BIO ENERGY CONNECTION
Spring 2011
Inaugural Issue

The World is Waiting

Mapping Global Mandates

Moving Closer to the Pump

Fuels for the Future

PLUS:

Pamela Ronald In the Lab

Brazil's Native Son

The Driving Force Behind GREET

From Bio...

ENERGY CANE

A Cane by Any Other Name Isn't, Actually, as Sweet

What is it? The same species as sugarcane, but bred to produce large amounts of fiber, rather than sugar. The potential advantages are promising: more energy per acre than sugarcane, and fiber that can be stored in the field and at the factory longer than sugar.

Where does it grow? Where other crops might struggle. The steamy and sandy soils of the southern United States aren't particularly productive, and energy cane might be an excellent crop on land that is currently abandoned or minimally used for pasture.

Why does it matter? Growing the best biofuel feedstock—with minimal inputs like irrigated water or additional fertilizer—for a given site will ensure both economic and environmental viability.

Who is working on it? University and government research centers focusing on biofuel crops for the southern United States, and BP Biofuels North America at its operations in Jennings, LA, and Highlands, FL.

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DEPARTMENTS

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FEATURES

THE CONNECTION

BIO ENERGY CONNECTION

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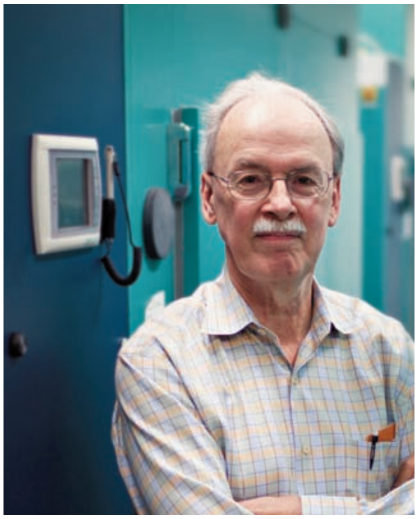
ABOUT THE EBI

The Energy Biosciences Institute is a partnership of the University of California, Berkeley; the University of Illinois at Urbana-Champaign; Lawrence Berkeley National Laboratory; and BP. In its quest to help the world transition from fossil fuels to a balanced portfolio of responsible, renewable energy sources, EBI researchers and scholars explore the application of advanced knowledge of biological processes, materials, and mechanisms to the energy sector. More than 300 EBI researchers are engaged in five main areas: feedstock development, biomass depolymerization, biofuels production, microbiology of fossil fuel reserves, and the economic, social and environmental dimensions of cellulosic biofuels development. To learn about recent EBI research and scholarship visit the EBI website at www.energybiosciencesinstitute.org

EDITOR'S NOTE

As you read the articles in this inaugural issue a common element emerges: people working in the bioenergy field are dedicated to creating a better future for our planet. How and when that will happen is an open question. Why it must is not, as we were reminded in delightful fashion as the magazine was going to press. Nathan Joseph Heaton was born to Emily Heaton (see, Big Grasses, Bigger Goal, page 26) as the New Year approached and Madison Marie Ahlers arrived to the delight her mother, and our art director, Haley Ahlers, as 2011 took hold. Two very good reasons to keep working on that elusive goal.



MOVING THE CONVERSATION FORWARD

One of the most difficult challenges of this century will be finding ways to reduce our dependence on fossil fuels while at the same time providing improved quality of life for an expanding human population and preserving biodiversity. While we cannot know the future, it is not difficult to predict that the intersection of major trends such as depletion of petroleum reserves, expanding population, and climate change will be accompanied by many ideological or political conflicts in which science and engineering will be called upon to support arguments for or against various proposed solutions.

Indeed, important aspects of this vital public dialog have been underway for some time and are likely to grow increasingly complex as new information and new perspectives are brought to the discussion. In the relatively young field of energy biosciences, the past several years have witnessed vigorous debate about issues such as the indirect land use consequences of biofuels and the effects of biofuels on food security.

Although these and other issues can be converted to convenient sound bites or headlines that advance one or another point of view, it is apparent that important facts and context may get lost in passionate but sometimes incomplete or oversimplified discourse. As informed participants in the academic side of the bioenergy field, my colleagues and I at the Energy Biosciences Institute are frequently approached by individuals from government, the media, educational institutions, and industry seeking to understand at a deeper level the complex issues facing our new field. We welcome these inquiries and are always grateful for the opportunity to provide analysis and understanding when we can and to learn from the issues raised and the dialog that ensues.

In response, we have launched Bioenergy Connection in the hope that this new magazine can become a useful summary of contemporary research, emerging policies, and trends in the general field of energy biosciences.

Our goal is to introduce the questions that drive current research, to spotlight the people who are moving the field forward, and to provide explanations to a range of issues in terms that will broaden knowledge and understanding by specialists and non-specialists alike.

Diversity of opinion is the lifeblood of meaningful discourse so we intend to present conflicting ideas where there are evidence-based arguments propelling divergent conclusions. Our long-term ambition is to present a global perspective but we believe that an initial focus on a few of the most active areas of the world represents enough of a challenge for a new magazine. We are grateful to the distinguished members of our editorial advisory board for their assistance in establishing the scope and advising on the content of the magazine.

Finally, while we will draw from the expertise of the EBI team and our academic and industry colleagues here and abroad, we hope to solicit advice from the readership of the magazine about what topics would be most useful in moving the conversation forward. We welcome your feedback on this, our inaugural issue, and encourage you to share your thoughts and suggestions for future issues. We can be reached at bioenergyconnection@berkeley.edu and through a website that will be launched soon to complement the printed version of the magazine.

Chris Somerville

Executive Editor and Director of the Energy Biosciences Institute

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ERIK VANCE (Fuels for the Future, page 8) is a science writer who has covered topics that span biology to chemistry to the world's hardest math problem, and often writes about the world of alternative energy. His work has appeared in Discover, Nature, The Utne Reader, and The New York Times.

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COMMENTARY:

ENERGY, EDUCATION,

By John H. Perkins, PhD
PHOTOGRAPHY: Peg Skorpinski

In the fall, I took nine educators to Ukraine to study the Chernobyl catastrophe of April 1986. We learned of Ukraine's ongoing work to manage the ruins of the Chernobyl reactor and its efforts to build a 21st century energy economy. In talking with many Ukrainians, we were struck with two points: First was the shear multitude of issues connected to energy, especially technology choice, climate change, water, economics, foreign policy, politics, and public understanding; and second were the difficulties of reaching consensus. American participants saw that looking at Ukraine helped them grasp the magnitude of similar challenges at home.

In the U.S., climate change from using fossil fuels and insecurity of oil supplies rank high on the list of public concerns. However, apart from the engineers and scientists who study energy, not many Americans can speak knowledgeably about our reliance on fossil fuels, the dangers posed by climate change, or the connections between energy and international conflicts. Even many of those who advocate for clean, renewable fuels would be hard-pressed to explain the steps needed for wind and solar power to replace coal or for plant-based biofuels to replace gasoline and diesel. Many may not realize that coal, petroleum, gas, and nuclear power today comprise 95 percent of the U.S. energy supply.

"Energy literacy," in other words, is low, far too low. Only with higher energy literacy can we mobilize the political and economic will to reduce uses of fossil fuels, a task with staggering challenges. America's educational institutions have work to do.

Some universities and colleges have a good course or two; a few even have excellent programs. Effective energy education, however, needs to be far more widespread, reaching more students and more geographic regions.

Moving away from fossil fuels requires remodeling the energy infrastructure. If the pathways to new energy practices were self-evident, then the problems would be easy. Troubles begin when we ask (a) what is to be done? (b) how shall we decide? and (c) which new investments will provide the best transition to the use of new technologies?

Many alternatives to fossil fuels exist. Nuclear power is the next largest source of energy after petroleum, coal, and gas in the U.S. Biofuels, wind, solar, and other renewables provide the smallest amount of energy but offer high future potential. The problem is that choosing the best new technologies is not so simple. The crux of the problem lies in the fact that people embrace conflicting choices. A solution that looks ideal to some will look like bad judgment or even a nightmare to others.

Building effective citizen participation requires educational resources that don't currently exist. At the very least, universities and colleges need two specific kinds of courses: (1) general education that explains the current energy economy, its strengths and weaknesses, the potential and reasons for change, and how democracies can design transition pathways; (2) advanced courses and internships in relevant fields to prepare students for professional-level work with industry, government, and non-profits.

Universities ultimately need to offer more than general education and advanced courses. As many have noted, energy will be a defining issue of the 21st century. Commensurate with this challenge, educational institutions should see "energy studies" as a field in its own right. Students need a better understanding of energy's multiple dimensions instead of highly fragmented knowledge taught in different schools and departments that do not communicate well. This unification is essential for building sustainable energy systems.

My own teaching experience, reports from other colleagues, plus studies from student groups indicate that, if offered, energy education will meet with enthusiastic student support. More importantly, it will help to raise energy literacy so that citizens can intelligently evaluate the staggering challenges of our global energy future. ■

& DEMOCRACY

The U.S. currently has no consensual methods for making energy choices, yet these decisions carry enormous investment and public policy implications. The world needs $15 trillion every 40 years to rebuild energy infrastructure, or $375 billion each year for two generations. As the world's population grows and more poor countries become richer, the yearly investment needed will grow.

