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01

POWER GAMES

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Technology Advancements Driving Biofuel Expansion

Given the growing concerns over global warming and a deteriorating environment, much attention is being paid to biofuels such as ethanol and biodiesel. Biofuels differ from fossil fuels in that they produce fewer exhaust gasses and less CO_2, and because they make use of natural plant energy, which is environmentally friendly and abundantly available throughout the world. Research efforts are also ongoing to generate hydrogen, another alternate energy source, out of organic waste materials by help of bacteria.

- Shimadzu Scientific Instruments on Course for Expansion
- News & Topics from Shimadzu

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Power games

Can motor racing go green? Andreas Trabesinger asked Max Mosley, head of Formula 1, how he wants the sport to develop energy-efficient technology that will also work in road cars.

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When Robert Kubica moved to overtake a rival at the hairpin bend in the Canadian Grand Prix on 10 June, he lost control of his Formula 1 car and smashed head-on into a wall in a truly horrific-looking crash. His BMW-Sauber was travelling at 280 kilometres per hour as he tried to pass Jarno Trulli's Toyota, and after ricocheting off the barriers, the car somersaulted along the track before coming to rest with only one wheel still attached. Remarkably, Kubica emerged from the crushed shell of his car with mild concussion and a sprained ankle. His slight injuries are a testament to safety improvements in Formula 1 cars, and to the commitment made by the Fédération Internationalede l'Automobile (FIA), the sport's governing body, to safety standards. Kubica almost certainly would not have survived a similar crash 15 years ago.

The Montreal event, as with all 17 races held in this year's Formula 1 championship, is about the thrill of pushing automotive technology to the very edge of reason. Making sure that the speed seekers are reined in and the sport stays within sensible limits is a difficult task in a contest of such extremes.

This task is the responsibility of the FIA, which until recently worried mostly about drivers' safety while keeping the race exciting enough to satisfy the tens of thousands of spectators at the circuit and the tens of millions of television viewers. But this heady mix of reason and adrenaline can have unexpected results. Last year, the FIA set out a 'green agenda' for Formula 1, announcing its intention to turn a sport in which cars guzzle 60 or 70 litres of petrol every 100 kilometres into a catalyst for greener technology for road cars.

Max Mosley is the man behind the wheel of the green agenda. In a penthouse high above London's Trafalgar Square, he lays out goals for the FIA to reach by 2009 and beyond. Now in his sixties, Mosley graduated from the University of Oxford, UK, with a physics degree, before going on to study law. He admits that he is no expert when it comes to car technology, but he has been active in motor sports as a driver and team owner since the mid-1960s, and has been president of the FIA since the early 1990s. Mosley' s vision of how Formula 1 will contribute to green technologies is simple: make the research done in Formula 1 relevant to road cars, in particular reducing their emissions of carbon dioxide.

So how does Formula 1 plan to get there? The FIA has a powerful advantage in that it can rewrite the technical rules for the championship every year. In the past, the FIA restricted the power a car's engine was allowed to produce for safety reasons, typically by limiting the engine size. For the race engineers, the task was to extract the maximum possible power from a given size of engine (see 'Racing through the decades', overleaf), thereby ensuring that Formula 1 remains the fastest form of racing on a twisted circuit. But by the start of the 2011 season, Formula 1 teams will have to crack a new technological nut: making the most of a given amount of energy. From then, the amount of fuel the cars can use in each race will also be restricted.

For Mosley the link with road cars is obvious: "This is precisely

FOX PHOTOS/GETTY IMAGES

RACING THROUGH THE DECADES

① Formula 1 in the 1950s
Fatalities: 8 / Engine sizes: 1.5-4.5 litres / Power: 270 horsepower in 1958

② Formula 1 in the 1970s
Fatalities: 10 / Engine sizes: 1.5-3.0 litres / Power: 485 horsepower in 1974

③ Formula 1 in the 1990s
Fatalities: 2 / Engine sizes: 3.0-3.5 litres / Power: 755 horsepower in 1997

①


ALLSPORT UK/GETTY IMAGES
M. BRANDT/BONGARTS/GETTY IMAGES

②


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"Brilliantly clever, amazing engineering but utterly pointless, and irrelevant to the real world."

Max Mosley

the problem that the car industry is trying to solve and indeed the world is trying to solve." He adds, "As soon as you look at it like that, you say 'why didn't we do this years ago?'" The reason, he says, is the same as why the road-car industry hasn't done it and that the public hasn't demanded it, because energy is still very cheap.

The links between Formula 1 and road cars have strengthened over the past decade. Of the 11 teams racing today, six are sponsored directly by major road-car manufacturers, only two of which — McLaren-Mercedes and Ferrari — were running their own teams in 1997, although many manufacturers were involved in the sport as suppliers of engines and other parts. The change came as the road-car industry embraced Formula 1 as a marketing platform, and its involvement has in turn benefited the sport as the costs of racing started to outstrip the available resources. Owning a Formula 1 team is a luxury few can afford, with running costs of up to hundreds of millions of dollars a year. Thirty years ago, the change of a single gearbox could require extra fundraising, but today the sport is flush with money from big-name sponsors and advertising.

■ Over-engineering

What has that money achieved? According to Mosley, until the FIA froze engine development at the end of last year's season, an average of 4 milliseconds of lap time were gained for every million dollars spent on engine development, and 20 milliseconds for every million dollars spent on optimizing the aerodynamics. Mosley is clear in his verdict: "Brilliantly clever, amazing engineering but utterly pointless, and irrelevant to the real world, because the engines were inherently inefficient." He points out that the teams have massive wind tunnels, super computers and model shops and they work 24 hours a day just to refine known technology. "This I want to stop," he says. "Let's get the really clever people working on the problem the whole world is trying to solve — which is just as good for Formula 1."

