on pilot tests of enzymes that breakdown cellulosic feedstocks.

MiraCosta College Course Emphasizes Broad Scientific Knowledge and Safety

Elmar Schmid wrote *Biofuels Production and Analysis* that NBC2 plans to release in late 2013. The textbook is based on the five-week biofuels course he teaches at MiraCosta College in Oceanside, California. During his summit presentation, Schmid explained that he started the course out of the conviction that biofuels technicians benefit from a broad understanding of biology, chemistry, physics, and engineering. The hands-on course also emphasizes safety issues and proper material handling. In addition to algae cultivation and harvesting, algal oil extraction and biodiesel

production, the course covers cellulosic enzymes and biohydrogen production.

More than 50 students have earned Biomass Production Training Certificates at MiraCosta since 2009.

In addition to teaching as an associate faculty member at MiraCosta College, Schmid is chief scientific officer of T2e Energy Holdings, LLC. During a presentation at the summit, Schmid talked about his work with biofuels and industrial biotechnology companies in San Diego on a private-public partnership known as EDGE, which stands for Educating and Developing workers for the Green Economy. EDGE supports education and training, and provides biofuels job placement services. About 400 people are employed by the biofuels industry in San Diego, where biopharmaceutical and industrial biotechnology companies are established.

Austin Center Provides Cross-Disciplinary Research Opportunities

Rhykka Connelly, an adjunct professor at Austin Community College and technical director of Open Algae, in Austin, Texas, explained how cross-disciplinary teams of students from Austin Community College, Austin high schools, and The University of Texas Austin develop novel technologies at the industry-funded Center for Electromechanics. The center is an academic enterprise that has managed to act more like a start-up company during its 40-year history of transferring technologies to industry.

Students interact with industry personnel and have access to a wide array of university resources and faculty experts as they devise solutions to real problems and test new uses of specimens from the UTEX Algae Collection. Cross-disciplinary faculty teams advise the students.

"We want to make sure students leave with the skills necessary to enter the biotechnology workspace," Connelly said. The center's problem-based investigatory process teaches students how to communicate within a team, think critically, analyze data, and present reports about bioproduct applications for antivirals, antibacterials, food agents, aquaculture supplements, and fertilizers. Connelly cited students' work with researchers at The University of Texas Medical Branch on a wound healing product that uses Omega 7 derived from algae as an example of the center's high-level collaborations on promising products.

Madison College Offers Biofuels Programs for Technicians and Educators

Kenneth Walz, a chemistry instructor at Madison College and member of the engineering faculty at the University of Wisconsin-Madison, directs Career Education in Renewable Energy Technologies (CERET), which offers technician education and faculty professional development.

Since 2005, Madison College has offered a Renewable Energy Certificate program for employed technicians who want to learn renewable energy skills. In fall 2013, the college launched a Bioenergy Certificate program for currently enrolled students in various disciplines. "A lot of bioenergy jobs do require some specific bioenergy knowledge, but a lot of what they do is traditional skill," Walz said, explaining the new certificate will connect bioenergy skills with what students learn in traditional biology, chemistry, and mechanical maintenance programs to expand their career opportunities.

Walz also leads CERET's Train-the-Trainer Biofuels Academy with the support of a National Science Foundation Advanced Technological Education grant. High school teachers as well as faculty members from two-year col-

Indian Hills Community College Has Close Partnership with Industry

The close ties between Indian Hills Community College's Iowa Bioprocess Training Center and industry are evident by the center's location across the street from Cargill's enormous corn milling facility and near other bioindustrial companies that create products with corn sugar.

"Our program was designed to produce technicians because this complex, on any one day, just this complex in Eddyville, Iowa, has 1,000 employees," said Chuck Crabtree, director of Iowa BioDevelopment, the college's research and training arm. Iowa has more than 40 ethanol or biodiesel plants.

The center's labs and fully-functional pilot-scale fermentation plant serve as the hands-on learning facilities for students enrolled in the college's 24-month Associate of Applied Science Degree programs in Agriculture-Biofuels Process Technology and Bioprocess Laboratory Technology. The center also offers a Process Control Technician Certificate program and biotechnology workforce training courses.