Citizens must participate in complex energy choices. It is not enough to leave the matter to technical experts or the operations of a supposed free market. Technical experts have absolutely indispensable knowledge, but choices of technology also affect wealth and its distribution, politics, risks, land use and environmental quality, and ethics. In addition, many policies and subsidies for all energy sources mean that no truly free market in energy exists. The most important decisions will occur in the political arena, and citizens have both the right and the obligation to participate

Where Energy Education Gets an A

- ➔ Allegheny College: Energy courses offered as part of Environmental Studies and Sciences
- ➔ MIT: Energy Initiative provides excellent reports on prospects for different energy sources
- ➔ University of California, Berkeley: extensive courses in Energy and Resources Group and in other departments; many departments and institutes have significant research programs
- ➔ University of Delaware: Center for Energy and Environmental Policy and the Energy Institute

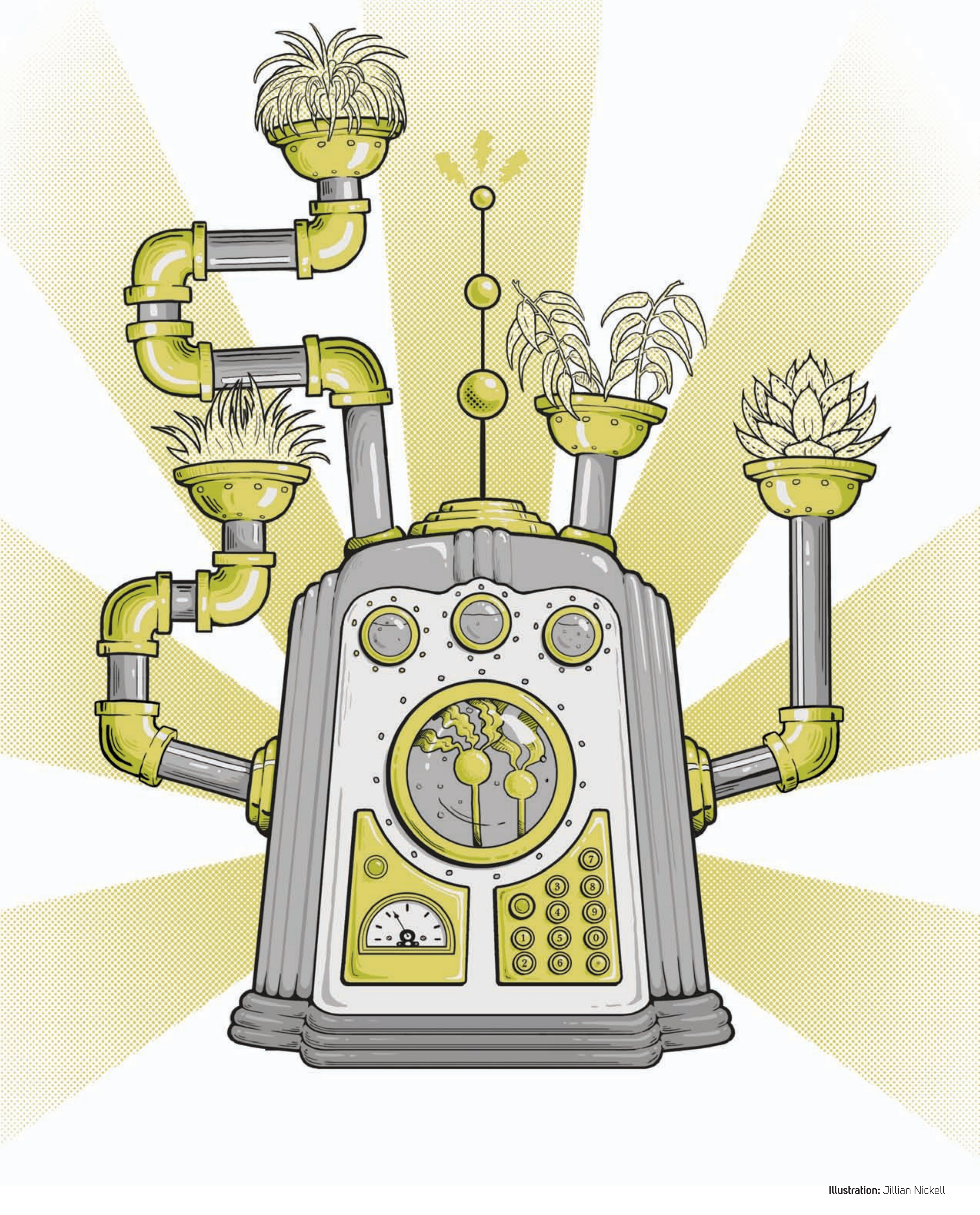

Illustration: Jillian Nickell

Fuels for the Future

From cellulosic to drop-in, the toolbox is expanding By Erik Vance

Rome was not built in a day and modern gasoline did not show up overnight. It took decades of refining and discovery to perfect the blends and design ever-better engines to suit the fuel. How long it will take to meet global aspirations for clean, sustainable, widely available transportation fuels made from plants remains an open question. But over the past few years biofuels research and technology—spurred by government support and private investment—are picking up speed even as new ideas of what's possible are expanding.

Those ideas are coming from every facet of the biofuel production chain—from farm to fuel tank. Researchers are grappling with how best to use and process the Earth's tremendous wealth of biomass—whether it be with enzymes, yeast, bacteria or some other way—to make cellulosic ethanol, liquid fuel made from the stems, leaves and woody parts of plants. At the same time, fuel scientists around the world are working to create entirely new biofuels to mimic gasoline, diesel, and jet fuel so that they can be dropped easily into existing engines, tanks, and pipelines.

All of this is happening as world-wide attention and, at times, scrutiny grows. Today, 36 countries mandate the use of biofuels for transportation. Most require only modest amounts of traditional ethanol made primarily from corn and sugarcane to be blended with gasoline or biofuels blended with diesel (see page 11). But some, led by the United States and the European Union, have put fuel standards in place for the coming decade that that are driving biofuel advances.

These advanced biofuels will not only need to be produced at large scale, they will need to be competively priced, and they will need to reduce greenhouse gas emissions. Further, the raw plant materials from which biofuels are made—the feedstock—will need to avoid competing with food crops for land and water.

To develop new biofuels, global energy giants (including BP, Chevron, Exxon, and Shell) are investing hundreds of millions of dollars in partnerships with leading research universities to resolve fundamental issues of science. The largest of its kind, the Energy Biosciences Institute, is a partnership among the University of California, Berkeley; the University of Illinois at Urbana-Champaign; Lawrence Berkeley National Laboratory; and BP, with BP providing $500 million over 10 years to the effort.

At the same time a host of new biotech firms, many headquartered in the San Francisco Bay Area, are emerging, joining forces with established energy companies or backed by venture capital. This new kind of biofuel company is moving fast to take the newest science from the lab straight to the consumer.

"I see these technologies getting ready to come into the market," says Mike McAdams, president of the Advanced Biofuels Association, which comprises companies working on new biofuels. "In the next 24 months you're going to see butanol, you're going to see renewable diesel, you're going to see renewable jet fuel."

Which fuels for the future?

One of the leaders in fuel innovation is Jay Keasling, a University of California, Berkeley chemical and bioengineering professor, and head of the Joint Bioenergy Institute. Located in the San Francisco Bay Area and modeled like an entrepreneurial start-up, JBEI is one of three Department of Energy research centers charged with accelerating research and development into advanced biofuels as part of the government's mandate to produce 21 billion gallons of advanced biofuels for transportation by 2022.

Keasling's specialty is synthetic biology, the ability to design and build biological systems for a specific purpose. For biofuels, by changing the basic DNA codes of the yeasts and bacteria that ferment sugar into alcohol, Keasling and his team hope to control the kind of chemicals that come out. So rather than ethanol, he can teach a microbe to produce perhaps a new form of biodiesel or, say, an iso-octane, a component of gasoline which is used to calibrate fuel performance standards.

Keasling, who grew up on his family corn and soybean farm in Nebraska, points out that 1.3 billion tons of biomass lie fallow every year, as much energy as 100 billion gallons of advanced biofuels a year. The key, he says, is that the new bio-sourced fuel must look and act like the petroleum-based fuels of today.

"What are the fuels of the future that will be most effective? Gasoline and diesel. They don't have to be petroleum derived, but they will be gasoline and diesel," he says. "We're trying to mimic as much of the petroleum-derived fuels as we can so that you don't have to compromise when you drive up to the pump."

Ideally, these so called "drop-in" fuels would be compatible with today's refining and distribution networks, thus being just as useful in a next-generation hybrid as a 1967 Mustang hardtop.

Others, though, are looking toward new kinds of fuels altogether. Researchers at the Massachusetts Institute of Technology and other organizations are retrofitting bugs to create biobutanol, a fuel that to this point has not been in the market. The potential for butanol is exciting because it appears to have all the benefits of ethanol without the drawbacks. Ethanol is corrosive, tends to pick up unwanted water, and lacks the power of petroleum. Butanol is non-corrosive, repels water, and has as much punch as jet fuel.

The MIT team, like many others, is trying to find a life form that can create this new fuel. Their microbe of choice is a bacterium that has been used in the past to clean up oil spills. Engineering a microbe that can create butanol is just the start, though.

> "We welcome new entrants to the market, but.....

Because butanol is toxic to microorganisms, it will collect and kill the very creatures that created it. So the team, led by professor Anthony Sinskey, has been trying to create bacteria that not only synthesize a novel fuel but are immune to it.

Not everyone is convinced, though.

"We welcome new entrants into the market—all fuels to replace petroleum are good—but I think it's going to be difficult for a molecule to compete with ethanol, just on a cost basis," says Jeff Broin, CEO of POET, a well-established ethanol producer. POET has an ethanol plant that produces ethanol from corn stover (the plant material left over after harvesting) for a competitive $2.35 a gallon.

Converting biomass into sugars

Regardless of the kind of biofuel you want to produce, you must start with the same component—sugar. And in the case of cellulosic fuels, that means turning the fibrous, pulpy plant material into usable sugar. For companies like POET, this breakdown (or pre-treatment as it's called) is the most expensive step. Scientists say the best way to break down fibrous cellulose and lignin is the same way that nature does it – with enzymes. Enzymes are natural catalysts that kick-start chemical changes.

"One of the big problems is the cost of enzymes," says Chris Somerville, UC Berkeley professor and head of the Energy Biosciences Institute. "Right now it's estimated to cost somewhere between 50 cents and a dollar per gallon of fuel just for the enzymes that convert the biomass into sugars."

With such a big price tag, enzymes are now seen as the major impediment to cost-effective biofuels and labs around the world are working to find cheaper alternatives. Much has been made recently about exotic and creative places in nature to hunt for new enzymes. Researchers, for example, have picked apart animals like termites looking for the ability to spin straw into sugary gold. Scientists make frequent trips to the rainforests of Puerto Rico, which are said to have the most aggressive and dynamic decomposition properties in the world (the theory being nothing breaks down cellulose like a rainforest).

