of the 30-plus IPMU scientists on site at the Kashiwa campus of the University of Tokyo are non-Japanese, coming in equal shares from the US, Europe, and other Asian countries.

The other WPI institutes are the Immunology Frontier Research Center at Osaka University, the Advanced Institute for Materials Research at Tohoku University, and the Institute for Integrated Cell–Material Sciences at Kyoto University. All five have different formats, and interactions with their host institutions vary. The common features, which were in part set by MEXT, include using the MEXT funding for salaries and start-up funds, aiming for a total of about 200 people per institute, setting a minimum number of non-Japanese members, and raising additional funds from other sources. Host institutions are expected to provide buildings and other resources. IPMU, for example, is getting a new building and two positions from the University of Tokyo. The MEXT money may be extended to a total of 15 years.

Bending the system

The goal of 200 people came from observing institutions around the world that were inspirations for the WPI. "We wanted our research institutions to be visible, like Stanford's Bio-X," says Okaya. Other models include MIT's Media Lab, the Robotics Institute at Carnegie Mellon University, British biochemistry institutions, and Germany's Max Planck institutes. "We see those as topnotch centers of excellence," Okaya says. "Our hidden agenda is a system renovation of the universities in Japan," he adds. "Things that happen at the WPI will have a ripple effect."

English is the lingua franca at the WPI institutes. And, to attract people to them, the seniority-based pay scale typical in Japanese universities has been turned on its head. For example, says Okaya, the director of IPMU earns more than the president of the University of Tokyo. More broadly, salaries at the institute are higher than professors typically earn in Japan, says Murayama. "We pay better to compensate for people [from Japanese universities] losing their pension plans" and to attract foreign scientists.

"To my pleasant surprise, people in their thirties gave up tenured jobs" to come to IPMU, says Murayama. "Because this place cannot offer tenure, the hardest generation to get is in the forties and fifties. Thirties is easier—they are ambitious, they think this is a place they can concentrate on research for 10 years and then go wherever they want. The forties and fifties think ahead, and might be worried about finding another good job. In the late fifties it's easier, because in 10 years they will retire anyway."

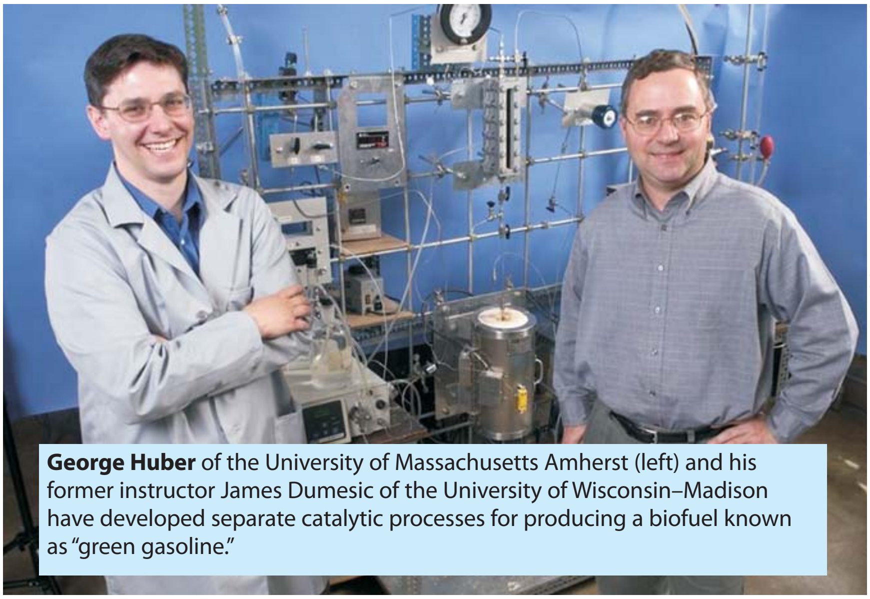
Mark Vagins is in his early forties, but he jumped at the offer to move to IPMU. He'd been shuttling back and forth between the Super-Kamiokande neutrino detector in Japan and a soft-money position at UC Irvine for years. "I have long believed that discoveries tend to get made where fields collide. It's very unusual to have pure math people interact with people who build experiments," says Vagins, who hopes to increase Super-Kamiokande's sensitivity by adding gadolinium salt to the water to make neutrons visible in a project called GADZOOKS! (gadolinium antineutrino detector zealously outperforming old kamiokande, super!). "My guess," he adds, "is if we achieve the success we are expected to, we'll be funded. It's our mission to make it so they can't pull the plug on us in 15 years."