There are two areas in which Mosley thinks Formula 1 can make a lasting contribution to road-car technology, and that in turn will ensure the lasting success of the sport. These will be to recover energy lost through waste heat and braking. About two-thirds of the fuel energy in a car is lost as heat into the atmosphere — through exhaust gases and coolants. The other third propels the car forwards, but some of that kinetic energy is also lost, ultimately turned to heat, when the driver brakes. From 2009, new regulations for Formula 1 will allow, and thus force, the teams to recover a restricted amount of energy lost in braking, and use it to propel the car. The harder task of recovering the two thirds of heat lost to the atmosphere is deferred until new regulations are introduced for 2011.

At present, the teams are not allowed to recover braking energy because of concerns about how the technology would perform under the extreme forces experienced by a Formula 1 car. The technology that does this is called a kinetic energy recovery system (KERS), better known to drivers of hybrid vehicles as 'regenerative braking'. In a modern hybrid car — which has both a petrol engine and an electric motor — the motor's batteries can be charged by either the petrol engine or regenerative braking. The energy can be stored in different forms, but the most viable options for Formula 1 seem to be electrical storage in batteries or capacitors or the use of a flywheel.

Although the 2009 regulations will not limit the cars' consumption of fuel directly — and refuelling will still be allowed during the race — the ability to regain kinetic energy means extra power for racing. In short, the car gains energy without having to carry extra fuel, and therefore weight. Another advantage of KERS is that the stored energy can be used to improve performance, especially during acceleration out of corners or overtaking of other drivers, giving racing fans a more exciting spectacle. Together, these factors make KERS extremely attractive to Formula 1 engineers.

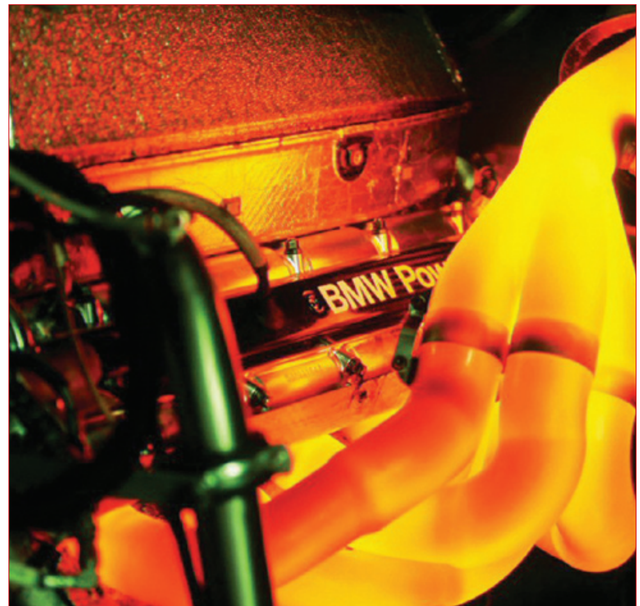
One formula for zero emissions

Can racing become emission free? A small Dutch company based in Amsterdam wants to create a race series, called Formula Zero, that will be based on cars powered by hydrogen fuel cells. Unlike conventional engines, fuel cells produce energy by reacting hydrogen fuel stored in a pressurized tank with oxygen taken from the air, so water is the only exhaust product.

It is still early days for Formula Zero. Founded in 2003 by Eelco Rietveld, an industrial design engineer, and Godert van Hardenbroek, an environmental consultant, the company is planning a race series for hydrogen-powered go-karts, which it hopes will kick off in 2008 or 2009. So far it has persuaded several university teams to build fuelcell go-karts, and it has earned an FIAendorsed speed record for a fuel-cell vehicle that weighs less than 500 kilograms. Last year, its go-kart, pictured here, reached an average speed of 61 kilometres per hour over 200 metres from a standing start.

But its long-term goal is more ambitious: a race series for car makers to showcase zero-emission technologies in full-sized race cars. Van Hardenbroek says they fully support the FIA's drive towards fuel economy: "Max Mosley made a very wise move; the world will move towards hybrid cars, and Formula 1 should reflect that." But he recognizes that the technology has a long way to go to compete with petrol engines: "For Formula 1 it would be very hard to make a transition towards fuel cells, this is not an incremental step."

A.T.



BMW

The heat is on: from 2011, Formula 1 teams will be able to reuse waste heat from the car's engine to boost performance.

Electric dreams

Burkhard Göschel, chairman of the FIA Manufacturers' Advisory Commission and former board member of BMW, is the 'technical brain' behind FIA's green agenda. He expects that most teams will go for electrical storage systems, either in the form of so-called supercapacitors (which have very high energy density and can store and release energy quickly) or new battery technology based on lithium-ion batteries.

Long term, both Mosley and Göschel are betting that the car industry will move towards using more electric power. "The electrification of the automobile can be anticipated, there is no way back. We are exactly on the right track with Formula 1, and road cars will follow this track," says Göschel. He is convinced that Formula 1 will make electrical energy-storage systems more efficient, smaller and lighter, and that the technologies developed on the way will be directly relevant to road cars. For example, the batteries used by hybrid fuel–electric vehicles are still too heavy, and the amount of energy that can be put in and taken out of a storage device is limited — problems that Formula 1 research, with its short design cycle and high-performance goals, seems ideally suited to fix. Mosley is confident that the race engineers will deliver: "You can't say you'll have it ready in two years, because the teams say they need it next week. The people in the next garage will have it next week."