Yet we don't really even have a good sense

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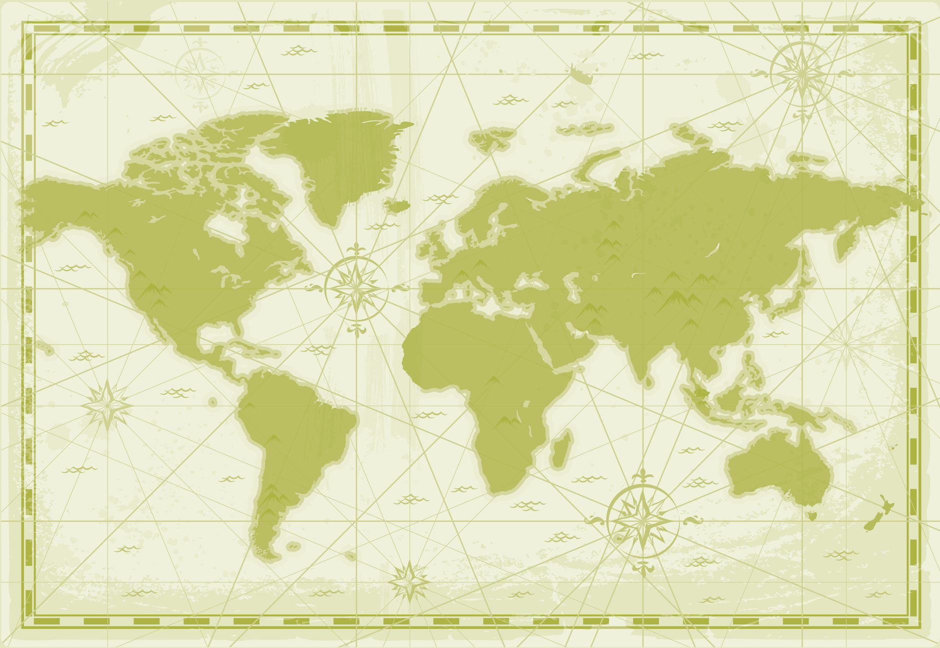
Global Mandates: MOVING TOWARD A BIOFUELS FUTURE

The goal to transition away from petroleum-based transportation fuels to clean and renewable fuels made from plants is an ambition shared by nations, states, and regions across the globe. To respond to the challenge, and to provide a framework to spur their use, 36 countries have mandates in effect for the use of biofuels and four more have put mandates partially in place, according to a 2010 report by the Global Biofuels Center. In addition, some governments, notably the United States and the European Union, have adopted far-reaching goals for the coming decade that set usage goals and address the role of advanced biofuels to reduce greenhouse gas emissions.



Mandates vary widely. In most cases current mandates call for fuel blends with a percentage of ethanol and biodiesel that typically come from traditional sources, primarily corn and sugarcane (ethanol), and rapeseed and soybeans (biodiesel). Most set a minimum percentage of biofuel to be blended into gasoline (for example, an E10 mandate requires gasoline blended with 10 percent ethanol) or biodiesel (a B3 mandate is 3 percent plant-based diesel blended with 97 percent diesel.) While not all of the 36 countries met their 2010 or earlier targets, most have been successful. As future mandates that call for higher biofuel-blend percentages and requirements for advanced and next-generation fuels come into play, however, balancing supply and demand to meet policy ambitions is expected to become a greater challenge.

Today, the United States and Brazil dominate the world's production of biofuels, led by ethanol. In 2009, of the nearly 20 billion gallons of ethanol produced worldwide, the U.S. produced 10.6 billion gallons, primarily from corn; Brazil produced 6.6 billion gallons from sugarcane. The next largest producers of ethanol were the EU, China, Thailand, Canada, India, Colombia, and Australia, according to the Renewable Fuels Association.

Biodiesel is also produced worldwide but in much smaller amounts, with 650 million gallons produced globally in 2008. An estimated 200 countries were producing some amounts of biodiesel in 2010.

The map on the next two pages highlights some examples of biofuels mandates and use across the globe. Note that "mandates" as used here is a generic term that may have varied meaning depending on each jurisdiction.

MAPPING GLOBAL MANDATES

KEY

E = % of ethanol blended with gasoline or petrol

B = % of biodiesel blended with diesel fuel

Sources: Multiple, including government and media reports; Hart Energy Consulting, presentation to the Global Biofuels Outlook 2010-2020 (Oct. 2010); Emily Kunan & Jessica Chalmers, Sustainable Biofuels Development Policies, Programs, and Practices in APEC Countries (APEC/Winrock 2009); Giovanni Sorda, et al., An overview of biofuels policies across the world, 38 Energy Policy 6977-6988 (2010); World Energy Council, Biofuels: Policies, Standards and Technologies (2010); Renewable Energy Policy Network for the 21st Century (REN21), Renewables 2010 Global Status Report (Sept.2010).


EUROPEAN UNION
• Renewable Energy Directive mandates 10% transportation fuels from renewable sources by 2020; to qualify must achieve 35% GHG reduction, accelerating to 50% & 60% after 2017
• Fuel Quality Directive (low carbon fuel standard) requires 6% reduction in lifecycle GHGs, per unit of energy, for all biofuels by 2020
• Individual member states responsible for implementation
GERMANY
• Biofuel Quota Act and Biomass Sustainability Ordinance in place since 2007
CHINA
• 10% ethanol blend mandate in 10 regions
• Plans to meet 15% of its transportation needs with biofuels by 2020
JAPAN
• No blending mandate
• Emphasizing cellulosic biofuels from plant waste, rice straw, and lumber
INDIA
• Blend mandate of 20% biofuels in gasoline and diesel by 2017
• Exploring non-food crops for biodiesel
INDONESIA, THE PHILIPPINES, SOUTH KOREA, TAIWAN, AND THAILAND
• Nationwide biodiesel mandates, typically at B2 levels
KENYA
• 10% ethanol blend
ZAMBIA
• Implementing E10 and B5 blending ratios
MOZAMBIQUE
• Sugarcane and sweet sorghum approved as biofuels feedstock; coconut and jatropha approved for biodiesel
AUSTRALIA
• Blend-level mandates for ethanol (E4) and biodiesel (B2) for only its most populous state, New South Wales
NEW ZEALAND
• Only country to date that set and then abandoned a biofuels mandate in favor of tax incentives to encourage use of ethanol and biodiesel

Continued from page 10

of the useful enzymes in our backyard. Take the cow rumen, which—as anyone who has stepped in a cow pie knows—is expert at breaking down grass fiber. It's a well-studied source of enzymes, yet EBI researcher Eddy Rubin recently found a staggering 27,000 new enzymes that play a role in biomass breakdown after sifting through 280 billion base pairs of DNA from the hundreds of microorganisms that inhabit cow rumen. Essentially, a single cow's rumen increased the world's enzyme library by 30 percent.

Bruce Dale at Michigan State University agrees it's important to look for new exciting enzymes at the far corners of the Earth. However, he says many of the same gains can be made by tweaking the mixtures of what is already in regular use.

"Commercial enzymes that most people have used in laboratories are mixtures. And they are actually quite undefined mixtures and haven't really been optimized," Dale says.

Breaking down cellulose is more complicated than putting grass clippings and wood chips with a generic bottle marked "enzyme" in a machine and setting it to spin cycle. Different enzymes work on different plants and even on different parts of the same plant. In addition, enzymes seem to work differently when they are mixed with other enzymes in an industrial setting.

So researchers working with Dale at the Great Lakes Bioenergy Center have been working to trim superfluous enzymes out of the mix. It turns out that oftentimes much of the enzyme mix is going to waste. By simply adjusting the existing mixtures, the team has managed to cut by 75 percent the amount of enzymes used in breaking down the feedstock grass Miscanthus.

But there may be other solutions beyond finding the sleekest mixture of enzymes. What if the plant could break itself down, rather than stubbornly forcing humans to do it with expensive cocktails? Perhaps the most innovative approach to enzyme use abdicates our adding them altogether. Agrivida, a Boston-based biotech start-up, hopes to essentially outsource the breakdown of the plant—to the plant itself.

Plants, after all, are life forms and with modern genetics there is no reason they can't be created pre-loaded with enzymes. The problem is that a plant that creates its own corrosive enzyme would obviously wither and die.

"You don't want to put a xylanase or a cellulase into a plant and have it chew up the cell walls while it's trying to grow. We've actually done that, and you get all these stunted plants," says Agrivida founder and president R. Michael Raab. "It's almost like they're melting while they're growing"

That's where a new tool, called an intein, comes in. An intein is a removable segment of protein that keeps the rest of the protein from working, like an internal "mute" button. Here's how it could work: You insert an intein into cellulase to mute the corrosive properties of the protein and the plant grows. When the plant is harvested for conversion into sugar, a simple trigger—like heating it—would remove the intein. The cellulase would reassemble and, like some kind of microscopic saboteur, start liquidating cells.

This technology is very new. Inteins were only discovered in 1987 and even then it took a while for some scientists to believe they were real. "People recognized RNA splicing and transcription but had never seen protein splicing before," Raab says. "It's pretty cool."

Using a single enzyme, Raab and his team have also cut the need for added enzymes in corn stover by 75 percent. He says when they start mixing several enzymes into one plant, that number may jump above 90 percent.

Zeroing in on the feedstocks

Of course, the type of fuel and how to prepare it is pointless without a massive and steady source of plant material.

"Feedstocks is a huge issue," says JBEI's Keasling. "We are not going to ship biomass all over. It's too bulky. We're going to ship it about 30 miles, maybe less."

That means that a feedstock needs to grow near the processing plant. Many species are under investigation and the list continues to grow.

The ideal feedstock, in addition to its energy benefits, would grow where food crops struggle and wouldn't tax local water resources or demand expensive and polluting fertilizers. The National Resource Defense Council, for example, supports biofuels but has adopted the mantra "not all biofuels are created equal" to highlight the importance of using only sustainable feedstocks.

Giant biomass-generating perennial grasses including switchgrass and Miscanthus are among the front-runners for temperate climates. Low-sugar varieties of sugarcane and Napier grass are favored in tropical climates with adequate rainfall. Fast growing poplar and eucalyptus trees, Jatropha for biodiesel, and even agave and bull kelp are among many that offer potential in various parts of the world.

No silver bullet—not a problem

In the end, of course, no one can predict with certainty how next-generation biofuels will succeed or to what extent they will challenge petroleum's dominance. More and more the sense is that that there will not—and perhaps even should not—be a silver-bullet solution.

Eric Toone, the deputy director for technology at the Department of Energy's ARPA-E program, says whether a company is growing energy crops or focused on breaking down the cellulose or synthesizing it into fuel, the most important part is that they be able to work with each other and be interchangeable. "These pieces are modular. Exactly like Legos, so you can mix and match," says Toone.

Toone says we don't know what the game-changer will be. "The tool box we have today is so much bigger than what we had even just a few years ago," he says, adding that the only certainty is that fuel production in the future will be a diversified endeavor. ■

THE PATH TO COMMERCIALIZATION

Are we there yet?