Toni Feder

Could 'green gasoline' displace ethanol as the biofuel of choice?

Researchers report advances in making renewable fuels that are compatible with the US petroleum infrastructure.

Mention the word biofuels and ethanol, or perhaps biodiesel, immediately comes to mind. But gasoline? Isn't that what biofuels are supposed to replace? The fact is that while ethanol has been grabbing all of the attention and the lion's share of federal R&D funding, a small but growing cadre of researchers is betting on a different sort of biofuel, one that would circumvent most of ethanol's drawbacks. Their "green gasoline" can be made from the same renewable biomass as ethanol, and it is virtually indistinguishable from petroleum-based gasoline.


UNIVERSITY OF WISCONSIN–MADISON

George Huber of the University of Massachusetts Amherst (left) and his former instructor James Dumesic of the University of Wisconsin–Madison have developed separate catalytic processes for producing a biofuel known as "green gasoline."

As the price of gasoline fluctuates wildly from very expensive to just expensive, and as the US strives, however improbably, to achieve energy independence, the federal funding spigots have flowed for research into expanding the nation's output of renewable fuels. The US Department of Energy alone has pledged more than $1 billion over the past two years for R&D and for subsidies to commercial-scale demonstrations of technologies that will turn non-food biomass such as crop wastes, wood chips, grasses, and municipal solid waste into biofuels. The Department of Agriculture (USDA) has shelled out another $600 million since 2006 for biomass research. Congress has mandated steep annual increases in domestic consumption of renewable fuels, topping out at 32 billion gallons in 2022. President Bush's "20 in 10" plan unveiled last year established a goal of replacing with biofuels and other alternative fuels 20% of projected US demand for gasoline in 2017.

But the vast majority of R&D and private sector investment for biofuels has been directed at ethanol and, to a lesser extent, biodiesel. Nearly all US ethanol production today is from corn; the goal of the federal effort is to tap the vast amount of energy that is stored in non-food biomass. The key to turning crop wastes, wood chips, grasses, and other plants into so-called cellulosic ethanol rests in finding cost-effective ways to break down the plant matter into simpler sugar and starch molecules for fermentation. DOE estimates that the 30- to 50-cents-per-gallon cost of enzymes needed to degrade the biomass must be lowered to just pennies per gallon to make the use of non-food sources competitive. The agency has set a 2012 target date for achieving that goal. Alternate approaches to breaking down biomass are also being pursued, including gasification of feedstocks and engineering of microbes.

But in just the last couple of years, a $12 million research program led by NSF has been reporting big strides in what John Regalbuto, director of that agency's catalysis and biocatalysis program, describes as "a new paradigm"— an approach that transforms biomass into fuels that are nearly identical to gasoline and other petroleum-based fuels. "When I arrived at NSF two years ago, there was a national action plan for biofuels that read 'ethanol only,' " he says. By October of this year, Regalbuto's program had gained recognition from Secretary of Energy Samuel Bodman, who has led the Bush administration's charge on ethanol. "We must accelerate the development and deployment of next-generation biofuels, fuels made from cellulose, algae, and from other non-food products, as well as fuels compatible with our existing energy infrastructure, including renewable diesel, green gasoline and bio-butanol," Bodman said during the 8 October unveiling of an interagency plan for accelerating biofuels development.