So is Formula 1 heading in the same direction as the road-car industry? Paul Eisenstein, publisher of *TheCarConnection.com* in Pleasant Ridge, Michigan, and observer of the automotive industry since 1979, has no doubt that the car business is under enormous pressure to improve fuel economy; at the same time however, consumers are not willing to compromise on car size or performance. For these reasons,says Eisenstein, hybrids are not doing as well in practice as on paper: "The cost is high, and the performance of many models mediocre, in particular in terms of fuel economy. Most existing hybrids don't deliver what they promise; that's not good."

The next breakthrough for hybrid vehicles will have to come from making the interplay between the electric motor and the petrol engine more efficient, says Eisenstein. What will race engineers contribute to hybrid technology? "I see no reason why race-car technology shouldn't make it into road cars," says Eisenstein, "but such technology will have to meet tough criteria: What is it going to cost? How long is it going to last? Nowadays, such components are expected to deliver at least 100,000 miles." Whether the technologies developed for Formula 1 will deliver both performance and durability, at reasonable cost, remains to be seen.

Heat treatment

Hybrid vehicles would benefit from improved regenerative braking, but the recovery of kinetic energy is still playing with only a third of the energy contained in the fuel that the car burns. There is still the two-thirds lost as heat to think about. Getting that energy back is attractive, says Göschel, but not as simple to address. Formula 1 cars have previously harnessed 'turbocharging' technology to improve the engine efficiency. In a turbocharger, exhaust gases drive a turbine that compresses the air flowing into the combustion chambers, and thus, eventually, allows fuel to be burned more efficiently.

Turbochargers were used by the teams during the 1980s, before being banned in 1989 because they gave engines dangerously too much power. The changes to the FIA regulations for 2011 onwards could provide a chance to bring the turbochargers back, but they have yet to be framed. What Formula 1 will bring to turbocharger technology for road cars — widely used in vehicles from turbodiesels to high-performance sports cars — is far from clear.

Carbon credentials

Since 1997, the Fédération Internationale de l'Automobile (FIA), motor racing's governing body, has supported a research project aimed at offsetting the carbon-dioxide emissions caused by Formula 1 teams (from the race cars themselves and from transporting teams to events) during a Grand Prix season. Through the FIA Foundation, a UK-registered charity, the FIA offsets annual emissions of the 11 teams racing. estimated in 1997 to be around 20,000 tonnes of CO_2. by supporting the 'Scolel Té' project, which helps communities in southern Mexico to develop sustainable land management and better livelihoods.

As of December 2005, 888 farmers from 43 communities across the states of Chiapas and Oaxaca were included in the project, says Richard Tipper, president of the Edinburgh Centre for Carbon Management, UK, which consults on the project.

Unlike other sporting events, such as the 2006 World Cup in Germany, the FIA does not offset emissions caused by fans who travel to the events, so it can't claim to be carbon neutral. David Ward, director general of the FIA Foundation, says that the project's effectiveness will be reviewed this year, and the foundation will review the carbon footprint for the Formula 1 teams to see whether it has changed since 1997. As yet, The FIA Foundation has no plans to go carbon neutral. **A.T.**

H. NELEMAN/GETTY IMAGES

Many hands make light work: short design cycles put Formula 1 engineers under pressure to deliver.

"We are exactly on the right track with Formula 1, and road cars will follow."

Burkhard Göschel

Charging up

More speculative are new ways to transform waste heat directly into electrical energy by use of physicochemical processes, but Göschel notes that such devices have very low efficiency. Further developed is a steam turbine that BMW introduced under the name of 'turbosteamer' — who would have thought that one of those could ever be discussed in the context of a Formula 1 car? — which is powered by the heat created by the petrol engine, so mechanical energy is recovered from heat. In a similar device, known as a 'turbo-compound', the exhaust gases drive not only the turbine of a turbocharger, but also a turbine in the stream of exhaust gases whose extra power can be used either directly or stored electrically. Unlike turbochargers, none of these devices is yet in production for road cars.

How have the Formula 1 engineers reacted to these rule changes? "The teams don't like it, because we ask them to stop doing things they understand, and do things they don't understand," says Mosley. Göschel has noticed a more positive trend: "In the very beginning, our engineers had some concerns, but now there is a lot of excitement in working on new technology." Nick Fry, head of the Honda Racing F1 Team, hopes that the rule changes will challenge young engineers, in particular, to come up with new solutions: "It's an investment in people, in learning and in intellectual property. By pushing this type of technology where we have to perform publicly every two weeks, we must advance very quickly."

Alternate take

But why stop with efficient energy recovery? Formula 1 could switch to using biofuels, maybe starting in 2011, says Mosley: "We would like to use a biofuel. The question is, which one. There are so many competing biofuel systems." What Formula 1 might end up doing is taking whatever fuel becomes adopted more widely, rather than picking a fuel in advance. Fuel cells relying on hydrogen are not yet being considered for Formula 1, although a small Dutch company is trying to launch a fuel-cell race series (see 'One formula for zero emissions'). In addition, the FIA has an Alternative Energies Commission that organizes an annual cup race with vehicles that use alternative energies.

Mosley is planning to step down as FIA president at the end of his fourth consecutive term in October 2009, so is this green agenda all about his legacy? He admits that it plays a part, but he compares today's environmental concerns (See 'Carbon credentials') with the safety concerns that dominated Formula 1 when he first became president of the FIA. "It's a little bit like the safety debate, in that you work on safety because you don't want to kill anybody, you don't want anybody to get hurt, but also, society won't permit you to kill people like we did in the 1960s." During that period a driver died every year in Formula 1. "So, you've got two reasons: you want to do it yourself, but also you have to have regard to what society allows you to do."