By Heather Youngs

In 2007, Congress set target goals for the production of renewable fuels—36 billon gallons per year by 2022, with a clear path of volumetric stepping stones to get there. While corn ethanol is on target to reach the 15 billion gallons per year cap, the remaining 21 billion gallons—16 billion gallons cellulosic fuel, 1 billion gallons renewable diesel, and 4 billion gallons of other advanced fuels—are lagging.

In particular, cellulosic fuel production targets have not been met and the 2010 target was reduced from 100 million gallons to 6.5 million, forcing a steeper path to the 2022 target.

So...why haven't we achieved the targets and will we get there?

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First, some perspective. It has only been 10 years since the U.S. Congress passed the Biomass Research and Development Act of 2000, the first federal policy to support production of biobased products. Cellulosic biofuels received their first specific incentive with passing of The Energy Policy Act of 2005 and policy supports have continued to grow.

The decade has brought serious research dollars to the advanced biofuel effort. BP, Shell, and Exxon have all invested millions. In 2008, Ethanol Producer Magazine listed nine companies planning to open commercial-scale cellulosic ethanol plants in the U.S. A year later, in the midst of a substantial economic downturn, half those projects were scratched or placed on hold. Many of the remaining companies had changed locations or feedstocks, most embracing non-cellulosic "starter" feedstocks to lower their entry costs.

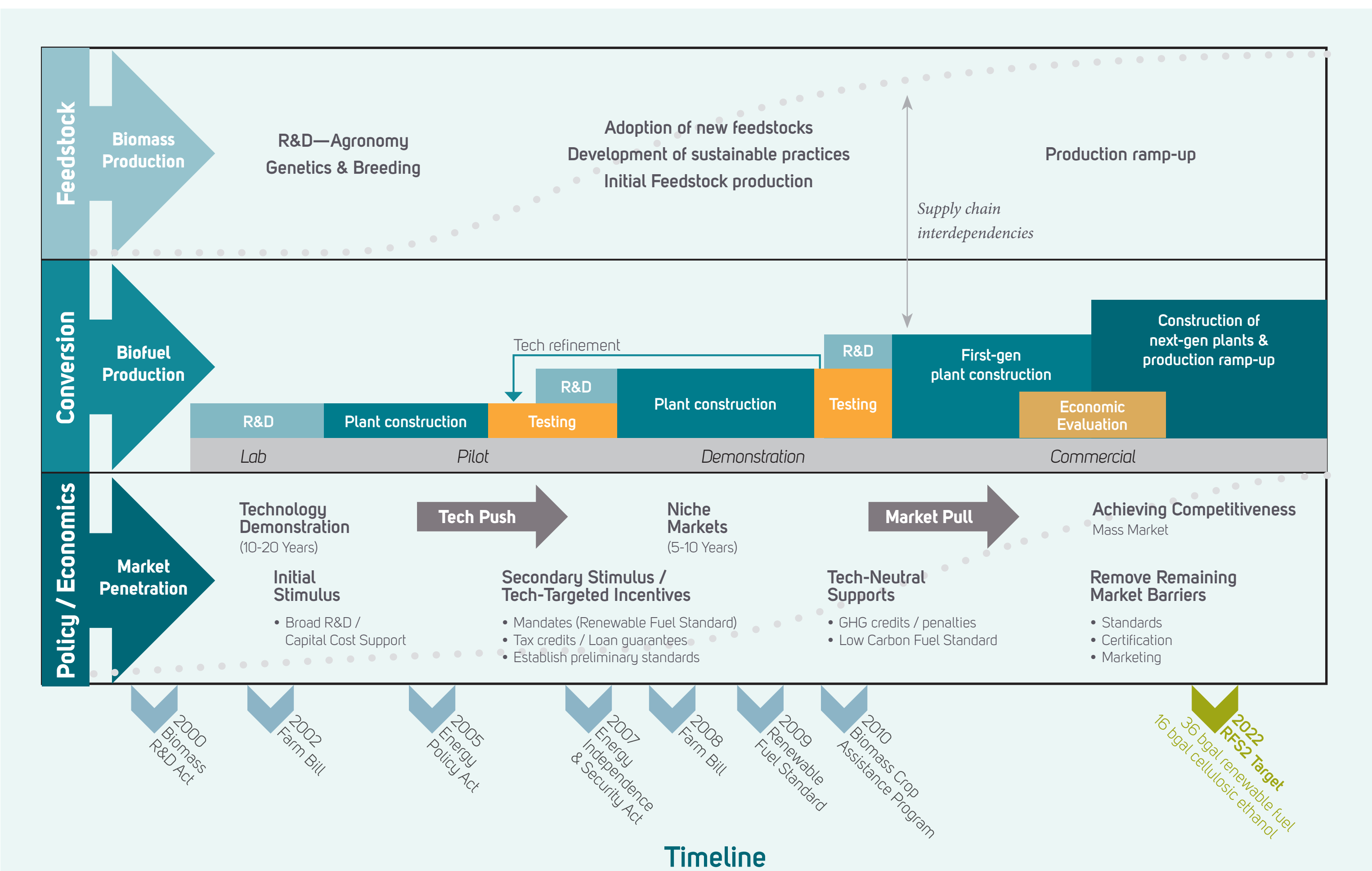
At present, there appear to be about a dozen companies planning commercial-scale cellulosic refineries in the next few years. While the turnover reflects recent economic constraints and technology hurdles, the continued entry of new companies provides some forward momentum to the industry. As a result, the U.S. sits at a pivotal junction—the jump to commercial production.

This transition to commercial scale, known as the "Valley of Death," is a critical stage for evaluating economies of scale, market potential, and looming techno-economic barriers in emerging technologies. Making this leap is difficult for many new ventures but it seems especially problematic for biorefineries for several reasons.

The success of a commercial biorefinery requires an assured, high quality biomass supply. Conversely, the success of biomass producers hinges on a reliable market to absorb their product. In effect, two new interdependent supply chains must co-evolve within very thin margins of economic viability and the risk associated with either endeavor is thus multiplied.

This risk is compounded by uncertainty in government support policies, spurred by caution to avoid unwanted indirect effects. The resulting lack of consensus definitions

The Path to the Pump



for renewable fuels and renewable biomass complicates the policy landscape for biofuels and negatively affects investment in capital expenditures for processing and adoption of energy crops by farmers and foresters.

Cellulosic refineries require additional infrastructure for breaking down biomass, with 2 to 3 times the capital costs of a standard corn or sugarcane ethanol plant, and risk is relatively high for these first-generation facilities. Leveraging public institutions such as the Department of Energy and the U.S. Department of Agriculture in the loan guarantee process has emerged as a useful bridging tool but it is still not easy. The DOE process is slow and rigorous and while the USDA process is less cumbersome, Enerkem reports interviewing 60 banks before finding a lender.

Long-term contracts between farmers and fuel companies mitigate some risk for lending institutions, freeing up investment capital needed for technology adoption and scale-up in both arenas. At least a third of the companies seriously planning commercial plants have contracts in place for feedstocks well in advance of breaking ground.

The final challenge is not just scaling one refining pathway, but an entire industry. Even if all the currently planned facilities are built, their combined capacity will only be around 300 million gallons per year, falling short of the adjusted federal target.

To meet 2022 target volume, an aggressive build rate will be required. USDA calculates that 527 refineries with 40 million gallon per year capacity would be needed at a capital cost of $168 billion—the equivalent of one new refinery per state per year over the next ten years.

Unfortunately, construction of new facilities is not likely to be a linear process. Rather, a short learning period of three to five years is expected while the first wave of plants undergoes testing and optimization. A secondary growth period should follow with construction of improved refineries but production volume will most likely remain under target, providing leverage for critics of the industry.

The final phase of accelerated fuel production should result in measurable market penetration. The rate of this build-out of second- or third-generation refineries will depend on construction costs, local permitting barriers, the availability of financing in the context of market signals, political drivers, and, of course, the price of oil.

Current research in academic centers and industrial labs has the potential to substantially enable and improve prospects for these latter stages of development. Process innovations continue to make huge strides. For example, enzyme costs for cellulosic depolymerization have fallen 80 percent in the last two years.

In short, the industry is moving ahead. While the potential to reach the target volumes is evident, how fast the industry can get there will remain unclear until the first scaled refineries are up and running. Policies that facilitate the transition to commercial-scale will continue to be vitally important to achieving the goal of displacing a significant volume of fossil fuel with renewables options. ■

Companies with plans to open commercial-scale cellulosic biofuel plants in the U.S. before 2015