Both degree programs start with introductory courses in biotechnology and good manufacturing practices, as well as applied chemistry, biochemistry, and microbiology. The process technology curriculum branches into the industrial maintenance and electronics that plant operators need to know. The lab technology curriculum has multiple chemistry and biology courses that can lead to immediate employment or transfer to four-year degree programs. Both degree programs require 240-hour internships.

With companies in the complex alone hiring 20 to 40 new technicians each year, Crabtree said the placement rate for graduates of the two degree programs is nearly 100%. Starting salaries are about $40,000 per year. "It's good pay; it's a career," he said.

leges and universities—more than 150 in all—came from 37 states to attend the week-long academies in 2012 and 2013. In addition to helping educators start biofuels programs, the summer academies encourage the educators to build "pipelines" between the education sectors in their communities to help students matriculate to two-year colleges. "For a lot of the high school teachers, they were trained at four-year universities, and many of them never set foot on a two-year campus and have a very shaky idea of what we actually do. So it's turned out to be pretty powerful, having those groups together."

Indian Hills Community College Expands Biofuels Programs with Federal Grants

Chuck Crabtree directs Iowa BioDevelopment, the research and training arm of Indian Hills Community College. The college offers Associate of Applied Science Degrees in Agricultural-Biofuels Process Technology and Bioprocess Laboratory Technology. Both 24-month degree programs require students to complete internships at one of the companies located at the Iowa Bioprocessing Center in Eddyville, Iowa.

The college has leveraged its partnerships with employers to obtain several large federal grants to expand its biofuels curriculum.

It developed an applied research internship program with a U.S. Department of Agriculture grant. The research conducted by 25 interns has been used to improve products or the processes for making products. Crabtree said the interns' applied research has helped several start-up companies obtain venture capital and make other progress toward bringing new products to market.

The college created an online Biofuel Technician Certification program with a U.S. Department of Education grant. During 2012-13, the first year it was offered, 90 students completed the program. Most online students are either new employees of biofuels companies or people who want to learn about ethanol and biodiesel to improve their job prospects. The college has received Advanced Technological Education grants from the National Science Foundation to develop career pathways and to plan a Midwest regional center for biofuels.

Northwest Initiative Recruits Underserved Populations for Biofuels Careers

Jason Selwitz, project manager for Washington's Agriculture Center of Excellence based at Walla Walla Community College, described three bioenergy education pathways—workforce, transfer, and certificate—that educators and industry are developing for the Advanced Hardwood Biofuels Northwest Initiative. Washington state officials have approved the Associate of Applied Arts and Science Degree

Kapio'lani Community College Uses Sustainable Practices

Kapio'lani Community College (KCC) emphasizes and employs sustainable environmental practices in two restaurants run by its culinary arts students, and in the banquet center, catering operation, and cafeterias run by its Commercial Enterprise unit.

The banquet center, where the summit participants ate during their two-day meeting on the Honolulu campus, is at the base of Diamond Head, the dormant volcanic cone and tourist hotspot.

Summit participants dined on local fish and produce while enjoying spectacular views of the ocean and coastal mountains. KCC's policy is to acquire local food whenever possible and if the cost is neutral with imported food. It purchases local organic produce if the cost is within 10% of non-local, non-organic food.

Such practices are meant to inspire students and the community, and encourage adoption of less-energy-intense food options by restaurant professionals, according to Ronald Takahashi, KCC professor and Culinary Arts department chairman.

He points out that per square foot, the food service industry is the most energy-intensive commercial sector in the country. In Hawai'i, where most food is imported, reducing energy consumption and helping local farmers are overlapping priorities.

In addition to using herbs and vegetables from its own gardens, KCC's Culinary Arts program composts food waste from its facilities and powers a campus utility vehicle and riding mowers with biodiesel created from its waste cooking oil. Both practices serve as models for other community colleges and food service providers.

in Bioenergy Operations, an online course with in-person labs, and the Associate of Science in Bioenergy, also an online degree.

The regional initiative intends to recruit dislocated workers, veterans, Native Americans, incumbent workers, Latino-heritage farmers , women, and Asian-heritage farmers for employment at Pacific Northwest companies that convert biomass from sustainably grown hardwood trees into transportation fuels. "When we go out and talk with industry, at least in our region, they are interested in saving money on the training of their staff and hiring people that really want a career, that go into that technician or operator position and then move up either to become a manager, innovator or designer in the company," Selwitz said.

