FUTURE BUSINESS: Biofuels

In search of the BETTER OIL

The great promise of biofuels is hampered by harvesting logistics and high production costs – so an innovative solution is required. Bette Flagler investigates biofuels R&D and investment in New Zealand, and its potential to make a global impact.

Everyone's doing it. The whole world is trying to find alternatives to the fossil fuels on which we have become so dependent. It's become, it seems, an economical as well as environmental imperative.

And aren't we clever, growing crops to power our cars? But consider this: At the turn of the century – the 19th to the 20th century, that is – the first engines that carried Rudolf Diesel's name were designed to be powered by peanut oil. A few years later, in 1925, Henry Ford told the New York Times that the fuel of the future was ethanol. "There is fuel in every bit of vegetable matter that can be fermented," he said. "There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years."

So the idea of fueling our cars with vegetation has been around a long time, and plenty of countries are already growing corn, soybeans and sugar cane to run their fleets. But the solution to the global oil dependency is not quite as simple as it sounds: The production of biofuels, like the extraction of fossil fuels from the earth, brings with it a range of cost and environmental implications of its own. Utilising conventional crops for energy takes a certain toll on land resources, and in many cases the cost of harvest and production outstrips that of petroleum fuel.

Finding a suitable balance of these factors – turning the biofuels concept into a real replacement for dwindling petroleum oil supplies – requires an innovative solution. Or, rather, several innovative solutions. Because of differences in economies and climates, what works in one country or region may not be feasible in another. In New Zealand, there are several organisations busily researching biofuel technologies, with a view both to meeting domestic demand for transport fuels and to opening doors to economical biofuel production in other markets around the world. The exciting part: A few of them are showing pretty good potential.

Baa-baa, black gold

Like in most other countries, research in New Zealand is focusing on two types of biofuels for transport: biodiesel, to blend with diesel, and bio-ethanol to blend with petrol.

Biodiesel is produced by converting vegetable oils or animal fats into esters which behave very much like "normal" diesel. Vegetable oil can be squeezed from plants grown specifically for the purpose — soy bean oil is used widely in the United States, for example – or from cooking waste. But New Zealand has never been a big producer of oily crops, and though it's hard to imagine given all our fish & chips shops, New Zealand produces very little used vegetable cooking oil – only about 5000 tonnes a year (small-fry in the biofuels production scheme of things).

Luckily, our propensity for growing livestock leaves us with a fair supply of animal-based

Algae, some say, has potential as an extremely high-yield, low-cost feedstock for biofuels.

tallow. Each year, we produce about 150,000 tonnes of the stuff; 30,000 tonnes are already used domestically and the remaining 120,000 tonnes are currently sold offshore as a commodity, mostly to Asian soap makers. But if we kept that at home, it would be enough to provide about 5 percent of New Zealand's annual diesel demands.

Auckland-based BioDiesel-Oils NZ is the furthest along in the production of biodiesel in New Zealand. The company started out as a solvent recycling business and collector of used cooking oils, but when managing director Tom McNicholl came out of retirement in 1998 to take the reins, he quickly realised the company was losing money. Finding a profitable use for the waste stream set him on the course of biodiesel and McNicholl, who is not a chemist, says he had enough intelligence to employ people who knew what they were doing.

Within a year, the company had produced biodiesel and, over the next three years, concentrated on research and development. Realising cooking oil was in short supply, the company focused on making a continuous-flow plant using tallow as a feedstock. In 2004, the company entered an agreement with British Petroleum (BP) to perform laboratory tests and vehicle trials on the biodiesel it produced from tallow.

"We were making biodiesel that ran our own vehicles," says McNicholl, "but we had no way of knowing if it was a pure and quality product." The relationship with BP was "invaluable," he says.

BP took the biodiesel, ran it through the required tests and trialed it in some of its own tankers, with Stagecoach buses and Waste Management trucks. BioDiesel-Oils NZ also kept using it in its own vehicles. The tests proved that the product met international standards as well as those of New Zealand and the United States; the vehicle fleets, says McNicholl, also performed well.