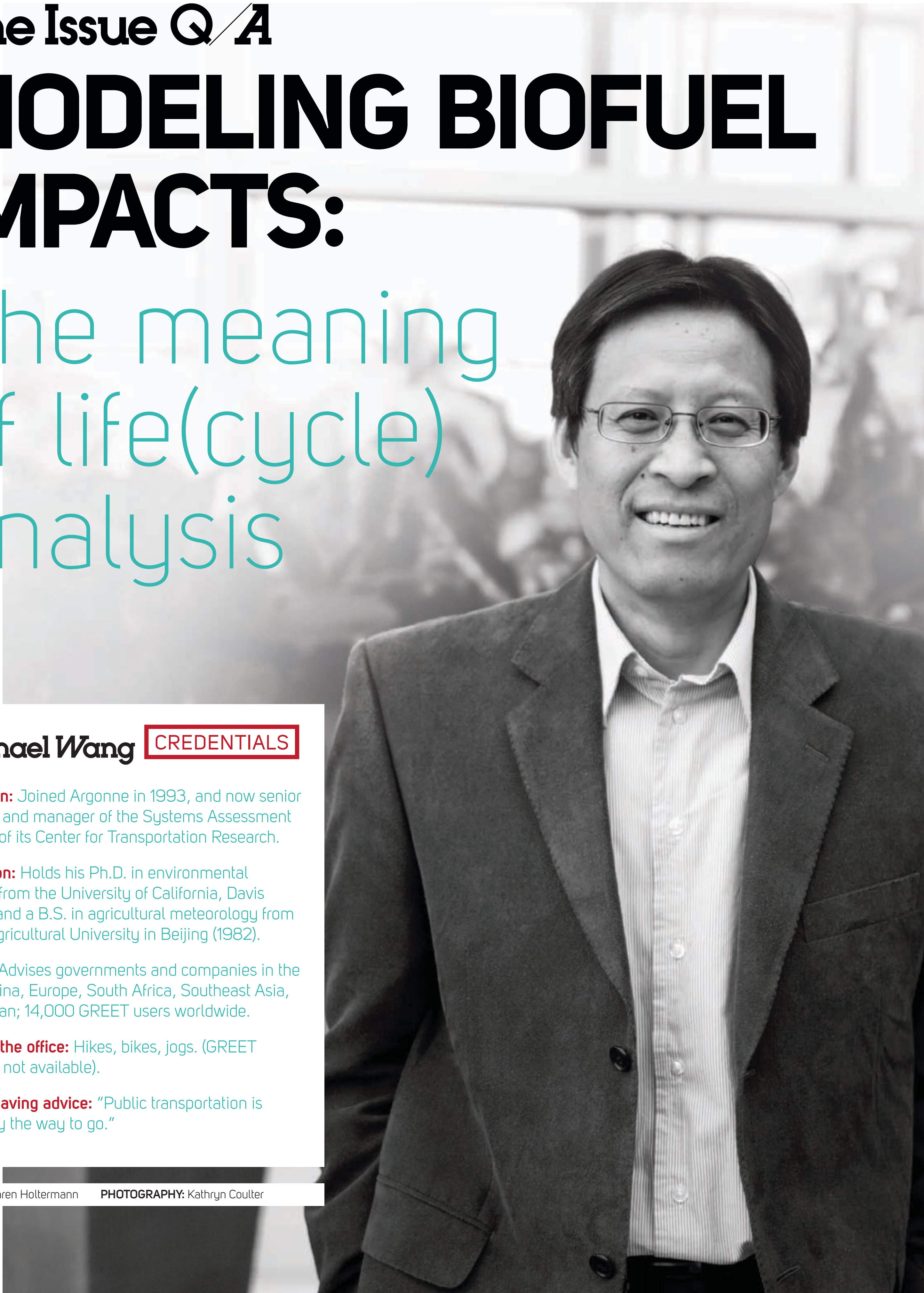
Company	Volume (Mgal/yr)	Feedstock	Location
Abengoa	20	Variable	Kansas
Bluefire	19	Wood MSW	Mississippi
ClearFuels Technology	20	Wood	Tennessee
Coskata	55	Variable	Michigan
Enerkem	10	MSW	Mississippi
Fulcrum	10.5	MSW	Nevada
Great River Energy	20	Wheat Straw	North Dakota
Genahol	30	MSW	Indiana
KL Energy	100	Wood	Michigan, Oregon
Mascoma	40	Wood	Michigan
POET	25	Corn cobs	Iowa
Range Fuels	20	Wood	Georgia
Vercipia	30	Energy cane bagasse	Florida

MSW: Municipal Solid Waste

The Issue Q/A

MODELING BIOFUEL IMPACTS:

The meaning of life(cycle) analysis



Michael Wang CREDENTIALS

Affiliation: Joined Argonne in 1993, and now senior scientist and manager of the Systems Assessment Section of its Center for Transportation Research.

Education: Holds his Ph.D. in environmental science from the University of California, Davis (1992), and a B.S. in agricultural meteorology from China Agricultural University in Beijing (1982).

Impact: Advises governments and companies in the U.S., China, Europe, South Africa, Southeast Asia, and Japan; 14,000 GREET users worldwide.

Outside the office: Hikes, bikes, jogs. (GREET analysis not available).

Planet-saving advice: "Public transportation is definitely the way to go."

WORDS: Karen Holtermann **PHOTOGRAPHY:** Kathryn Coulter

When it comes to assessing fuel efficiency and environmental impacts, the old days are gone. Once we were satisfied with vehicle MPGs and tailpipe emissions ratings, but no longer. Today, transportation fuels and vehicle technologies are the subject of life cycle analysis (LCA), which assesses the impact of each stage of their production and use—cradle to grave, or in fuel-expert shorthand, "well to wheels."

Michael Wang of Argonne National Laboratory is the driving force behind GREET (Greenhouse gases, Regulated Emissions and Energy use in Transportation). An LCA modeling tool with humble beginnings, GREET today is the gold standard for evaluating and comparing advanced fuels, vehicle technologies and their many combinations.

Why did you develop GREET?

A project we were doing in 1994 for the Department of Energy required us to examine energy and emissions implications of different transportation fuels and vehicle technologies. Mark Delucchi, a friend from graduate school, had generated a model that I thought I could use. But it was in Lotus 1-2-3 on the Mac, and I couldn't open and use it. So I put together an Excel spreadsheet, just to finish the project. Afterward, DOE asked if we could make it available for others. That was the start of GREET.

How does it work for fuels?

The purpose is to put all fuel options on a comparable basis. To do that, you have to consider each stage of the whole life cycle of each option. For example, for petroleum it's recovery, refining, gas distribution, and so on. For biofuels, we look at fertilizer production, feedstock farming, feedstock transportation, fuel production, fuel distribution, etc. We simulate energy use and emissions at each stage, and then make overall comparisons.

Since the first version in 1996, how has the tool evolved?

Each new version is more complicated, with more fuel and vehicle options and more issues to address. The ongoing effort is to get the best, most up-to-date data and our LCA research results into GREET—this is what life cycle analysis is all about. The area is evolving very fast. We have to be open-minded and keep abreast of new technology developments. On the other hand, we have to evaluate new information carefully, especially when so much is disseminated on the web. You have to do your homework and make judgment calls on what is credible. People trust the information we use and put into GREET, and we have to be extra careful on our default data and parameters in GREET.

GREET is a free tool, available to anyone—do you monitor its use?

Having GREET in the public domain, on the web and in Excel, has made it transparent, a step-by-step form to follow. If I've made any contribution in this field, it has been to popularize LCA and demystify it. GREET has a large user base, and most just download and use it themselves. We do not have full control of how they use it, and Argonne does not endorse user results. When you change the parameters of GREET, the results are yours.

A 2008 study partially using GREET concluded that the impacts of biofuels on global land use would be dire, and advocated halting biofuel development. You challenged that study in a letter to Science magazine. Did the episode affect your thinking about GREET?

Land use change has been a major issue in expanding GREET's system boundaries for biofuel analysis. It's complicated. You have economic, social, political, even cultural factors in different countries and regions. To use only economic factors to simulate land use change, to me, is too limited. That's

what was done in the study I challenged. Even in the context of economic modeling of land use change, I challenged in my letter to Science that several key economic factors need to be taken into account and need to be researched. We did not feel comfortable that available models could quantify land use change then. Since then, we, and others, spent a considerable amount of effort to address a few critical economic issues in modeling of land use changes. Though many improvements were made, we are still not 100 percent satisfied with our efforts, and others' efforts, in this area.

What do we need to know that life cycle analysis can't tell us?

Most models, including ours, cannot tell you the economics of technologies, technology readiness, or the social factors that determine consumer acceptance of new technologies. And new infrastructure needs are not now part of LCA comparisons. For example, if we're going to have battery-powered electric vehicles, we know we'll need to have a recharge infrastructure, either at home or at fast-charge stations. With LCA models now available, you still only get a piece of the puzzle.

How will GREET develop in the future?

We continue to expand GREET. On the biofuels front, we're working on algae-based pathways, and to update the land use change module that we recently added to GREET, technology improvement, and other complicated factors for evaluating biofuels. For vehicle technologies, we are going to build into GREET modeling of new regulations that are now on board or proposed, such as the new national fuel economy standards, starting in model year 2015, and the heavy-duty truck fuel economy standard proposed in late October, so that people can compare technologies to meet those standards.

With such scrutiny of biofuels, can any ever measure up?

There is no denying that biofuels are being scrutinized more than any other transportation fuels. This is healthy evaluation as the society pursues fuel options with truly realizable energy and environmental benefits. I hope we're going to use the same scrutiny to examine all of the transportation fuels on this level of detail, so we can truly pursue sustainable fuel and technology options. On the other hand, I do worry that if we tend to become perfectionists, we may lose opportunity of adopting certain technologies with immediate, though incremental, benefits. Loss of realizable opportunity is a risk that many have not thought about. ■

Zeroing In: IMPACTS COUNTY BY COUNTY

Life cycle analysis is not an exact science, especially when it comes to biofuels. Inputs are uncertain. Processes are unknown. Targets move, constantly. Yesterday's data can become irrelevant tomorrow. What plant source? Which technology? What land? Which fuel?

According to scientists Arpad Horvath and Tom McKone of the Energy Biosciences Institute in Berkeley, biofuel LCA attempts to predict the unpredictable. Three years into their research program on the topic, they haven't resolved the dilemma, but they are narrowing the boundaries on the risks and challenges.

"We built more specificity into our program," says Horvath, a UC Berkeley professor and expert on environmental analysis. "We've spent three years mining massive amounts of data and enormous resources, drilling down to find the information that is most useful to what we (in the EBI) are doing."

Using their resulting computer model, they take scenarios carefully crafted by EBI bioenergy analysts Caroline Taylor and Heather Youngs and then plug the relevant data—more than 20 different criteria—into the program. Then the tool walks through every life cycle state, starting with biomass production, then biorefining, distribution and storage, and transportation.

> "After all, most of the impacts are local—carbon, health, and water are the Big Three."

"The analysis is done at the county level," says McKone, a health risk assessment expert at Lawrence Berkeley National Laboratory. "We try to figure out the exact location of production, refining and use. After all, most of the impacts are local—carbon, health, and water are the Big Three." Eventually, they'd like to be able to project biofuel impacts for all 3,109 counties in the United States, and then internationally.

The first test scenario is based on Miscanthus, a tall, fast-growing grass, as the source biomass, and an enzyme-based cellulose deconstruction and bioprocessing technology that is prospective but promising. As varying feedstocks and technologies emerge, their values can be plugged into the tool and impact estimates given for their full life cycles, information that will help decision-makers in their quest to develop sustainable, environmentally responsible biofuels. ■

IMPROVING RICE FOR FOOD AND GRASSES FOR ENERGY

INTERVIEW: Michelle Locke



IN THE LAB WITH PAMELA RONALD

At Work: *Vice president of feedstocks and director of grass genetics, Joint Bioenergy Institute (JBEI); and professor of plant pathology at the University of California, Davis.*

Her Focus: *Studying rice and Arabidopsis (a member of the mustard plant family) as model species for understanding how to extract sugars from potential energy crops such as switchgrass and Miscanthus.*

In Print: *Tomorrow's Table: Organic Farming, Genetics and the Future of Food. Oxford University Press (2008). Written with her husband and organic farmer, Raoul Adamchak (above, with Ronald).*

The big question. When?