A U.S. Department of Agriculture grant supports the center's efforts to cultivate hybrid polar trees that can be harvested in just two to three years for use as biomass that is converted into drop-in jet fuels, biodiesel, and gasoline.

The initiative is also creating career pathways with programs that begin in the fourth grade and continue through secondary schools, community colleges, and university doctoral programs.

Santa Fe Community College Offers Wide Array of Biofuels Education Programs

Charles Bensinger, director of Alternative Fuels Program at Santa Fe Community College in New Mexico, developed a 29-credit Biofuels Certificate program in 2009 for its new Trades and Advanced Technology Center. He based the curriculum on Central Carolina Community College's biodiesel program. Certificate credits apply toward associate degrees and articulate to four-year degree programs.

Students enrolled in the certificate program use a wide array of equipment to make ethanol, biodiesel, and other alternative fuels. For instance, an anaerobic biodigester with a solar thermal panel uses organic waste from the college's cafeteria and other sources to give students experience with multiple ways to cook and heat water, and generate electricity and light totally off the electric grid. The program also takes students on tours of bioindustry facilities in Southern New Mexico.

Bensinger used a U.S. Department of Labor grant that he received in 2010 to develop instructional modules for production of biodiesel, ethanol, biogas, biomass, and algae. The college currently offers more than two dozen three- to six-day workshops based on these modules to address the various levels of community interest in biofuels.

Santa Fe Community College Professor Encourages Biofuels Entrepreneurs

Charles Bensinger's entrepreneurial biofuels initiatives have inspired and informed his students' business enterprises. Bensinger directs Santa Fe Community College's Alternative Fuels Program.

Bensinger's interests shifted from solar energy to alternative transportation fuels in the early 1990s when he realized that few other academics were working on alternative transportation fuels. With a $100,000 grant he created a non-profit corporation that developed the first retail pump for simultaneous sales of three different types of biofuels in the U.S. in 2004. During its first year of operation, the Santa Fe outlet sold more than $1 million in biofuels.

Interest in exploring the public service and commercial potential of biofuels attracts students to both the credit and non-credit programs at Santa Fe Community College.

"Our students are very much interested in algae as a nutriceutical. They are concerned about the world food problem. And they really see the potential here for one of nature's miracle foods, that is algae, particularly spirulina [a cyanobacteria], and they want to see how they can use what they learn in those classes to address some of those world problems," Bensinger said.

Companies started by Bensinger's students include: Algae Industry Magazine.com, a website that covers the algae industry; Reunity Resources, a biodiesel cooperative; New Solutions Energy, a photobioreactor builder and supplier; and a start-up algae fertilizer company that has yet to settle on a corporate name.

Biofuels Technicians Share Their Work Experience and Career Advice

Four technicians discussed their experiences working in biofuels research and commercial operations. They advised people who are interested in entering biofuels careers to bring enthusiasm to the workplace along with technical skills and realistic expectations. They all agreed on the importance of technicians understanding what data indicate about various processes, documenting data accurately and consistently, and mastering software to graph data.

Emily Effner (far left in photo) earned a Biofuels Science Technician Certificate from the Educating and Developing Workers for the Green Economy (EDGE) program at the University of California San Diego (UC San Diego). As a research associate at Sapphire Energy, she has found that algae cultivation requires a combination of engineering and biology knowledge. Her work tasks include monitoring environmental parameters, collecting samples using various techniques, and troubleshooting systems if issues arise. She considers knowledge of phototropic model organisms valuable and sees the courses she took in molecular biology as a good long-term career investment. At the time of the summit, she was studying cyanobacteria and lipid metabolism as a volunteer in the Golden Lab at UC San Diego.