Compatible with oil products

A major advantage of green gasoline is its compatibility with the nation's existing energy infrastructure. Whereas hydrocarbons separate from water, ethanol's solubility in water means that it isn't suited to shipment through the country's network of pipelines that carry gasoline across the country. Ethanol is transported mainly by railcar from biorefineries in the Midwest to terminals located near where it will be consumed, for blending into gasoline. In many cases, particularly in the Northeast, blending operations take place in railyards adjacent to residential neighborhoods, an obvious safety concern.

Green gasoline is inherently a superior fuel to ethanol, with an energy content that matches that of the petroleum product. Pure ethanol holds only two-thirds of the chemical energy stored in an equal volume of gasoline. Moreover, the green fuel is compatible with any gasoline-powered car or truck, compared with only about 7 million, or less than 3%, of the vehicles on US roads that are flexible-fuel and capable of operating on the 85% ethanol, 15% gasoline (E-85) blend that is sold at a handful of pumps at service stations in the Corn Belt. Green gasoline should require less energy and water to produce than ethanol, given that the energy-intensive distillation process isn't involved.

In view of all the subsidies and mandates for renewable fuels, it's ironic that the US market for ethanol is limited. Apart from the flex-fuel vehicles they've built, automakers have certified the gasoline-powered vehicles they manufacture to operate on fuel blends containing a maximum of 10% ethanol (E-10). A "National Biofuels Action Plan" issued by the interagency Biomass Research and Development Board warns that unless fuel blends with 15% or more ethanol can be approved for sale, US output of ethanol made from corn will outstrip demand in the next few years. DOE and the Environmental Protection Agency are now sponsoring research to determine whether higher ethanol fuel blends can be used without worsening emissions or harming engines and fuel-system components.

New processes explored

As with ethanol, the biomass used for green gasoline must be broken down into simpler constituents for it to be usable. James Dumesic, a chemical engineering professor at the University of Wisconsin–Madison, has been trying out a variety of degraded biomass streams supplied by Bruce Dale, a chemical engineering professor at Michigan State University, to determine which are good candidates for green gasoline. Both men are being supported by the UW-led Great Lakes Bioenergy Research Center, one of three centers set up last year by DOE's Office of Science with nearly $400 million pledged over five years in support of the basic science that it's hoped will crack the cellulosic puzzle.

Dumesic says there may be synergies between the catalytic route to green gasoline and fermentation to ethanol. For example, five-carbon sugars, which are not readily fermentable into ethanol, can be processed with catalysts into green gasoline. And catalytic processes don't necessarily require that the biomass be broken down as far as is necessary to make fermentation work. Still, Dumesic says he can't predict whether green gasoline, though clearly the better fuel, will attain economic viability before cellulosic ethanol. Green-gasoline research is less mature, he cautions, and it's possible that some impurity in a feedstock stream could cause a problem with the catalysts.

One of Dumesic's former students, George Huber, announced in April a green gasoline process that apparently has solved the pretreatment problem. Huber's single-stage catalytic reactor can transform any sort of ground-up biomass into an oil that contains the aromatic components of gasoline, he says, and all within minutes. Those compounds could then be refined further to make gasoline. Now at the University of Massachusetts Amherst, Huber says the bench-scale reactor employs zeolites, the same class of silica and aluminum catalysts that are used in detergents and oil refining. Huber hopes to have a pilot facility running within a year, producing two tons of the oil per day. He anticipates that the technology could become fully commercial in 5 to 10 years.

Dumesic and his former postdoc Randy Cortright are the co-developers of a two-step catalytic process that refines green gasoline and other hydrocarbon biofuels, such as diesel and jet fuel, from a slurry of biomass-derived sugars. Cortright left the university to become chief technology officer of Virent Energy Systems Inc, a Madison startup company that received two commercialization grants from NSF's Small Business Innovation Research program. Virent has partnered with Royal Dutch Shell to make "biogasoline" from sugar cane. A description of the process (http://www.virent.com/BioForming/Virent_Technology_Whitepaper.pdf) co-authored by Cortright estimates that the process is competitive when the price of oil goes above $60 a barrel.

David Kramer