That's a question scientists always hate to answer. It's possible to do it now; we can get fuel from grasses—the thing is, it's really expensive. There are a lot of factors that are involved that are at some level hard to predict and are outside the realm of science such as the price of oil, how fast we can use some of our marginal lands to produce switchgrass, incentives to farmers. On a scientific basis, I think there is progress made every day with making the process cheaper and more cost-efficient, but when we'll be driving up to the pump and filling our cars with biofuels… I think it's going to be at least 10 to 20 years.

Better plants

First-generation biofuels include fuels from corn grain. The problem is that the farmer must replant the crop every year and water it and till the soil. Our goal for next-generation biofuels is to develop an approach using stocks and leaves from perennial grasses or agricultural wastes—grasses that you don't have to water and fertilize and replant every year. You also don't have to give them as much nitrogen and you don't have to spray them with insecticide. But we want to be able to get the sugars out easier. What we're trying to do is to build on what the plant has already given us, which is this fantastic ability to grow for 15-20 years without replanting, but to make it so that we can get the sugars out easier.

Immediate challenge in the lab

We're trying to really understand how the cell wall is put together so we can take it apart better, really, and so we're doing fundamental experiments trying to figure out what genes are important for cell wall biosynthesis and modification. The way cell walls are put together, there are a lot of complex molecules that are intertwined and there are other molecules on top of that. If you can figure out a way to break up some of these molecules or if you can figure out a way to enrich for sugars that are easier to make fuel from, then you immediately increase your efficiency. It's a balance because the cell walls are there for a purpose; they're there to protect from pathogens and environmental stresses. In other words, we're trying to figure out ways that we can modify the plants so we can get to the sugars easier without compromising the integrity of the plant in diverse environmental conditions.

Her career inspiration

Rice feeds half the world's people. Early on I wanted to work in an area that was interesting from a molecular, genetic, scientific point of view, where you could make fundamental discoveries, but also where you could have a large impact on the lives of poor farmers and their families.

Biggest misconceptions about genetic engineering

I think that something people don't know is that genetic engineering is simply a process of developing seed and that the process is benign. The more important question is—what does the seed do? Can it enhance a sustainable agriculture system? Those are important questions for any kind of seed, whether it's genetically engineered or not. I always encourage people to take a step back and ask those bigger questions about how we're going to conserve our land, use less water, use less insecticides, feed the growing population, benefit small farmers. If a particular genetically engineered crop fits into sustainable agriculture, then we should use it. Each new variety must be looked at on a case-by-case basis.

Native grasses in the garden

I like grasses. I've worked on rice for a long time, so I've always been very interested in grasses. I actually planted the Miscanthus in my yard before I started working on bioenergy.

Laundry in the backyard, too

We definitely, as a family, have been very concerned about energy consumption. That's why we hang out clothes to dry. We don't even have a dryer. We cut down our energy bill 75 percent one year by getting rid of our dryer and making a few other changes.

Best unexpected gift

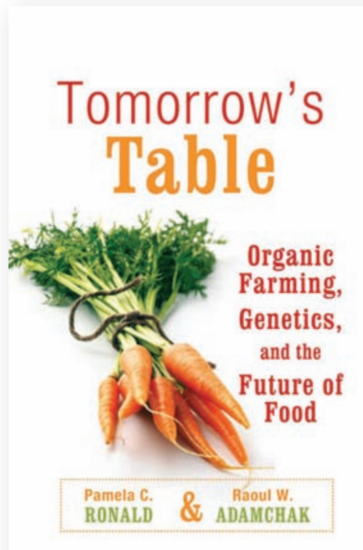
My lab isolated a gene conferring tolerance to flooding, which is a major problem in flood-prone areas of the world where much of the world's rice is grown. My collaborator at IRRI (International Rice Research Institute) introduced the gene into varieties favored by farmers in Bangladesh and India. The variety has been quite a success (farmers are seeing three-to five-fold increases every year). After reading about our work, a woman in India sent me this beautiful batik of women planting rice in the field. That really touched me.

Sparking a life's work

My mother was an avid gardener and her parents were avid gardeners, so that certainly had an influence on me. I was always into growing food. And then I spent a lot of time in the wilderness. Even at a very young age, like 12, we'd go off and go backpacking. Very early on, I got interested in identifying all the plants in the Sierra Nevada wilderness. I remember meeting a botanist. We'd been hiking. We were high on a mountain pass, deep in the wilderness and we ran into a man and a woman sitting in the sun identifying plants. They were with a university or working for the state, probably. And I thought, "Oh, that's what I want to do. That's a good job."

Meeting her husband

His farm was on a river and we have a mutual friend whom he was going to teach how to paddle a kayak. So, I went along. I went botanizing while they went boating.



Dinner table conversation

A lot of people have asked us that. That's why we wrote this book, "Tomorrow's Table." We're really plant people. I had worked on a couple of organic farms when I was younger and he had studied science so we definitely have overlapping interests. We just like plants and we like food and we like science.

Most enjoyable part of teaching and research

Talking to students and post-docs about their most exciting results. That's always the thrill. That's what drives us. It's really exciting to make a discovery on the forefront of knowledge, something no one knew or no one had thought about before. You have to be very flexible and open as a scientist because there are new ideas coming in; sometimes old ideas have to go out. The more research we develop the more solid the framework becomes about a particular model for a particular cellular process or biological structure.

Least fun part

Being too busy. When the research is so exciting, it is hard to find time to take a break.

First car

My first car was a diesel hatchback. What was the name? I can't even remember any more. I'm not into cars, obviously. But I remember it got pretty good mileage. I was tuned in pretty early on. ■

Next Gen: A Native Son Commits TO BRAZIL'S FUTURE

By Rick Malaspina

PHOTOGRAPHY: Peg Skorpinski

He could have been a cowboy, a *vaqueiro*, working cattle on the arid plains of his native Brazil. Or a beekeeper. Or a farmer, or maybe a surfer dude.

Instead, Amancio Jose de Souza embraced his family's strongly held conviction that one must contribute to society and bring others along with you. He chose to dedicate himself to agronomic engineering and today studies the structure and metabolism of plant cell walls, seeking to provide the knowledge that someday will enable the genetic engineering of plants tailored for biofuel production.

"If you compare me to the average grad student, I'm a little older because I took a different route to get here," says Souza, tall and boyish-looking at 32.

His path may have been unusual, but for Souza, born and raised in Brazil's northeastern coastal city of Salvador, it enabled him to collect a wealth of real-life and scientific experience that he sees as valuable to his work and reflective of the outcome he hopes for his research and his own future.

"I really believe that the future of agriculture and agronomy lies in the ability to engineer better plants," Souza says. "The challenges of population growth, the need to be more efficient in our use of resources, the ability to control pests and disease – I think we'll find answers to all this through the use of genetically modified crops. We're at the very beginning of this era."

Souza, who earned his master's degree in agronomy from the University of São Paulo, joined the Energy Biosciences Institute in Berkeley in December 2009 as a graduate student pursuing his Ph.D. Within weeks, he and his wife, Tais, were celebrating the birth of their first child, a boy named Gonçalo. Previously, Souza had been a visiting scholar at Michigan State University, working with Markus Pauly, now an EBI principal investigator and UC Berkeley associate professor of plant and microbial biology.

"Amancio firmly believes that he will make a difference in moving his country into the next generation of biofuels," Pauly says. "Such conviction is quite impressive and deserves the best education possible."

At his research bench in the open, circular setting of UC Berkeley's historic Calvin Laboratory, Souza reflects on that "different route" of his and what may come next.

Bilingual owing to his education at an English-speaking grammar school in urban Salvador, he treasured the time spent on his family's cattle ranch 600 miles inland. He herded cattle and "played cowboy," he says, calling horseback riding "one of my favorite things."

"Since I was a kid I've been attracted to the land, animals, and nature. My grandfather planted all kinds of fruit trees—coconut, mango, tamarind, cashew, jackfruit, papaya. My best memories as a kid are being around trees and having a different fruit every month."

Surfing is another pleasant memory. Souza did lots of it, and it led to another passion, beekeeping. A surfing buddy's father kept bees, as did a family friend. As a teenager Souza learned from them and later started the first large-scale beekeeping business in the rural area surrounding his family's ranch.

"It's a region of hardship and poverty," Souza explains. "I showed people how to keep bees, trained them. Now beekeeping is in greater use there. People are selling honey and wax; it's seen as an area of economic growth."

He also had a role in economic growth as an agribusiness technician for the Brazilian government, a position he received after completing his bachelor's degree, and as a forage management consultant. Traveling the countryside on horseback, he advised farmers and ranchers on strategies to increase productivity and economic competitiveness.

"At the time," Souza says, "I wasn't thinking about biofuels, but all of these things, like growing grasses and working with cows, are related to what people are doing today in biofuel research and production."

Looking ahead, Souza says he wants to contribute through biotechnology to Brazil's economy and his country's position in the global economy—and he has his sights on a way to reach that goal: "I hope to be part of a research institution dealing with the production of liquid fuels from plants. Something like EBI is today, but back home." ■

EMILY HEATON

Big Grasses BIGGER GOAL

"Save the world," Emily Heaton says. "That's my goal."

Coming from Heaton—believed to be the first graduate student in the United States to research the use of Miscanthus as a perennial biofuel feedstock and now an assistant professor and biofuels agronomist at Iowa State University—her personal quest seems emminently attainable.

"What I do, in a nutshell, is try to save the world with giant grass," Heaton says, calling Miscanthus "the best thing since sliced bread." Likening her work to that of a soybean agronomist in the 1930s, Heaton explains she is preparing Iowa farmers "for what's coming" by "figuring out what crops to grow and how they work together – and how that crop mix impacts fuel availability, quality and supply."

"I have no reason to think we can't do this," she says. "We just have to make people want to do it." Heaton, 32, grew up on her family's farm in Monticello, IL, and remains actively involved with it.

While pursuing her doctorate in crop sciences at the University of Illinois at Urbana-Champaign, Heaton's research indicated Miscanthus grown in the U.S. could produce 250 percent more ethanol than corn, without requiring additional land. After earning her doctorate, Heaton worked as an agronomist at Ceres, Inc., a California agricultural biotechnology company where she led the development of the largest dedicated biofuels variety evaluation network in the country. She joined the faculty of Iowa State's biomass engineering program in 2008.

"I'm not the only woman in the room anymore," Heaton says. "A lot more women are either land owners or representing land owners, or in grad school. Women are advancing in this field and it's working just fine."