Will Formula 1 be perceived as a 'green sport' in the future? "I don't know whether the fans will like it," says Mosley but he doesn't think that reason and adrenaline are incompatible. As people become increasingly conscious about carbon emissions and fuel economy, he hopes they will still be fascinated by a very fast, very powerful — but fuel efficient — Formula 1. In general, Mosley is pragmatic about the effect of the rule changes: "If it's technically interesting, that's fun, and if it makes a contribution to society, that's good," but ultimately he thinks Formula 1 needs public support in order to survive. "The number one thing is to make it so attractive and interesting that the public continues to pay for it."

Andreas Trabesinger is an associate editor for *Nature Physics.*

Technology Advancements Driving Biofuel Expansion

Given the growing concerns over global warming and a deteriorating environment, much attention is being paid to biofuels such as ethanol and biodiesel. Biofuels differ from fossil fuels in that they produce fewer exhaust gasses and less CO_2. They also make use of natural plant energy, which is environmentally friendly and abundantly available throughout the world. Research efforts are also ongoing to generate hydrogen, another alternate energy source, out of organic waste materials by help of bacteria.

The Kyoto Protocol notes that biofuels used in motor vehicles are helping lower engine emissions. Any CO_2 exhaust produced by these fuels will be accounted for by the absorption of the CO_2 by the crops grown to produce more such fuels. Consequently, it can be said that the CO_2 gas from biofuels should not be considered as a greenhouse gas. In Japan, the Ministry of the Environment and other government ministeries are promoting the prevention of global warming by minimizing CO_2 generation.

Ethanol is produced through the fermentation of carbohydrates contained in various plants including the sugar in sugarcane, starch in corn and the cellulose found in rice. When ethanol is used to power motor vehicles, it is used as an additive in petrol, either in its pure form or as ETBE (ethyltertiary-butylether) a product of ethanol and isobuthene.

Many countries are now mixing ethanol with petrol, and at increasingly higher rates. In Brazil, for example, a government-regulated ratio of 20% to 25% ethanol to petrol per unit is the highest in the world for conventional petrol-based cars. There are also 100%-ethanol-powered cars available. In the USA an ethanol-to-petrol ratio of 10% is mandatory, though cars using a ratio of 10% to 85 % are also sold.

Conventional petrol-based cars are still in a major stream in the US and EU, while approximately half of the commercially new cars are dominated by flexible-fuel vehicles in Brazil, which make use of arbitrary percentages of ethanol in the petrol.

In Japan the maximum amount of ethanol added to petrol is restricted to 3%, and the production volume of ethanol is also less than in Brazil and the USA.

Brazil also produces and uses the world's highest volume of biofuels, in part because it is able to derive the world's highest energy efficiency from using these materials. A major reason for this high ratio is that it has replaced the burning of coal with corn pomace to drive some of the tubines producing the country's electricity. Brazil estimates that the energy efficiency of its overall use of biofuels is eight times that of petroleum. By comparison the estimated energy efficiency of biofuels used in the USA is 1.3 times that of petroleum.

Japan's Trial Use of Ethanol in Motor Vehicles Underway

The Petroleum Association of Japan has been conducting trial sales of bio-petrol or bio-ETBE, a mix of 3% ethanol and petroleum (C_4H_8, isobutene), since April 2007. Fifty petrol stations in the Tokyo metropolitan area are selling bio-ETBE, which is imported. Government regulations prevent the car industry from changing the percentage of this ethanol ratio.

The Petroleum Association plans to expand bio-ETBE usage to 16,000 kiloliters this year and the number of petrol stations will double to 100 sites. The Association will further increase this volume to 840,000 kiloliters in 2010 when volume sales are due to commence.

The law setting the maximum ratio of 3% bioethanol added to petrol was established in August 2003. According to a study conducted by the Ministry of Economy, Trade and Industry (METI) an alcohol concentration of 50% may corrode fuel systems in cars and cause accidents.

During the North American International Auto Show held in Detroit this January, a Japanese automotive manufacturer exhibited a prototype car that runs on E100 or 100% ethanol, indicating that the technical challenges concerning its use in vehicles can be solved. The ethanol was supplied by British Petroleum in UK.

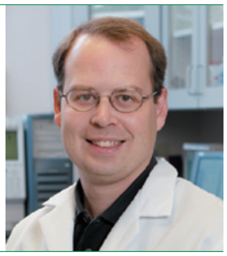
Non-Food Materials, a Must for the Future

Ethanol or ethyl alcohol is produced by fermentation of sugar obtained from certain kinds of plants. Plants can be categorized into C3, C4 and CAM (crassulacean acid metabolism) plants based in part on the way they process CO_2. Most plants belong to the C3 category and these absorb CO_2 directly, while only C4 plants employ a CO_2 condensation mechanism that helps increase their photosynthesis capability. Corn and sugarcane are categorized as C4 plant and because they maximize their photosynthesis capability, their growth rate is rapid. More ethanol is produced from corn than any C3 plant.

Production of corn for fuel purposes, however, has been criticized for causing a shortage of land for growing food, and for an increase in food prices. It is possible to produce ethanol from wheat, rice and beet, as well as corn, but these materials are also used for food. One answer to this issue is to create a method that produces ethanol from the pomace of sugarcane. The pomace of other plants such as rice and wheat are less efficient than corn, but these non-food materials can also become a source for producing ethanol in the future.

Biodiesel fuel is produced through trans-esterification of triacylglycerols (TAG) in virgin vegetable oil. It can also be produced from waste vegetable oils, but most commercial refiners are able to use these waste oils for other purposes.

USA: Ethanol Pioneer ICM Seeks to Produce Cellulosic Ethanol



Scott Kohl
Technical Director
ICM

"Ethanol is the best thing to happen to agriculture since the combine," says Dave Vander Griend, founder and president of ICM Inc., Colwich, Kansas, a design and engineering company that has helped pioneer the North American ethanol industry. He is referring to the surging demand for renewable fuels that has turned corn, the main ingredient in US fuel-grade ethanol, into a prized cash crop for farmers, rather than the government paying them cash not to grow corn in times of surplus.