Jesse Briley (far right in photo) enrolled in Indian Hills Community College's Agriculture Biofuels Process Technology program because he knew it would likely lead to employment. He has found that learning ethanol production technologies and understanding concepts like the logarithmic nature of pH gave him an advantage over other entry-level technicians. After completing his associate of applied science degree, he was hired as a "cook" at Lincolnway Energy, LLC. Production of 50 million gallons of ethanol annually requires cook technicians at the Nevada, Iowa, facility to grapple with the intricacies of accurately measuring enormous quantities of corn, water, and enzymes. In his current job as a quality control lab technician, Briley calibrates analytical lab equipment, tests the plant's water, checks the alcohol and water content in ethanol, and monitors an anaerobic digester.

Working as a technician at Mera Pharmaceuticals from 2004 to 2007 taught Evan Wallman (second from left in photo) the importance of following a checklist. His assignments included producing the antioxidant astaxanthin in microalgae; testing microalgae's capacity to purge flue gases at a mock coal-burning power plant; and growing a human antibody in microalgae. Cultivating microalgae came with "very high points and very low points," he said, explaining that the sensitivity of the algae meant its status could change quickly. Checking algae samples for contaminants were among the repetitive, but important tasks that, Wallman said, reinforced the need to be "religious" about keeping everything sterile. With a Bachelor's Degree in Environmental Geology, Wallman owns a survey company and teaches a surveying course at Hawai'i Community College.

Ikenna Nedosa, operations manager at Promethean Biofuels, enrolled in MiraCosta College's EDGE program during the spring of 2012. At the time Nedosa (third from left in photo) was completing a Master's Degree in Professional Sciences from California State University San Marcos and was implementing a quality control management system at Promethean as part of his degree program. (The company subsequently hired him.) Nedosa wanted to know more about the technical aspects of biofuels production, and found it "an eye-opening experience" to learn what biofuels technicians do. But, he said, the small size of most biofuels companies requires technicians to have versatile skills. These include analyzing feedstock, doing mini-batch tests from atop tanks, handling diverse materials, and fixing pipes and pumps. "A hands-on approach will distinguish you," he said.

Break-Out Sessions Deliberate On Draft Skill Standards for Biofuels Technicians

On the second day of the summit, participants were asked to consider the summit panelists' presentations and their own professional experience to identify skill standards for technicians to build careers in the evolving biofuels industry. Participants were separated into occupational, educational, and technical break-out sessions based on their areas of expertise. After receiving directions from break-out session moderators the participants were further separated into small discussion groups of four-to-six people.

At the beginning of the discussion sessions the participants were given Preliminary Skills Templates, which were prepared in advance by the summit steering committee to facilitate discussions. The small groups were asked to work through lists of questions about the draft skill standards.

The occupational groups were asked: How complete is the list of critical work functions? Are there any key ones missing? For each of the critical work functions, are there any key activities you would add or revise?

The educational groups were asked: Are there any science categories missing? If so what are they, and what bullets would you add to each? Are there any math categories missing? If so, what are they, and what bullets would you add to each? Are there any other skills or knowledge you would change, add, or delete?

The technical groups were asked: Are there any technical knowledge and skill categories missing? If so, what are they, and what bullets would you add to each? Are there any other skills or knowledge you would change, add, or delete?

Based on the discussions and deliberations among the members of each group, the break-out session moderators prepared summaries of key revisions and recommendations that were shared during the closing session of the summit.

There was consensus among the participants that biofuels technicians will need core technical skills and knowledge similar to those already taught for biomanufacturing. They recommended that community colleges use modules to teach the advanced technical skills needed to work with biofuels. It was suggested that modules be added to existing biomanufacturing curricula and tailored to local industry needs. The modular approach, rather than distinct degree programs for particular branches of the biofuel industry, is expected to provide students with the broad skills they need to enter the biofuels workforce. This approach also gives community colleges flexibility within their curricula as the biofuels industry continues to evolve and grow.

Following the meeting, the moderators and NBC2 staff members refined the Draft Skill Standards based on the break-out session discussions. The most numerous and significant revisions were suggested for the technical skill standards. Given the break-out sessions' recommendation that the template of technical skills be reorganized, the summit team prepared a lengthy follow-up survey that was emailed to summit participants in late summer. This survey asked summit participants to rate the importance of an array of skills as either required, preferred, or not applicable for each industry sector. The technical skills were updated in September 2013 based on the survey results.

