FUELLING DEBATE: A LOOK AT THE PROS AND CONS OF GREEN FUELS

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Some people look to the electric car, others to hydrogen, but in reality, we are likely to see several technologies converge to produce the fuel efficient engines of tomorrow.

Recently, the United Nations weather agency said that gases blamed for global warming have reached record levels in the atmosphere. Concentrations of CO_2 and nitrous oxide (N_2O) touched new highs in 2008, and methane had its largest annual increase in a decade.

There are many technologies that will be used to keep our equipment working economically in the future. Rather than a single predominant one, such as gasoline or diesel engines (CO_2 per litre of gasoline burned = 2.34kg/L; CO_2 per litre of diesel burned = 2.68kg/L), we will more likely use a combination. Some people look to the electric car, others to hydrogen, but in reality, we will probably see several technologies converge to produce the fuel efficient engines of tomorrow.

Let's look at the different fuels we might use in the future and their pro and cons.

Battery

Electric cars are far from new. They were common between the 1830s and 1930s and re-emerged in the 1960s and 1970s. The first modern electric car was produced in 1996 by General Motors. The source of power for the electric car usually comes from rechargeable batteries (pure electric cars), fuel cells (fuel cell cars), or a combination of gasoline and rechargeable batteries (hybrid cars).

These technologies are used today on walking greens mowers and riding mowers available in hybrid or battery drive, providing power, economy and low environmental impact. Unfortunately, pure electric equipment is impractical because the batteries need to be recharged, sometimes after cutting only a few greens or fairways, or even less in extreme hot or cold weather.

Recharging batteries can take as long as three hours for a full charge. To get more power, more batteries would be needed, increasing both weight and footprint on

greens and fairways. Furthermore, batteries have to be disposed off, which creates another environmental concern.

Biodiesel

Biodiesel is a renewable fuel derived from vegetable oils, animal fat and cooking oils. These oils and fat are made into methyl or ethyl esters. One of the big advantages to using biodiesel shows up in the engine. Analysis revealed that the improved lubrication qualities of biodiesel may increase some major engine parts longevity by as much as 100 percent and increased longevity reduces maintenance costs.

Disadvantages are that biodiesel has slightly less energy than regular diesel, so if we were to use biodiesel in a vehicle, the engine would either have less power or use more fuel to deliver equal power. Biodiesel causes fuel-system problems in cars, especially at low temperatures. It oxidizes faster due to its chemical makeup so storage of the fuel is more difficult.

The biggest disadvantage of biodiesel is that pure biodiesel begins to freeze or solidify at low temperatures. Nitrous oxide can increase up to 6 percent and refining the renewable source of biodiesel causes greenhouse gases. To combat these problems, the Austrian company BDI (Bio Diesel International) is currently working on using algae as raw material for the production of biodiesel. The algae are grown either in fresh or salt water, need no agrarian land, and are fed by exhaust emissions stemming from caloric power stations which leads to a further reduction of the gases responsible for climate change. Algae produce 80 times more usable biomass than rape seed per hectare thus potentially eliminating the use of valuable agricultural product needed to feed the world.

Ethanol

Ethanol is a clear liquid that can be made from natural products and is diluted with gasoline to provide a cleaner, more natural fuel source. About 30 percent of all gasoline consumed is blended with ethanol, usually a combination of 10 percent ethanol and 90 percent gasoline. Ethanol is produced from crops such as corn, grain sorghum, sugar cane, wheat and biomass.

Ethanol has both economical and environmental shortfalls. Many acres of cropland are needed to produce ethanol, which makes it more expensive than gasoline. It contains one third less energy than gas, which means mileage is 30 to 40 percent lower. Massive ethanol production could cause a shortage of corn available for food and destroy habitat. It also increases smog in urban areas. The cost to produce and refine one litre of ethanol was $2.19 in 2008 and is subsidized heavily by government.

Methanol

Also known as wood alcohol, methanol is an alternative fuel that can be produced from any carbon-based source like natural gas, coal, wood wastes and seaweed. Using methanol as an alternative fuel source is good because it produces lower emissions, yields higher performance, and has

a lower risk of flammability than gasoline. Because the use of methanol creates better performance and acceleration, it is used as the fuel for Indy race cars, monster trucks and model vehicles.

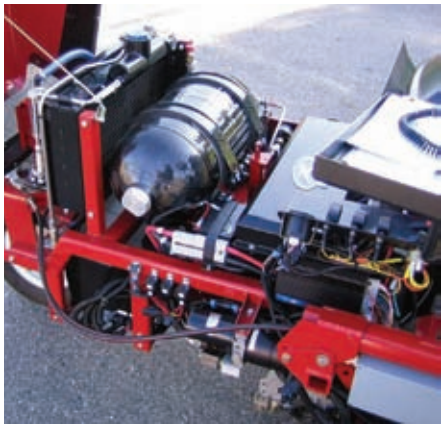
Methanol is more corrosive than gasoline so parts that come into contact with methanol must be able to withstand its corrosive ability. Also, because the air to fuel mixture is richer than gasoline, a given volume of gasoline will take you about 70 percent farther than the same sized tank of methanol. Methanol is a very toxic substance and can be harmful if swallowed, absorbed through the skin or inhaled. Ingestion of just 1 to 4 ounces can cause injury to the nervous system, blindness or even death.