To be commercially viable, though, the company needed greater production than the 11 million litres its R&D plant in East Tamaki can make each year. In January it announced plans to build a full-scale commercial plant in Waharoa which will operate BioDiesel Oils' patented continuous system, have the capacity to produce 60 million litres of biodiesel per year and, depending on resource consent, be functioning by the end of 2007. A second equal capacity plant is planned for the South Island. Collectively, says McNicholl, the two plants can satisfy the government's biofuels content mandate of 3.4 percent by 2012.

Catching the world's eye

Producing biodiesel to run engines isn't inventing any new wheels – but developing a cheaper and more efficient continuous production facility is. As far as Tom McNicholl is aware, other plants operating around the world are on a batch process. The company has also designed its system to be flexible with feedstocks: Current systems

Bringing prices at least in line with those of petroleum fuels will be key to biofuels' success.

designed to use vegetable oil, he says, can't use tallow. The Bio-Diesel Oils NZ system is designed to be used with either.

International interest in the company's technology has come from Brazil, Chile, the United States and Australia – all countries with large-scale meat production. While the company is interested in expansion, it's not interested in selling its technology – it's looking for joint ventures with producers of raw materials.

Meanwhile, UK-based Argent Energy is investigating New Zealand as a potential site to build a bio-diesel refinery. The company's Scotland operation was the world's first commercial tallow-to-biodiesel plant.

"There's a lot of demand around the globe at the moment for renewable fuels," says Dickon Posnett, managing director of Argent Energy NZ. "We have to be very careful about where we select to show an interest and where we spend time and energy."

Three things came together to pique the company's interest in New Zealand: Argent is experienced in the conversion of animal fat and other oils into high quality biodiesel; New Zealand has significant quantities of animal fat; and, because of the government's commitment to biofuels, the company is assured of consumer demand.

New Zealand appeals to Argent for other reasons, as well. "When one looks to do business internationally," says Posnett, "certain similarities ease integration into a foreign country." A common language and links to customers in Europe help and, Posnett laughs, the fact that New Zealand was an easy sell for his family didn't hurt, either.

One part of Posnett's job was to source customers and, in mid-February, Shell New Zealand and Caltex signed a letter of intent with Argent in preparation for meeting the biofuels sales target announced by the government.

Posnett has identified potential sites for a plant that could process 75,000 tonnes of raw material a year and produce 85 million litres of biodiesel; design work on the plant continues. While not committing to building a refinery quite yet, Posnett is optimistic that New Zealand will be looked upon favourably when he reports back to his board in the UK.

The great green hope

While tallow seems an obvious and available feedstock, it is in limited supply in many parts of the world. Mike Packer, a biochemist at Cawthron Institute in Nelson, is passionate about the potential of micro-algae.

It turns out that micro-algae make an enzyme that they use to produce hydrogen gas. And Packer points out that the oil we are using today is the legacy of algal photosynthesis from thousands of years ago.

Packer is conducting basic research on the utilisation of micro-algae as an energy source

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OCEAN FILM BOAT

Spreading the word, Kiwi style

Even if New Zealand isn't yet winning the biofuels race, one determined Kiwi is gunning to spread the word about biodiesel around the world.

Hamilton-born Pete Bethune was an oil exploration engineer in New Zealand, Scotland and Libya. "In the oil industry," he says, "everyone knows there is about a trillion barrels left. If you do the numbers, that's about 40 or 50 years." Still, he says, it's not something you talk about. When Bethune left his job in 2002, he had a growing unease with the world's dependence on fossil fuels and started to wonder just what we were going to do when we ran out of the stuff.

It was just an interest at that stage. But for an MBA programme he was taking in Sydney, Bethune wrote a paper on alternative fuels for road transport. His unease began to take the form of a passion. He also began to realise what a great alternative biodiesel was – particularly for a small, flexible country like New Zealand.

"New Zealand has a largely agriculturally based economy. Biodiesel is a fantastic fuel for us," he says. But at the time, he had never heard anything about biodiesel in New Zealand. "What's with that?" he thought.