NBC2 intends to gather industry feedback on the draft standards that were revised based on the summit participants' input. The Draft Skill Standards for Biofuels Technicians as of September 2013 appear on the following pages.

Draft Occupational Skills for Biofuels Technicians

Critical Work Functions

Critical work functions represent the general areas of responsibility for technicians in biofuels workplaces. The functions tell us what must be done to achieve the key purpose of an occupation.

Critical Work Function	Key Activity	Key Activity	Key Activity	Key Activity	
1. Perform record keeping and create documents.	1.1 Write and review operating procedures.	1.2 Prepare batch records.	1.3 Obtain, review and communicate data.	1.4 Write technical reports.	
2. Clean, maintain, and troubleshoot equipment.	2.1 Clean and maintain basic equipment.	2.2 Clean and maintain cell culture or fermentation equipment.	2.3 Perform calibration of instruments.	2.4 Perform preventive maintenance and schedule vendor maintenance.	
3. Prepare items for laboratory and biomanufacturing activities.	3.1 Order materials.	3.2 Store materials.	3.3 Prepare glassware.	3.4 Prepare equipment.	
4. Perform cell culture and fermentation.	4.1 Establish working cell bank.	4.2 Initiate starter cultures.	4.3 Perform scale-up operations.	4.4 Inoculate seed reactor and perform media additions.	
5. Perform testing and data analysis.	5.1 Perform microbiology testing.	5.2 Perform chemical testing.	5.3 Perform upstream testing.	5.4 Perform downstream testing.	
	5.10 Determine significant results using statistical analysis.	5.11 Present data for decision support.	5.12 Comply with industry standards for product.	5.13 Perform process flow and logistical modeling.	
6. Perform product purification.	6.1 Prepare purification equipment.	6.2 Receive product from upstream processing.	6.3 Filter product as necessary.	6.4 Perform product analysis.	
7. Provide effective and appropriate communication.	7.1 Communicate with coworkers to ensure quality work.	7.2 Provide technical assistance to customers.	7.3 Provide training to coworkers.	7.4 Communicate with all plant personnel.	
8. Comply with environmental health and safety (EH&S), good practices (GXPs) and other national, state, and local regulations.	8.1 Comply with standard operating procedures (SOPs).	8.2 Wear appropriate personal protective equipment.	8.3 Access and utilize safety data sheets (SDSs).	8.4 Comply with GXPs.	
9. Maintain clean and safe work environment.	9.1 Clean work environment according to SOPs.	9.2 Report unsafe conditions.	9.3 Attend company safety training.	9.4 Maintain security.	
10. Handle large-scale materials.	10.1 Reduce size of raw materials.	10.2 Sample raw materials.	10.3 Transfer and convey raw materials.	10.4 Coordinate raw product sourcing or collection.	

Key Activities

Key activities are the tasks that must be performed by technicians to accomplish the related critical work function. The tasks are made up of work activities that are measurable, observable, and result in a decision, product, or service.

Key Activity	Key Activity	Key Activity	Key Activity	Key Activity
1.5 Maintain logbooks.	1.6 Participate in change control activities.	1.7. Monitor and record biofuels processing data: flow meter performance, batch, continuous flow, hybrid biofuels production processes, stored biofuels products or secondary by-products.	1.8 Track inventory.	1.9 Use process control software such as computer-aided design (CAD).
2.5 Perform equipment validation.	2.6 Participate in the installation and modification of equipment.			
3.5 Make media, solutions, and buffers.	3.6 Store media, solutions, and buffers.	3.7 Preprocess feedstock in preparation for physical, chemical, or biological fuel production process.	3.8 Prepare biomass for conversion to biofuel.	
4.5 Monitor culture.	4.6 Execute sampling and assess materials for process release.	4.7 Perform process release for product.	4.8 Collect, characterize, and optimize microbes for specific traits and performance.	
5.5 Troubleshoot aberrant results or parameters.	5.6 Assess the quality of biofuels additives for reprocessing.	5.7 Measure and monitor raw biofuels feedstock.	5.8 Monitor the blending operation to assure correct proportions of the products.	5.9 Obtain and review trend and benchmark data.
6.5 Remove contaminants and concentrate product as necessary.	6.6 Bulk fill purified product for storage.	6.7 Complete final formulation.	6.8 Operate equipment (such as chemical processing equipment, centrifuges, pumps, valves and shredders) to extract biofuels products and secondary by-products or reusable fractions.	6.9 Package according to standard operating procedure (SOP) and ship according to customer needs.
7.5 Manage personnel conflicts in a timely manner.	7.6 Practice emergency communication measures.	7.7 Maintain intellectual property security.		
8.5 Handle, label, and dispose of hazardous and biohazard materials.	8.6 Follow Environmental Protection Agency regulations, and other applicable local, state, and federal regulations.	8.7 Participate in all company safety training and audits as required.	8.8 Maintain quality control (QC).	8.9 Respond to incidents such as spills, fires, gas releases, or biocontamination.
9.5 Comply with Occupational Safety and Health Administration (OSHA) regulations.	9.6 Wear appropriate personal protective equipment.			
10.5 Store raw materials.	10.6 Drain and inspect all trucks, railcars, and vessels prior to loading.			