Production figures speak for themselves. In 1980 the US produced a mere 175 million gallons (One gallon equals 3.785 liters) of ethanol, according to the Renewable Fuels Association. In 2001 the figure had jumped to 1.6 billion gallons annually and last year production hit 7.5 billion gallons, with another 5.7 billion gallons of capacity currently under construction.

"There are several major reasons for the dramatic increase," says Scott Kohl, technical director at ICM. "Farmers have seen that locally refining corn into ethanol adds value to their crop. So they have invested significantly to build local biorefineries." Surging oil prices are also helping make ethanol attractively priced. In addition, Kohl points out that adding ethanol to petrol helps reduce harmful car emissions, a plus for the environment and motivation for the federal and state governments to mandate its use in reformulated gasoline.

Along with engineering new plant construction, ICM also designs and manufactures the advanced equipment employed in them, including dryer systems, thermal oxidizers that eliminate over 99 % of airborne emissions, and wastewater treatment systems that allow plants to recycle their process water.

With demand soaring, ICM is stretching to keep up with plant and equipment orders. Of the 130 ethanol facilities currently in operation in the US, "Nearly 70 plants utilize ICM's patented process technology," says Kohl.

Instruments Are Key

When it comes to plant operations, ICM has turned to Shimadzu Scientific Instruments, Inc., Columbia, Maryland for assistance. "Smooth plant operations rely greatly on quality control equipment, explains Kohl. "Shimadzu supplies us with an HPLC (high performance liquid chromatography) system, which we use to monitor the critical fermentation process." He explains that the system meets ICM's needs because it is especially robust and reliable. "The software used to operate it is also user-friendly and easy for anyone to learn," Kohl adds.

A gas chromatograph from Shimadzu is another piece of equipment found in all ICM-engineered plants. This is used to monitor the final product to ensure it meets the specifications spelt out by customers of fuel-grade ethanol.

"It's not so much that Shimadzu's equipment is magic—other suppliers probably have similar products," says Kohl. "It is Shimadzu's customer service and support that is exceptional. You don't need a college degree to use their software, and if there is a problem with an instrument they respond immediately."

Rapid growth in the industry has raised challenges, however, like the current food vs. fuel debate. Critics say devoting cropland for ethanol feedstock production has reduced the land available for growing food, which in turn has led to rising food prices. While that is hotly contested, the search is on to find additional feedstock sources, with cellulose regarded as the most promising solution.

"Cellulose is found in virtually any plant matter," Kohl notes. "Trees, grass, corn stalks, even newspapers and much of our garbage have significant amounts of cellulose in them. Our goal is to innovate processes that can turn such non-food materials into fuel."

In 2005, a government interagency report found that US land resources are capable of producing a sustainable supply of 1.3 billon tons of cellulose materials a year, an amount equal to supplying 30% of the country's oil usage.

Now the race is on to turn this potential into a reality. Four years ago, ICM employed just four research scientists. Today it has almost 30. Besides developing technologies to make cheaper and better products for the industry in general, a majority of these researchers are now focused on the task of developing a practical process for converting cellulose into ethanol.

"To help us do this we are using the same types of Shimadzu instruments employed in our plant labs, as well as relying on some of their more advanced instrumentation," says Kohl. "An example of the latter is a GC/MS (gas chromatograph/mass spectrometer) that enables us to precisely identify many chemical compounds in liquids and gasses. Shimadzu is a great partner, even taking unusual research samples we've given them and analyzing them on more advanced instruments in their own labs."

Based on the progress ICM has made in its conversion goal, Kohl says he's now optimistic success is not far off. "We are currently building a small pilot plant to test out our process and already have plans to build a larger pilot plant within the next three years," he says. "Following that we could well be ready to move on to commercialization of cellulosic ethanol—probably within the next five to seven years."

Germany: Campa Biodiesel Ensures Quality of its Products

Udo Auerbach
Head of Quality Control Laboratory
Campa Biodiesel

German Campa Biodiesel located in Ochsenfurt close to Wuerzburg is producing 150,000 tons of biodiesel per year. Due to the fact that biodiesel is a natural product, its parameters and characteristics can change depending on the basic material used to produce it. To ensure the constant quality of biodiesel the DIN EN 14214 Standard was created, which defines the quality parameters of biodiesel.

Campa Biodiesel is a divison of Campa AG Holding in Ochsenfurt. The Holding company contains three divisions: Campa Süd in Straubing (Lower Bavaria) and Campa Biodiesel in Ochsenfurt produce biodiesel, while Campa Energie in Germany and Campa Iberia in Spain are distributing and selling it. Campa Biodiesel started production in 2000, producing 70,000 tons of biodiesel a year and was one of the first producers of this type of fuel. The current capacity of the Ochsenfurt plant is 150,000 tons of biodiesel per year. In order to save

the use of petrol-based diesel the government has mandated a content of 5 % biodiesel in diesel fuel. In 2009 it plans to increase this content to 7 % and possibly to 10 % further in the future.

"The manufacturing process of biodiesel is quite simple," says Udo Auerbach, head of Campa Biodiesel's Quality Control Laboratory. "Due to the fact that it is produced by transesterification, biodiesel comprises mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats." Consequently, it differs structurally from the alkanes and aromatic hydrocarbons found in petroleum-derived diesel. But because it is miscible with traditional diesel oils in any proportion, biodiesel is compatible with the existing diesel-fuel support infrastructure, which need no major modifications.

The choice of feed stocks for biodiesel manufacture depends on local availability and price. Biodiesel can also be produced from waste vegetable oils, however most commercial refiners currently find other uses for these oil wastes.