Coincidentally, he had a mate who was a boat builder and introduced him to a wave-piercing hull design that allowed boats to go through the waves rather than over the top; these odd looking boats could go much faster on rough seas. Bethune wasn't much of a boater – he thought he'd like one of these for fishing and diving – but when he stumbled over a website that showed records for power boats going around the globe, he thought that looked pretty darned easy. The next thought: I'll put the two ideas together and build a very fast boat that would run on biodiesel and break the speed record for circumnavigating the globe. That would be sure to gather a lot of attention and raise awareness of biodiesel as a fuel option.

That was in 2003. And as these things are wont to do, things took longer than Bethune had expected. Originally, he figured two years, but he needed to raise some cash and build the boat. The 78-foot trimaran, Earthrace, was designed by Craig Loomis Design Group and built by Calibre Boats in Kumeu at cost; Cummins MerCruiser Diesel donated the engines; ZF Marine chipped in with gearboxes, propellers and engine controls; Panasonic gave video equipment; and BioDiesel-Oils NZ has given more biodiesel to the project than any other fuel supplier.

In the process, Bethune has raised a lot of attention both for the boat and for biodiesel. Bethune – and the boat and the race – has been profiled in both the New York Times and the Los Angeles Times; he's been in the Boston Chronicle and plenty of business magazines; he's given 60 or 70 radio interviews and been on the Discovery Channel. Bethune told Popular Science, "I look forward to getting on the water and proving to the world that renewable fuels are synonymous with power and performance."

"One of the cool things about this fuel," Bethune says, "is that economies and countries can utilise whatever resources they've got." When *bright* spoke with Bethune, the boat was in Florida and leaving for Puerto Rico the next day. That trip will be fueled by poultry fat.

From Puerto Rico, Earthrace is off to Barbados, where the race starts. The current record is 75 days and Bethune figures he can do it within 65. After that, he'll head across the Atlantic and tour Europe, the Middle East and Asia before returning to New Zealand in 2008.

Think Bethune's got a great idea worthy of support? Two five-day legs of the journey are still available for sponsorship: Palau to Singapore and Singapore to Cochin, India. For between $10,000 and $15,000, you can join in the race. Bethune guarantees a few bumps and bruises as the boat pierces through the waves.

www.earthrace.com

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– as are other scientists around the world. Estimates have been made that algae is capable of producing 30 times more oil per acre than corn and soybean crops, and when you think about where the stuff grows (sewage ponds, waste water at dairies, wineries and paper mills to start), it's hard to imagine ever running out of algae. One of the problems, though, is gaining adequate access to uniform sources of algae that can be dependably turned into high quality diesel. Therefore, farmed algae may prove to be a likely, while somewhat bizarre, source.

At least one New Zealand company has dipped its toe into the slimy green stuff. Marlborough's Aquaflow Bionomic claims to be the first in the world to commercially produce bio-diesel fuel from algae sourced from sewage ponds. While there is still a way to go before algae-based biodiesel is being pumped into our cars and trucks, last year the company set up a U.S. affiliate and was the first New Zealand company to join the Girvan Institute of Technology, a non-profit institute headquartered near Stanford University established to speed the development of technologies.

Aquaflow Bionomic chairman Barry Leay explains the company is currently building a pilot plant that can produce up to one million litres of bio-diesel per year. Eventually, he says, the company plans to make modular production units that can be constructed in locations where algae are abundant.

Found in the forest

On the petrol side of the biofuels equation is bio-ethanol – formed from the fermentation of sugar or starch into alcohol. Crops such as corn and sugar cane are often used as feedstocks for ethanol, but while New Zealand has a benign climate where agricultural crops grow enthusiastically , we don't have mile after mile of centre-pivot irrigation growing hundreds of thousands of bushels of corn – and we don't grow endless fields of sugar cane like Brazil and Australia. New Zealand – like other parts of the globe – requires another solution, and from that need sprouts some interesting development.

Anchor Ethanol, a subsidiary of Fonterra, is producing ethanol by fermenting lactose. Anchor produces 15 to 17 million litres of high-quality, pharmaceutical grade ethanol annually for beverage and industrial use – but currently none of the company's product goes into petrol tanks to power vehicles. General manager Rodger Ryan suspects that within the next couple years, up

Left: Food crops such as corn are readily available, but are costly and resource intensive for biofuels applications.

to 20 percent of the company's business will be for transport fuel. However, he expects the total production of Anchor Ethanol to drop, as the raw material of lactose is proving more valuable to the company for other uses.