Draft Educational Skills for Biofuels Technicians

Educational Knowledge and Skills

Educational knowledge and skills are basic academic and personal skills that biofuels technicians need to build more advanced competencies.

Science Skills	Math Skills	Engineering and Technology Skills

Basic and Applied Biology
• Cellular propagation
  • prokaryotic
  • eukaryotic
• Sterilization
• Sanitization
• Media preparation
Basic and Applied Microbiology
• Identification of microbes
• Basic microbiology techniques
• Microscopy
• Aseptic techniques
• Growth and death kinetics
• Fermentation pathways
• Cell counting
Basic and Applied Chemistry
• pH
• Acids and bases
• Solution mixing
• Organic chemistry
• Titration
Basic and Applied Biochemistry and Basic Laboratory Activities
• Spectrometry
• Pipetting
• Weighing
• Volumetric measurement
• Sample collection
• Sample preparation
• Filtration
• Centrifugation
• Titration
	Basic Math
	Intermediate Math
	• Algebra (solving for one unknown)
	Applied Math
	• Molarity/Normality
	• Concentrations (ppm, ppb)
	• Mass per volume
	• Dilutions
	• Serial dilutions
	Advanced Math
	• Statistics and principles of data analysis
	• Advanced Algebra
	• Applied Calculus
	• Basic Statistics
	• Ability to apply theory to perform mathematical functions
		Basic and Applied Physics
		• Principles of electricity
		• Gas laws
		• Optics
		Basic Bioprocessing
		• Quality assurance and quality control
		• Standard operating procedures (SOPs)
		• Documentation/Batch records
		• American Society for Testing Materials (ASTM)
		• Facilities
		• Environmental health and safety (EH&S)
		• Metrology
		• Validation
		Bioprocess Engineering Principles
		• Heat transfer
		• Fluid flow
		• Chemical reactions and stoichiometry
		• Thermodynamics
		• Unit operations
		• Feedback control loops
		• Mass transfer
		• Reaction kinetics
		Computer Technology Skills
		• Word processing
		• Spreadsheets
		• Industry standard software

Personnel Management Skills	Employability Skills
• Leadership • Self-confidence • Learn from failure • Display appropriate work ethic and etiquette (dress, cell phone, email, etc.) • Good general organizational skills • Ability to troubleshoot • Ability to apply knowledge • Ability to multitask; Time management skills • Ability to prioritize • Globally-minded; Cross-cultural understanding • Accountable • Engage in life-long learning • Accept constructive criticism	• Problem-solving • Ability to work with minimal supervision • Initiative and self-direction • Ability to train others • Appropriate work ethic • Word processing and spreadsheet proficiency • Read and follow instructions • Detailed and accurate record keeping • Use interpersonal skills to work in a team setting • Written and oral communication skills • Goal oriented • Adaptable and flexible • Participate in the community • Analyze and interpret data

Draft Technical Skills for Biofuels Technicians

Technical skills, knowledge, and abilities are those areas of expertise which biofuels technicians must have in order to perform a given key activity with excellence. A collection of skills, knowledge, abilities, and tools make up competencies. Skills refer to proficiency in an applied activity. This activity could be physical, mental, or interpersonal in nature. Knowledge is a particular set of information. Abilities are broad human characteristics that result from natural talent, education, or experience. Tools are materials, equipment, and implements that a biofuels technician must be able to use competently to meet the requirements of the job. The table identifies skills needed in biofuels, in general, and in each biofuels sector. The information in the table will help to determine a core set of skills across these sectors.