Biodiesel Complies With DIN EN 14214 Standard

To ensure the consistent quality of biodiesel in Europe the DIN EN 14214 Standard was created in 2003. It defines the quality parameters of the fuel and the ingredients used, as well as their specific quantities. Some of the quality parameters can change during production and so the standard requires a daily and a monthly analysis of the changeable parameters.

"To ensure the high quality of our biodiesel we decided to establish our own quality control laboratory and so looked for an appropriate gas chromatograph (GC)", says Auerbach. He contacted the headquarters of Shimadzu

(Fig.1) The Shimadzu GC-2010 set-up in the Campa Biodiesel Ochsenfurt plant

Europe Gmgh, Duisburg, Germany, because he knew that the Japanese scientific instruments supplier had worked closely with the standards body to simplify the measurement techniques used for determining the DIN EN14214 Standard. In 2004 Campa Biodiessel bought its first GC-2010 (Fig.1) from Shimadzu to analyse the quality of its biodiesel. The transesterification reaction of triacylglycerols (TAGs) in oils is most commonly done by reacting TAGs with methanol in the presence of a catalyst yielding the fatty acid methyl ester (FAME). During the process, monoacylglycerols (MAGs), diacylglycerols (DAGs) and other intermediate glycerols are formed. These, along with unreacted TAGs, may remain and contaminate the final product.

The GC-2010 is specially designed for fast gas chromatography analysis and so increases productivity. It improves analytical efficiency by employing an advanced high pressure (970 kPa) flow control and high split-ratios as standard. Other features include extremely sensitive detectors, fast sampling times, and a high powered oven with high speed cooling capability. Thus it can double or even triple productivity compared to that of conventional instruments. It also incorporates excellent data reproduction capability (even for solvents with large vapor volumes such as acetone) by way of a newly developed injection system and highly sensitive detectors.

"Due to the success we had with the first Shimadzu GC-2010 we decided in 2006 to buy another one, which is mainly used to analyse our manufacturing process," says Auerbach."

Free glycerin, along with water, is a by-product of fatty acid methyl ester production. GC analysis of the glycerine concentration provides an effective measure of the fuel's quality. The American Society for Testing and Materials' (ASTM) D6584 method provides a test procedure for the quantitative determination of free and total glycerin in B-100 methyl esters using gas chromatography. Also, ASTM's EN14105 test method specifies a test procedure for the determination of free and total glycerol and mono-, di-, triglyceride contents by gas chromatography.

Of the 26 parameters to be analysed according to the DIN EN 14214 Standard, Campa Biodiesel uses the GC-2010 to analyse 10 of them. "We plan to buy other instruments from Shimadzu for analysing sulphur content, alkali metal, alkaline earth metal and phosphorous content," says Auerbach. "Analysing the sulphur content is necessary because it is found in some vegetable oils, while certain production processes use sulphuric acid." He also emphasizes the excellent customer service and support provided by Shimadzu. "Our close relationship with the Shimadzu Duisburg office and their prompt reaction to our needs has helped us realise a biodiesel of the highest quality."

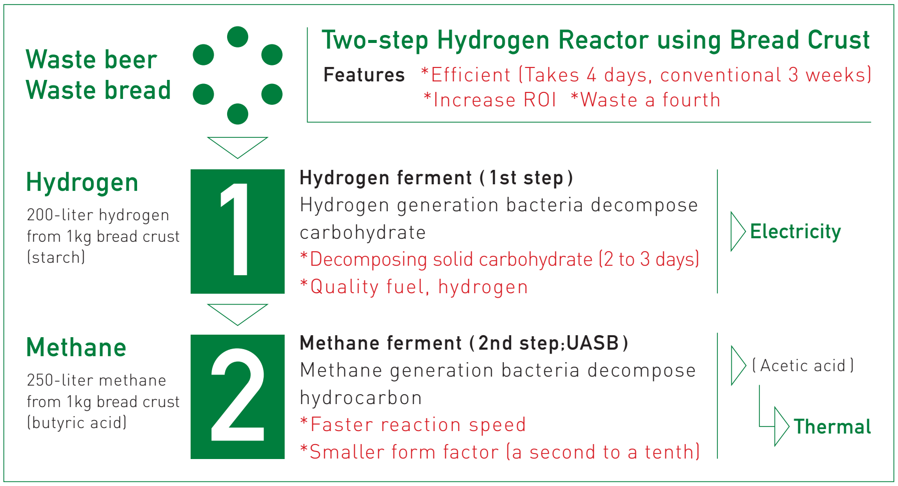
Generating Hydrogen with Bacteria

Tetsuo Hiraga
Manager
Corporate Strategy
Planning Dept.
Shimadzu

While ethanol and biodiesel fuels are used in car combustion engines, alternative emerging engine technologies are making use of electric power and hydrogen fuel cells. Recent research shows that hydrogen can be generated with the help of bacteria and this hydrogen in the form of fuel cells can be used to power a car engine directly without the need for fossil fuels. Tetsuo Hiraga, manager of Shimadzu Corporation's Corporate Strategy Planning Office, is one researcher making progress in developing technology to extract hydrogen from biomass.

Four years ago, Shimadzu, working jointly with Professor Naomichi Nishio of Hiroshima University, began development of a hydrogen generation system that uses bacteria to convert organic materials into hydrogen. The technology is a two-step production method that produces hydrogen and methane from organic waste materials remaining after food processing. Selected bacteria grown in a bioreactor consume the glucose contained in the food wastes and in the process generate hydrogen. The residue is then transferred to a second bioreactor where a different kind of bacteria consumes the remains, creating methane in the process (Fig.2).