That leaves New Zealand with very little ethanol production – but this shortfall is spurring development in other directions. What New Zealand does have is a topography that is perfect for growing woody plants that don't compete with food crops. And here we have feedstuffs and technologies that might prove innovative.

run in Taupo with a view to killing several birds with one stone, so to speak: Not only don't salix shrubs need fertiliser, they are also efficient at soil remediation, something Taupo needs since the region's soil has increased nitrification, thanks to urinary run-off from livestock and the use of fertiliser. Add to that pile of good qualities the fact that salix is "coppicable": When it is cut off at the base, it sends out shoots to grow more plants, so it doesn't need to be replanted.

Up the road in Rotorua, Crown Research Institute Scion, along with AgResearch, has

Diversa's enzyme technology.

MacRae says Diversa was keen to make New Zealand a test bed for its technologies; in New Zealand and internationally, she says, people are testing many options, and there is no silver bullet. Each technology, she reminds, will need to be tailored to each country's attributes.

While Diversa is coming up with new enzymes to break down plant cell walls, ViaLactia, a subsidiary of Fonterra, is enlisting the help of those who are already doing it: dairy cows. In a cow's rumen, says commercialization and alliance

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AgriGenesis spin-out BioJoule was launched in 2006 with a commitment to energy farming and a three-pronged business approach for using the woody crop salix. When the shrub is harvested, says founder Jim Watson, it can provide cellulose for the production of transport ethanol; lignin for a plastic substitute; and xylose as a sweetener with non-diabetic properties. Site trials have been

partnered with San Diego-based Diversa on a feasibility study to determine whether or not a pulp and paper mill can be converted to turn its waste into biofuel. Scion project manager Elspeth MacRae explains that for six months beginning in February, the group will look at technology, logistics and impediments around the biofuel project. The study will focus on New Zealand tree stocks, energy grasses and

manager Ashvin Sood, are enzymes that break down the plant cell wall and turn it into simpler sugars. Understanding what those enzymes are and how they work is a promising way to figure out how to break down cellulose for biofuels production. Vialactia is collaborating with Dr Fredy Altpeter at the University of Florida and, in the hopes of finding companies interested in licensing this technology, will be showcasing what has been learned at the May 2007 international biotechnology conference in Boston.

Bypassing the maize

New Zealand has a land mass capable of producing enough woody crops to meet domestic biofuel demand without interfering with food production, says Elspeth MacRae, while Europe and the United States lack enough land mass to meet demand. (If all the corn in the United States, for example, was used for bio-ethanol, it would still only meet about 15 percent of the country's transport fuel needs.)

Further, "cellulosic" ethanol production uses plant fibre – not starch – and woody crops are more sustainable than energy-intensive corn, or maize, the farming of which often results in topsoil erosion and pollution of surface and groundwater with pesticides and fertiliser.

Even so, ethanol production from corn is well established. Local company LanzaTech is working to adapt international technologies to make bio-ethanol from maize in New Zealand. But it's the company's medium-term project that has LanzaTech thinking outside the mainstream ethanol box completely. The company – led by former Genentech scientist and founder of Tercica, Ross Clark; former chief Scientist of AgriGenesis BioSciences Richard Forster, and chief science advisor Sean Simpson – is developing a technology to use microbes to convert carbon monoxide and other industrial gases into ethanol.

Making use of high volume industrial waste has pricked international ears. Watch this space.

It's all in the delivery

If producing biofuels is the first step to kicking our petroleum dependence, actually getting it into our cars is the next. Again, this stage is not as simple as it sounds. Ian Coard, a project manager at New Zealand Ethanol, says the fact of being hydrophilic – or easily mixing with water – is one of the problems with ethanol when it comes to transport fuel applications.

In order to reduce the opportunity for water to enter ethanol blends, most ethanol-based fuel is mixed immediately prior to being transported to the service stations. Coard says his company is developing technology that will reduce the cost of ethanol to service stations and increase flexibility to the customer. We can't go into detail quite yet, but New Zealand Ethanol's solution may be an important step in changing the cost equation for bio-ethanol.