R	Required Skills	p	Preferred Skills

Mechanical Skills	Biofuels	Biomaterials, Biopolymers, Bio-Based Chemicals	
Operate distributed control systems (DCS)	R	R	
Troubleshoot and perform basic maintenance and repair on electromechanical devices	R	R	
Read & interpret piping & instrumentation diagrams (P&ID)	p	R	
Operate programmable logic controllers (PLC)	p	R	
Interpret electrical schematics		R	
Identify and maintain different types of pumps and drives	p	R	
Understand technical information (manuals, blueprints, diagrams)	R	R	
Handle large systems	p	p	
Operate and monitor job-specific equipment and systems	R	R	
Use the following:			
• Basic hand tools	R	R	
• CO_2 systems	p	p	
• H_2O systems (RO, waste coilers, cooling)	p	R	
• Bioreactor, chemical reactor, and fermentation systems	R	R	
• Vacuum systems			
• Filtration, separation, and purification systems	R	R	
• Milling systems			
• Hydro heaters and jet coolers			
• Ovens and dryers	p	p	
• Pallet jacks and forklifts			
• Heat exchangers	p	p	
• Sieves		p	
• Evaporators		R	
• Agitation systems		p	
• Conveyor systems			
• Automotive vehicles (including manual drive vehicles and towing a trailer)		p	
• Pneumatic systems		p	

Measurement and Calibration Skills	Biofuels	Biomaterials, Biopolymers, Bio-Based Chemicals	
Operate scales and balances	R	R	
Perform unit conversion	R	R	
Knowledge of how to calibrate an instrument	R	R	

Algae and Microbial Systems	Bioprocessing	Agbiotech	Forestry Resources
R	R	R	
R	R	R	R
p	R	R	p
p	R	R	p
p	p	p	p
p	R	R	R
R	R	R	R
R	R	p	p
R	R	R	R
R	R	R	R
R	R	R	p
R	R	R	p
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R	p	p	p
R	R	R	R
	p	p	R
	p	R	p
R	p	p	p
	p	p	p
R	R	p	p
	p	R	p
p	p	R	p
R	R	R	p
p	p	R	R
p	p	p	R
	R	R	R

Algae and Microbial Systems	Bioprocessing	Agbiotech	Forestry Resources
R	R	R	R
R	R	R	R
R	R	p	p

Chemistry and Biology Laboratory Skills	Biofuels	Biomaterials, Biopolymers, Bio-Based Chemicals	
Basic performance of the following:			
• Aseptic techniques	R	R	
• Chemically clean techniques	R	R	
• Culture methods (plating, replication, maintenance)	p	p	
• Serial dilutions	R	R	
• Media and buffer preparation	R	R	
• Chemical and basic lab inventory	R	R	
• Sampling	R	R	
• Cryopreservation	p	p	
• Cell counting	R	p	
• Assay design		p	
• qPCR		p	
• Genotyping		p	

Instrumentation Skills	Biofuels	Biomaterials, Biopolymers, Bio-Based Chemicals	
Basic operation, maintenance, and troubleshooting of:			
• Autoclave	R	R	
• Conductivity meter	R	p	
• Centrifuge	R	R	
• Shaker and water bath	R	R	
• Incubator	p	R	
• Dissolved oxygen meter	R	p	
• Temperature probe	R	R	
• pH meter and pH probe	R	R	
• Turbidity probe	p	p	
• Light meter	p	R	
• Autopipettor and pipettes	R	R	
• Microscopes	p	p	
• Autotitrator	R	R	
• Ovens (drying and ashing)	R	R	
• Hydrometer	R	p	
• Viscometer	R	R	
• Sieve	R	R	
• Spectrophotometer	R	R	
• Chromatographs	R	p	
• Gas chromatography	R	p	
• Liquid chromatography/high-performance liquid chromatography (HPLC)	R	R	
• Spectrometers (near infrared [NIR], atomic absorption [AA], inductively coupled plasma [ICP], mass [MS])	p	R	
• Autohemocytometer	p	p	
• Flow cytometer	p	p	
• Flow meter	R	R	
• Flash point tester	R	p	
• Identification key	p		
• Protein analyzer	p	p	
• Bulk density analyzer	p	R	
• Total organic content (TOC) analyzer and carbon-nitrogen-sulfur analyzer	p	p	
• Vacuum apparatus	p	R	