The fermentation process that result in the creation of hydrogen is produced by bacteria, each measuring one micron in diameter. Professor Nishio first published a paper on the two-step generation of hydrogen and methane



(Fig.2) Two-step Hydrogen Reactor using Bread Crust

(Fig.3) 900-liter reactor <top>
1-liter prototype reactor <bottom>

ten years ago. When Hiraga came across the paper, he proposed that Shimadzu work with Nishio to jointly develop the technology. The two-step fermentation process starts at the first bioreactor, where the bacteria consume the glucose contained in the fermented food waste and generate hydrogen as a by-product. The residue of organic acids or acetic acid is transferred to a second bioreactor where it is consumed by a different kind of bacteria, which produce methane during the process (Fig.3).

Because Shimazdu is an analytic instrument manufacturer and not a fuel producer, Hiraga invited Sapporo Breweries, Ltd to help develop the technology, as the fermentation process is similar to the production of beer. He also sought the cooperation of the National Institute of Agrobiological Sciences and was able to obtain a grant from the Japanese government. The research team selected bread crust for the process material because it has high sugar content and can produce more hydrogen than other food wastes. Though some bread crust is used in pig feed, much is also discarded, making it an ideal source material.

Many kinds of bacteria coexist together. Consequently, bacteria other than the kinds that generate hydrogen and methane can also grow in the reactors. If certain types of bacteria enter a reactor, they may prevent the desired bacteria from increasing in sufficient numbers. Hiraga likens the various bacteria coexisting in the human body's intestines and the balance they maintain there, to the bacteria that can inhabit the two-step reactors. His goal is to find ways of maintaining the optimum number of the desired hydrogen-producing bacteria needed to make the process efficient.

One answer is to operate the reactors continuously, so as not to destroy the desired bacteria. The researchers took another step forward when they developed ways to enrich the cultures that produce the desired bacteria. As a result, the researchers have achieved some of the highest rates of hydrogen generation in the world: 2.5- to 3.5-mol hydrogen from 1-mol glucose. In practical terms the two-step technology produced 200 liters of hydrogen and 250 liter methane from 1kg of bread crust.

A Decision in Three Years

The two-step technology takes only four days to produce hydrogen and methane, compared to the 20 days it takes to produce methane alone by other means. Despite such success, Hiraga points out that though Shimadzu is an analytical instruments manufacturer producing a wide product portfolio, it has no experience in developing fuel processing technologies. So the company will decide in the next three years if the technology should be commercialized. Given that the first target application would likely be generating hydrogen for fuel cells, Hiraga says that commercial viability will depend on what the demand for fuel cell technologies is in that time frame.

The joint project with the National Institute of Agrobiological Sciences, Hiroshima University and Sapporo Breweries ended in April 2007. Now Hiraga is preparing to head a new three-year project with the help of a grant from the Ministry of the Environment. He will test the feasibility of using the two-step method for mass producing hydrogen in Hiroshima, and will set up a research facility adjacent to a bread factory there in order to facilitate easy access to the bread crust and other waste food materials the factory can supply.

Hiraga has chosen Hiroshima because Mazda, one of Japan's leading automotive manufacturers, is based there. Mazda has developed a prototype hybrid engine that employs both a petrol engine and a hydrogen engine housed in the RX-8 Mazda's proprietary rotary-engine-driven car. The hybrid car can switch from petrol to hydrogen power at the press of a button. However, Mazda has no plans to commercialize the hybrid vehicle anytime soon because the infrastructure to support hydrogen-powered vehicles, including fuel stations is non-existent. Nevertheless, Hiraga believes that as concern over the environment grows, cities will form eco-friendly and energy self-sustaining communities and these will facilitate the adoption of hydrogen-generated energy. He expects Hiroshima will become such a city.

Shimadzu Scientific Instruments on Course for Expansion

With double-digit growth in sales and new markets opening up in the Life Sciences, the future looks bright for this analytical instruments supplier

Look behind the cutting edge technologies beginning to impact our lives—genomic sequencing, the early detection of diseases through molecular imaging and biofuels to name but several—and you will find scientists and research engineers dependent on analytical instruments and measuring tools supplied by Shimadzu Scientific Instruments. SSI is the United States subsidiary of Shimadzu Corp., a Kyoto, Japan-based company with a history stretching back over 130 years to 1875. SSI represents the US analytical instruments arm of the $2 billion multinational, while Shimadzu's medical diagnostic and aerospace/industrial businesses also have subsidiaries in the US.

"We can break down our business into three main sectors," says Chris Gaylor, vice president of sales for SSI, speaking from the company headquarters in Columbia, Maryland. "Life sciences, the environment and physical measurement."

The life sciences cover virtually anything concerning basic biological mechanisms. Here, SSI instruments such as mass spectrometry systems are used by researchers and technicians for tissue imaging to aid clinical diagnoses and they are also employed in protein analysis to help produce medical therapies. Among the instruments targeting environmental scientists, the company offers Gas Chromatography Mass Spectrometry (GCMS) products to measure quantitatively many analytes found in soil and water. In the physical category SSI supplies, for example, test equipment to measure the tensile strength and the thermal properties of various materials.

"All told, we market more than 50 different types of analytical and measuring instruments and systems, not including various models of the same type," says Gaylor. "But there is a fair amount of crossover in the three sectors."

For instance the company's biggest sellers are HPLC (high performance liquid chromatography) systems. These can be used in a variety of fields for the separation, identification, purification and quantification of various compounds leading to faster development of new drugs, improved food safety or meeting environmental regulations.

SSI supplies its products to laboratories and research centers from Canada in North America down to Central America and has built up a network of over 50 centers to provide sales, service and technical support.

"In 2007 sales grew by around 10% overall and up to 25% in some product areas—and that was purely organic growth without any mergers or acquisitions," says Gaylor. "We also saw revenues pass the $100 million mark for the first time."