There's an especially personal aspect to Heaton's world-changing quest: She and husband, Andy, welcomed their first child in December. "I want to make the world better for him," Heaton says. "If we don't clean up our air and CO_2 concentrations, that can't happen." ■

BIOENERGY CAREERS

Why being flexible and dedicated matter

By Abby Cohn

Algae is fueling new bioenergy careers at a rate of one hire a week at Solazyme, a biotechnology company in South San Francisco with no shortage of applicants.

"What we're working on here is truly world-changing stuff and that's inspiring to people," says Harrison Dillon, president, co-founder, and chief technology officer of Solazyme. "You have no idea how many emails we get with resumes attached."

Launched in 2003 in Dillon's garage, his company now has more than 100 employees deploying algae to make a variety of clean fuels and bioproducts.

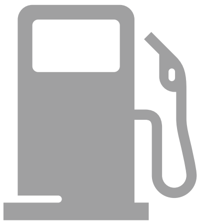
Like Solazyme, the advanced biofuels industry is young. Many current jobs are in research and development. But as start-ups mature and commercialize their technologies, the industry will bring on workers for a full range of production needs. That diverse workforce will range from farmers to molecular and cell biologists, and chemists to mechanical engineers. Refinery operators, construction workers, logistics specialists, and marketing personnel will all be needed in the new field, according to U.S. Department of Labor projections.

The Biotechnology Industry Organization (BIO) in Washington, D.C., has tallied some 70 biorefinery projects that are either operating or planned in 30 states. To scale up, "We have to build hundreds of these plants across the country," says Brent Erickson, executive vice president of BIO's Industrial and Environmental Section.

For now, the career path is lined with both opportunity and risk; some start-ups will succeed and others won't. But with industry executives and advocates believing that it's a matter of when—not if—advanced biofuels become a mainstream source of transportation energy, job growth in the field is seemingly a sure bet.

"We're looking at an industry in its infancy that has a potential to be paradigm shifting in the transportation market in the next 20 years," says Michael McAdams, president of the Advanced Biofuels Association, a Washington, D.C., advocacy group representing 33 bioenergy companies.

In the U.S., a prime driver of job growth, say those closely watching, will be the ability of the industry to meet the nation's goals for advanced biofuels set forth by the Renewable Fuel Standard.



The national mandate calls for production of 21 billion gallons of advanced, cellulosic, and biomass-based diesel fuel by 2022. Based on that goal, a 2009 report by Bio Economic Research Associates estimated those standards could generate 29,000 direct jobs by 2012 and 807,000 jobs overall by 2022. Industry officials say the biggest hurdle facing growth in the field is private investment and the federal loan guarantees and tax policies to ignite it. "Private sector investment has dried up in the last year and a half," says Erickson, who, along with other advocates, has lobbied the Obama administration for increased government backing.

The growing pains don't appear to be discouraging young people. In December 2010, the first handful of students graduated from the University of Illinois at Urbana-Champaign with a newly created master's degree in bioenergy. For Derek Latil, a 24-year-old master's student from Spain, the gamble of pursuing a new venture makes it all the more enticing. "I'm still young," he says. "I'd like to be developing something that is new and starting from the beginning."

At Amyris, Inc., a leader in the use of synthetic biology to replace petroleum-based chemicals and transportation fuels with renewable fuels, staffing director Salvador Rivera offers this advice to job seekers: "In a startup environment, being a Swiss Army knife is a strong asset. We look for people who have tremendous amounts of flexibility and versatility."

Amyris recently went public and hopes to commercialize soon. Now employing 220 people in its Emeryville, CA, headquarters and 80 at a sugarcane plant in Brazil, the company expects to nearly double those numbers by the end of 2011.

Not surprisingly, Rivera foresees plenty of interest for those spots. "I think everyone is clearly aware of the damage we've done to the globe," he says. "There's a lot of purpose in what we're doing."

That sense of purpose is what brought Harvinder Chagger to Solazyme. Eager to heal an ailing planet and lured by the thrill of scientific discovery, she tested the waters as a bioengineering student intern and then, in 2007, became one of its early employees. "I wanted to do something that would make a difference," she says. ■

The President Backs Biofuels Job Creation

Rural America seen as major beneficiary

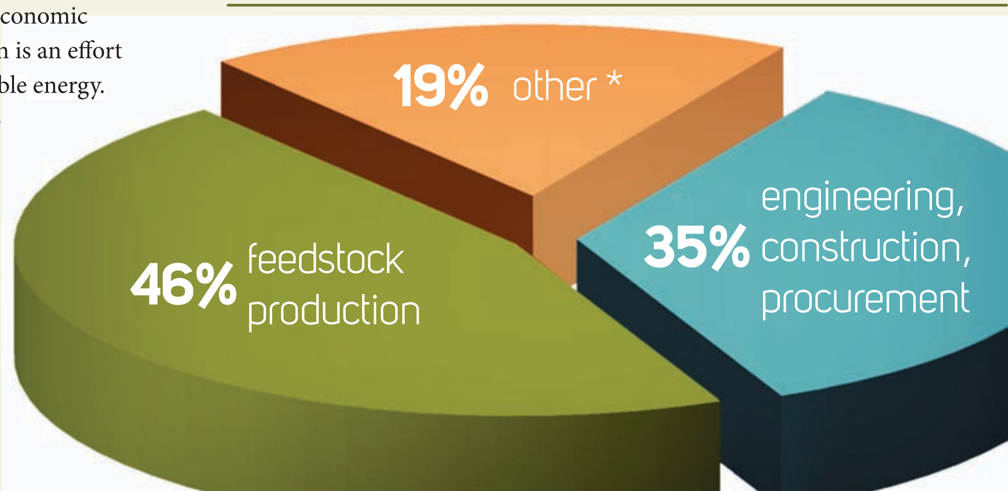
President Obama's 2011 State of the Union address underscored his administration's commitment to advanced biofuels to create both renewable energy and new jobs on the domestic front.

What jobs will be created and where will they be?
High-value jobs in science and engineering are vital on the research and development front. But on the day of the speech, Secretary of Agriculture Tom Vilsack also made it clear on his own blog posting that rural America will play a key role in renewable energy's job growth.

"Over the past two years, the Obama administration and USDA have worked to build a foundation for sustainable economic growth in rural America. At the center of our vision is an effort to increase domestic production and use of renewable energy. Someone has to build these plants. Someone has to produce the parts for these plants. Someone has to maintain these plants. Someone has to run these plants. Someone has to transport the fuel. That can all happen in rural communities," he wrote.

Someone also has to grow the plants that will produce the feedstock to make the energy. In its study of the economic impact of advanced biofuels production in the U.S., Bio Economic Research Associates estimated that of the 190,000 direct jobs created by 2022, "46 percent are in the feedstock production (primarily agriculture) and 35 percent are in construction, engineering, and procurement." Further, as it projected growth in advanced biofuels production to 45 billion gallons by 2030, it estimated nearly 70 percent of new, permanent jobs would be in feedstock supply.

Job Creation by 2022



Source: Bio Economic Research Associates 2009 report
* includes transportation, distribution, and R&D

...to Fuel

CONSPICUOUS CONSUMPTION

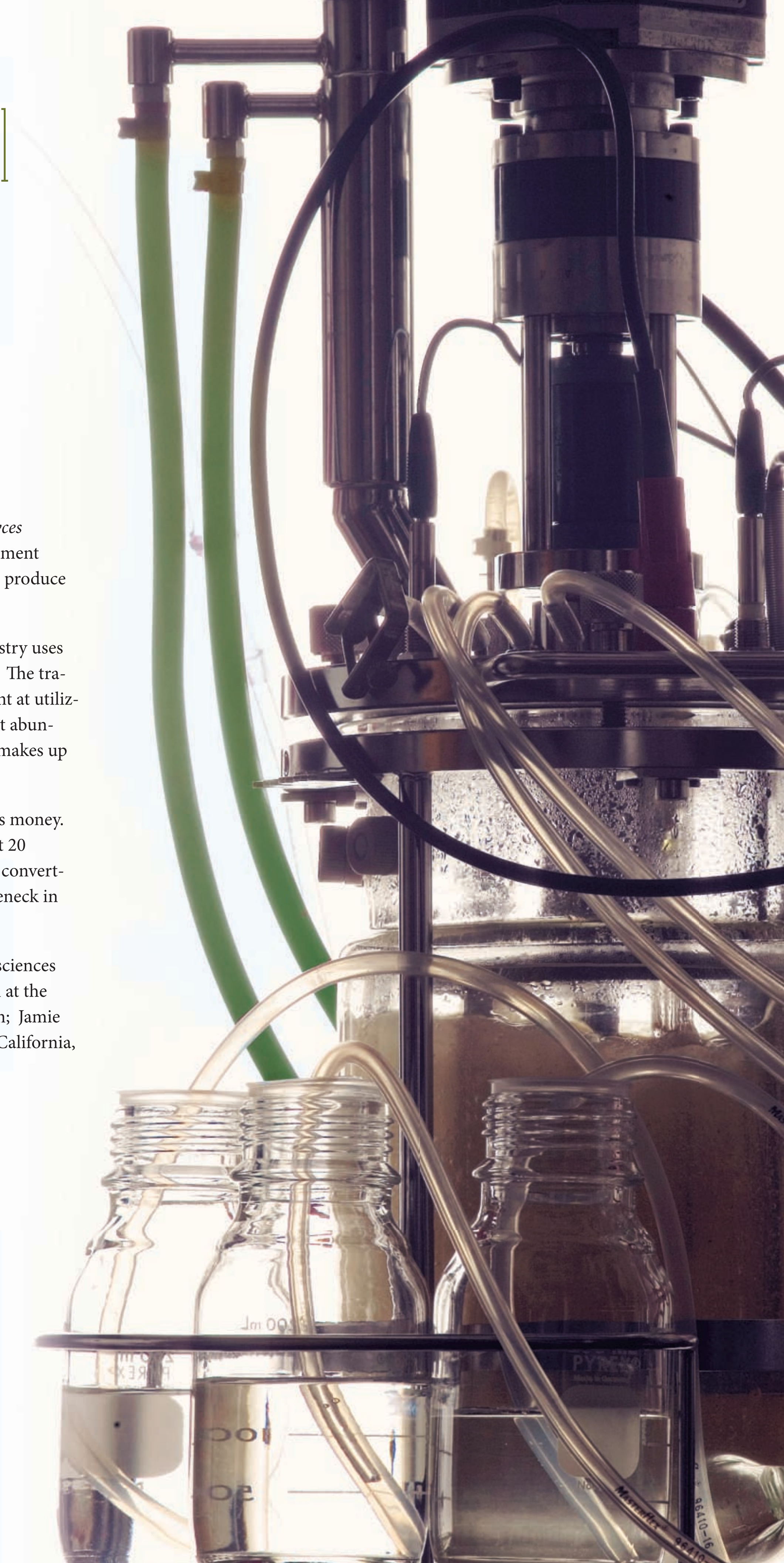
New Yeast Strain a Breakthrough in Biofuel Production

What is it? A new strain of *Saccharomyces cerevisiae*, yeast that can simultaneously ferment two kinds of sugars (glucose and xylose) to produce biofuels.