Algae and Microbial Systems	Bioprocessing	Agbiotech	Forestry Resources
R	R	R	p
R	R	R	p
R	R	R	p
R	R	R	p
R	R	R	
R	R	R	p
R	R	R	R
R	p	R	p
R	R	R	p
R	p	R	p
p	p		p
R	p	p	p

Algae and Microbial Systems	Bioprocessing	Agbiotech	Forestry Resources
R	R	R	
R	R	R	p
R	R	R	p
R	R	R	
R	R	R	
R	R	R	
R	R	R	p
R	R	R	p
R	R	R	p
R	p	R	p
R	R	R	p
R	R	R	p
R	p	p	p
R	p	R	p
p	p	R	p
p	p	p	p
R	p	R	p
R	R	R	R
R	R	R	p
R	p	R	R
R	R	R	p
R	p	p	p
R	p	p	p
R	p	p	p
R	R	p	p
	p	p	R
p	p	p	R
R	R	R	R
p	p	R	p
p	p	R	R
R	p	R	R

Process Engineering Skills	Biofuels	Biomaterials, Biopolymers, Bio-Based Chemicals
Develop, follow, and optimize a workflow	R	R
Read and interpret process flow diagrams (PFD)	R	R
Minimize wasted energy, resources, and time	R	R
Know how to develop and follow a standard operating procedure (SOP)	R	R
Basic quality control related to feedstock, process, and products	R	R

Laboratory and Workplace Safety Skills	Biofuels	Biomaterials, Biopolymers, Bio-based Chemicals
Know how to:		
• Perform first aid and cardiopulmonary resuscitation (CPR)	p	R
• Perform lock-out and tag-out	R	p
• Read and interpret safety and material signage and general safety nomenclature	R	R
• Implement acid and base spill procedures	R	R
• Handle hazardous waste and materials according to chemical hygiene plan	R	R
• Monitor ISO and HAACP	R	R
• Follow Occupational Safety and Health Administration regulations (OSHA)	R	R
• Comply with HAZMAT/EHS/HAZCOM	R	R
• Prevent explosions	R	R
• Read a material safety data sheet (SDS)	R	R
• Don personal protective equipment (PPE)	R	R
• Dispose of chemical, biological, and hazardous materials properly	R	R
• Use of a fume hood	R	R
• Prepare a vehicle for safe transport including rigging and handling	p	p
Work in the following areas:		
• High decibel	R	R
• Electrical	R	R
• Hot works	R	R
• Steam systems	R	p
• Pressurized gases	R	R
• Bulk machinery	R	R
• Confined spaces	R	p

Data Management Documentation and Communication Skills	Biofuels	Biomaterials, Biopolymers, Bio-Based Chemicals
Data Management	R	R
• Record and enter data (keep a written and/or electronic laboratory notebook)	R	R
• Report data (for internal laboratory use, presentations, publications)	R	R
• Perform bioinformatics, data analysis, and trends analysis	R	R
Computer Proficiency	R	R
• Use word processing and spreadsheet programs	R	R
• Operate basic data management system	R	R
• Perform Internet research	R	R
• Communicate in writing (reports and email) with proper etiquette	R	R
• Interact via online social networks	p	

	Algae and Microbial Systems	Bioprocessing	Agbiotech	Forestry Resources
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R

	Algae and Microbial Systems	Bioprocessing	Agbiotech	Forestry Resources
	p	p	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	p		p	R
	p	R	R	R
	p	R	p	p
	p	R	p	p
	p	R	p	p
	R	R	p	p
	R	R	p	R
	p	R	p	p

	Algae and Microbial Systems	Bioprocessing	Agbiotech	Forestry Resources
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	R	R	R	R
	p			

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