SSI imports a number of products from the parent company and localizes them for each region. But sometimes the needs of researchers differ significantly, depending on the location.

"To deal with regional differences Shimadzu has begun sending design engineers to the US, where they meet directly with SSI customers to find out how they can better accommodate local needs," says Kevin McLaughlin, marketing communications coordinator for SSI. "This represents a new level of commitment that has helped to raise the quality of communications with Kyoto and also helps SSI better satisfy our specific market needs."

As well as factories in Japan, Shimadzu manufacturers its products in China, the Philippines, the UK and in Portland, Oregon. The latter produces mainly HPLC systems, gas chromatography mass spectrometry instruments used to identify chemicals based on their structure, and ultra-fast liquid chromatograph systems used by analytical chemists in various fields such as the pharmaceutical industry. These products ship primarily to the North American markets but are also exported around the world.

"The Portland plant houses an R&D group," notes McLaughlin. "This enables us to take on tactical engineering projects because we can make small product changes or customize features for specific markets and customers."

Such customization has become more important as the instruments become more sophisticated. "Shimadzu was created by scientist and engineers and innovation has long been its strong point," says Gaylor. But in today's competitive business climate, he adds, maintaining and improving customer relationships is also a vital ingredient for continued success.

In pursuit of this goal the company is implementing a CRM or customer relations management system. "This gives us the capability of measuring customer satisfaction by analysing product implementation time, service call-backs, customer feed-back and the like," explains Gaylor. "In turn, it helps us provide more specialized training and support for our customers."

SSI is changing in other ways, especially in response to shifts in the market. Until the recent past about half the company's sales were made to the pharmaceutical industry. Today that ratio has decreased to around 20% as SSI works to become more broad-based in its marketing by expanding into new markets.

"Life sciences is a particular exciting area for us right now," says Terry Adams, SSI's Life Sciences marketing manager. Driven by customer input, a number of new laboratory-scale biological analysers are being rolled out to complement the larger mass spectrometry systems used for such things as tissue imaging and biomakers analysis. "In general, scientists are looking for reasonably priced, easy to use instruments with higher resolution, increased sensitivity and better sampling handling capability. The future looks bright."

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Integrated Turbomolecular Pump Plant Completed at Shimadzu Corporation Head Office in Kyoto

Shimadzu Corporation completed a new integrated turbomolecular pump plant at its Kyoto head office in December 2007. This new plant, designed to integrate manufacturing processes ranging from ultra-high precision machining to assembly and inspection, is a four-storey 16,000 square metre steel structure, built at a cost of approximately 3 billion yen.

Installation of manufacturing equipment, including ultra-high precision machining, will continue in readiness for a phased operation startup in spring 2008. This new plant will house the entire manufacturing system under one roof, from machining and fabrication to assembly and inspection of key components such as pump rotors (multiple-structure turbine blades).

Turbomolecular pumps consist of aluminium blades rotating at high speeds, which impact with and then expel nitrogen, hydrogen, or other molecules to produce an ultra-high vacuum. Considered essential for semiconductor manufacturing, turbomolecular pumps are expanding in market and future demand is expected to remain strong and rising.

In addition to its own turbomolecular business, Shimadzu has recently acquired the turbomolecular pump business from Mitsubishi Heavy Industries, Ltd. to widen the range of products especially to large capacity models. As a result, Shimadzu expects to nearly double yearly turbomolecular pump sales to 15 billion yen, becoming the world's leading turbomolecular pump manufacturer by the 2010 financial year.

Asian Pharma Summit Held in Singapore

Recently the pharmaceutical industry has achieved remarkable growth in India, Singapore, and other South East Asian countries. In view of this, Shimadzu Asia Pacific (SAP) hosted a user's meeting (Asian Pharma Summit 2007) in December 2007. An expert university researcher in pharmaceutical processes and other international guest speakers from the pharmaceutical industry were invited to address 220 customers who attended the Summit.

This summit began with an address by the president of Shimadzu Corporation. He explained how expertise in both medical and analytical technology gives Shimadzu a unique position in the fields of drug discovery and diagnostics and also discussed next-generation medical technologies, such as molecular imaging. Next, experts from India and Singapore took the podium. The Indian expert described conditions in India, where the pharmaceutical industry has been undergoing annual growth of nearly 20 percent. The Singaporean expert outlined the scene in Singapore, where the pharmaceutical industry is responsible for 12% of gross domestic product (GDP). Shimadzu intends to hold this summit annually to provide a forum of valuable information exchange for those involved in the rapidly growing South East Asian pharmaceutical industry.

A Subsidiary Established in Dubai for Selling Analytical, Measuring and Medical Instruments covering Middle East and Africa Regions

Shimadzu Middle East & Africa (SMEA) was established in September 2007 as a Shimadzu Group company. With headquarters in Dubai, UAE and an office in Istanbul, Turkey, SMEA is responsible for sales and service support of measuring and medical instruments in the Middle East and Africa. Establishing a distribution centre for measuring equipment in Dubai, now a popular import/export hub for the Middle East and Africa, allows products to be delivered more quickly to customers. Furthermore, based on a policy of providing service closer to customers, training facilities for analytical instruments will be established in Turkey and Dubai to further improve Shimadzu's after-sales service capability. The markets for which SMEA is responsible are geographically very large and represent a wide variety of customer demands. SMEA will provide solutions and services corresponding to customers' demands and needs in this diverse territory; in Turkey, the manufacturing portfolio, including automobiles and chemical products, is developing fast and turning the country into a manufacturing base for exports to Europe; South Africa is seeing the largest expansion in industrial scale in Africa; and the Gulf states, led by Saudi Arabia, are the leading global producers of petrochemicals. SMEA will serve customers there and in many more locations.

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