How does it work? The biofuel industry uses yeast to convert plant sugars to bioethanol. The traditional strain of *S. cerevisiae* is very efficient at utilizing glucose, but not xylose, the second most abundant sugar forming the lignocellulose that makes up plant stems and leaves.

Why does it matter? Because time is money. The newly engineered yeast strain is at least 20 percent more efficient than other strains at converting xylose to ethanol, removing a key bottleneck in ethanol production.

Who is working on it? Energy Biosciences Institute research teams led by Yong-Su Jin at the University of Illinois at Urbana-Champaign; Jamie Cate and Louise Glass at the University of California, Berkeley; and BP scientist Xiaomin Yang.



The late afternoon sun shines over the mixed prairie research plots at the Energy Farm at the University of Illinois at Urbana-Champaign.

PHOTOGRAPHY: Don Hamerman

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SUSTAIN ABILITY

WHAT IT IS AND WHY IT MATTERS TO BIOENERGY'S FUTURE

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Source: The 1987 Brundtland Commission Report (issued under the auspices of the World Commission on Environment and Development, convened by the United Nations in 1983).

This widely cited statement was one of the first formal attempts to define sustainable development. Now, as governments world-wide attempt to set standards, develop regulations, and offer incentives for the development and use of bioenergy, a host of interests—policymakers and scientists, farmers and refiners, environmentalists and others—are working to define sustainability in the specific context of bioenergy. Among the key components under discussion are air, water, and soil quality; greenhouse gas emissions; biodiversity; land conversion; and socio-economic considerations, including the support of rural development.

MUCH AT STAKE

There is little doubt that a growing world population will heighten debate over how to meet human needs while protecting fragile ecosystems and improving those already degraded. Crops grown to be processed into fuel, often called biomass, have great possibility to provide high-yielding energy feedstocks with fewer inputs such as water and fertilizer, and smaller greenhouse gas footprints, while at the same time improving water quality and wildlife habitat.

Many are hopeful that acceleration of biomass-based energy incentives may spur a new sustainability model in agricultural and forest landscapes as governments reconsider land use policies to better balance humankind's social and economic needs with those of natural systems.

How policymakers refine the definition of "sustainability," therefore, will be a critical question moving forward in the development of the biomass sector.

BACKGROUND

In the U.S.

As Americans reeled from the Middle-Eastern oil embargos of the 1970s, Congress passed the nation's first biofuels legislation. The Energy Security Act of 1980 was the first to recognize the role of "gasohol" in achieving energy independence on a "renewable" and "sustainable" basis.

The dual goals of energy independence and rural development formed the initial U.S. definition of "renewable" fuels. Elsewhere, greenhouse gas (GHG) reduction emerged as an additional element of biomass "sustainability" in the 1990s and 2000s, as agreed to in the Kyoto Protocol. But it was not until the 2007 Energy Independence and Security Act (EISA) that U.S. policy introduced a requirement that biofuels achieve GHG reductions when compared with fossil fuels.

Today, as policy makers in Washington attempt to fill remaining voids in federal GHG policy, states such as California continue to pursue aggressive bioenergy policies introduced in the early 2000s, primarily to reduce GHG emissions, and including transportation fuels.

"As emphasized by Congress in requiring triennial biofuel impact assessments, it is important to evaluate the environmental implications associated with the ongoing growth of the dynamic biofuel industry."

—Biofuels and the Environment: The First Triennial Report to Congress (Jan. 2011)

KEY ISSUES

Environmental sustainability

While biofuels may be an effective GHG reduction tool, fears have surfaced that increased demand for biomass driven by GHG policies could, without sufficient safeguards, encourage overharvest of forests and conversion of ecologically-sensitive lands.

In addition, careless practices can threaten biodiversity and diminish water and soil quality.

Invasiveness controversy also looms on the horizon, as litigation challenging the release of genetically engineered food and feed crops without sufficient environmental review threatens to spill over to crops being developed specifically as a raw material for bioenergy.

Socio-economic sustainability

This has grown in recent years parallel with development of bioenergy policies. Concerns abound. The "food versus fuel" moniker that emerged from the price spikes of 2008 almost certainly will linger to the extent biomass appears to compete with food crops for land.

There are fears that land "grabs" in developing and underdeveloped countries may harm indigenous peoples or subsistence farmers without formal delineation of property rights.

In the U.S. the shuttering of Midwestern ethanol plants in the late 2000s dealt blows to rural economic development initiatives, while adding to critics' claims that rural prosperity should not depend heavily on chemical inputs that degrade soil and water quality. And, there are concerns that if large expanses of land are devoted to growing one crop for biomass production, it could hurt vital habitat dynamics.

FIVE QUESTIONS

1 What is the difference between renewable and sustainable?

The words "renewable" and "sustainable" are often used interchangeably with biofuels. Originally, renewable referred merely to the growing of crops used for energy. It has evolved to also include the practices used in growing, cutting, and transporting the crops—the entire production chain. In policymaking, renewable is the more typically used word, as in "Renewable Fuel Standard," while in law, sustainability typically refers to practices.

2 What are the current greenhouse gas rules for biofuels in the U.S.?

Policymakers continue to grapple with development, application, and coordination of greenhouse gas emission accounting methodologies for biomass-based feedstocks. The U.S. Environmental Protection Agency is supposed to calculate GHG emissions from indirect land use change in order for fuels to qualify under the Renewable Fuel Standard (RFS). Economic modelers, however, have further work to do in refining assumptions and parameters, and fortifying information, for various fuel pathways. Challenges to EPA's methodologies were recently filed in federal court by Friends of the Earth.

3 Is bioenergy considered carbon neutral?

Other than the Renewable Fuel Standard the federal Clean Air Act does not address GHGs specifically, let alone the intricacies of methodologies for measuring life cycle emissions from biomass combustion. Thus, whether biomass is "carbon neutral" remains the subject of considerable debate. The EPA has signaled recently that for stationary sources that use biomass as a feedstock, although it "plans to provide further guidance on how to consider the unique GHG attributes of biomass as fuel," permitting authorities may balance the environmental, energy and economic benefits of biomass combustion, including goals of state bioenergy mandates. Lastly, while the U.S. Department of Agriculture (USDA) has tied at least some Biomass Crop Assistance Program (BCAP) payments to GHG reduction, no formal calculation methodology currently exists within BCAP rules.

Meanwhile, the European Union in December delayed a decision on how it will account for indirect land use in lifecycle emission calculations for GHGs under its Renewable Energy Directive (RED).

4 What about other environmental issues?

Bioenergy laws and several voluntary standard initiatives are designing ways to address the "other" environmental and socio-economic aspects of increased biomass production. The Triennial Report on the sustainability of the RFS, which EPA only recently issued, identifies many of the sustainability concerns associated with biofuels, including water, soil and air quality, and biodiversity. The USDA currently is in the process of developing conservation planning for federally subsidized biomass crops, but concedes that biomass-specific practices remain underdeveloped. USDA conducts some levels of environmental assessment of U.S. agriculture under other laws, and has required conservation planning at least on highly erodible lands for over 25 years. The effectiveness of these programs, however, has been subject to growing scrutiny.

5 How is the issue of displacing food crops being addressed?

Policymakers must continue to hone mechanisms to measure and mitigate any negative effects crops grown for energy may have on food prices. EPA has the authority to adjust federal renewable fuel mandates if food prices are affected. Environmental groups have mounted legal challenges, however, to EPA's methodologies in measuring land conversion. The European Union's RED requires the commission to periodically report on food price impacts, encourages member states to develop policies that incentivize non-food and waste feedstocks, and provides a GHG "bonus" for crops grown on "degraded" land. The U.S. does not currently have a comprehensive policy in place to incentivize biomass production on lands that are idle, marginal, degraded, or abandoned.

LOOKING AHEAD, WHAT TO WATCH

> Whether government-sponsored or private in nature, any sustainability standard for energy biomass relies critically upon supporting scientific research which, at the moment, is in its embryonic stages. Measuring the costs, benefits, and barriers to achieving and enforcing different levels of sustainability will be critical to the nascent sector.

> The Food and Agriculture Organization of the United Nations last year devised an analytical framework in which to consider food security questions within the context of bioenergy production, and is in the process of developing assessment criteria and indicators that may be helpful.

> How biofuels policies define "degraded," "marginal," "abandoned," and "idle" land will be pivotal to the food versus fuel question as well as protection of biodiversity and other environmental values.

> In the U.S., the Council for Sustainable Biomass Production is field-testing a provisional standard that contains principles governing air, water and soil quality, GHG emissions, biodiversity, land conversion, and socio-economic considerations such as respect for labor laws. Similar voluntary standards for energy biomass are in development in Europe and Brazil, and at the international level.

> Both California and the European Union are pursuing sustainability standards to accompany their greenhouse gas reduction programs.

RESOURCES:

United States

EPA's Renewable Fuel Standard: **http://www.epa.gov/otaq/fuels/renewablefuels/index.htm**

Biofuels and the Environment: First Triennial Report to Congress (External Review Draft) **http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=217443**

California's Climate Change Portal: **http://www.climatechange.ca.gov/**

The European Union

Commission Directorate General, Renewable Energy/Biofuels: **http://ec.europa.eu/energy/renewables/biofuels/biofuels_en.htm**

International

Global Bioenergy Partnership (GBEP) Task Force on Sustainability: **http://www.globalbioenergy.org/programmeofwork/sustainability/en/**

Roundtable on Sustainable Biofuels (RSB): **http://rsb.epfl.ch/**

Food and Agriculture Organization (FAO) Bioenergy and Food Security Project: **http://www.fao.org/bioenergy/foodsecurity/befs/en/**

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The Briefing is a special section of Bioenergy Connection magazine, a publication of the Energy Biosciences Institute.

We welcome your comments, questions, and ideas. Contact us at **Bioenergyconnection@berkeley.edu**