Hybrids

A hybrid electric vehicle (HEV) uses an electric motor and a gasoline engine. The engine charges the battery and extends the range and provides extra power. The fuel tank is the energy storage site for the gasoline engine. The generator produces electric power. The batteries are the energy storage devices for the motor. The motor can put energy into the batteries as well as take energy away from them. The engine has enough power to keep the equipment moving, and the extra electric motor and battery provide the additional power needed to go up steep hills. The batteries in today's hybrids require nickel, which is costly, and big battery packs and other components can add $2,000 or more to the cost compared to conventional models. The large battery packs degrade performance and increase the footprint of the associated turf equipment.

Natural Gas

Natural gas is basically methane (CH_4). Its largest advantage is its chemical composition. Because methane only has



Adjacent Top. The on-board hydrogen 26L Dynatek fuel cylinder capable of containing 0.63 kg of hydrogen at 5000 psi. Adjacent. Toro's mid-duty fuel cell hybrid combining a Maxwell ultracapacitor bank and Hydrophonics fuel cell.

one carbon in its composition, it produces very low carbon emissions. The second major advantage of natural gas is convenience. The gas is pumped directly on the consumer's property. Because of the abundance of natural gas, it is cheaper to burn than oil.

Fuel Cells

These devices generate electricity by converting hydrogen and oxygen into water. Here is what happens in a fuel cell. When hydrogen gas pumped from the fuel tanks arrives at the anode, which is made of platinum, the platinum catalyzes a reaction that ionizes the gas. Ionization breaks the hydrogen atom down into its positive ions (hydrogen protons) and negative ions (electrons).

Both types of ions are naturally drawn to the cathode situated on the other side of the membrane, but only the protons can pass through the membrane (hence the name "proton-exchange"). The electrons are forced to go around the proton exchange membrane, and along the way they are shunted through a circuit, generating the electricity that runs the car's systems.

Using the two different routes, the hydrogen protons and the electrons quickly reach the cathode. While hydrogen is fed to the anode, oxygen is fed to the cathode, where a catalyst creates oxygen ions. The arriving hydrogen protons and electrons bond with these oxygen ions, creating the two "waste products" of the reaction – water vapour and heat. Some of the water vapour gets recycled for use in humidification, and the rest drips out of the tailpipe as "exhaust."

This cycle proceeds continuously as long as the car is powered up and in motion; when it's

idling, output from the fuel cell is shut off to conserve fuel, and the ultracapacitor takes over to power other components. Ultracapacitors (sometimes called double-layer capacitors or supercapacitors) store energy electrostatically by polarising an electrolytic solution. Unlike batteries, no chemical reaction takes place when energy is being stored or discharged and so ultracapacitors can go through hundreds of thousands (or even millions) of charging cycles with no degradation.

Ultracaps are highly efficient, so little energy is lost during the charging and discharging process (typically <1 percent). As they do not depend on a chemical reaction to store energy, ultracapacitors can operate in a very wide temperature range effectively – typically from -40º to +70ºC.

When hydrogen is used in fuel cells, there are zero emissions. Toro and the New York State Energy and Research Development Authority (NYSERDA) joined forces to assess the potential of fuel cell utility vehicles at Niagara Falls State Park. NYSERDA had selected Toro to receive grant funding to develop the hydrogen powered vehicles. Toro converted two mid-size utility vehicles and one heavy duty utility vehicle using a fuel cell in a series-hybrid configuration. Without the fuel cell, the batteries would only provide about 20 to 30 minutes of run time. Since the fuel cell keeps the batteries charged, the batteries can provide 15 to 20 kW (20 to 27 hp) of peak power when needed. To date, these utility vehicles have operated fairly reliably and met or exceeded performance expectations.

Hydrogen

Hydrogen is a colourless, odourless gas that accounts for 75 percent of the entire universe's mass. Hydrogen is found on Earth only in combination with other elements such as oxygen, carbon and nitrogen. To use hydrogen, it must be separated from these other elements. The most inspiring and exciting use for this element would be for use as a fuel. Scientists have been exploring this for many years and now it is becoming more of a possibility as prototype hydrogen equipment and motors are being tested.

The production of hydrogen is very cheap and easy. Hydrogen is actually a by-product in the steam reforming of natural gas. Since natural gas already has a variety of uses in our society, this would be a very cost efficient way to produce pure hydrogen. Although the change will be tough, some of the benefits will be great.

For example, it is much more environmentally friendly to burn hydrogen than to burn gasoline. Another advantage to switching to hydrogen would be the availability of the resource. One last major advantage is the fact that it would be cheaper to refine than gasoline and thus would be cheaper for the consumer. Golf courses could have their own stations to produce and store hydrogen. The only tailpipe emission is water.

Prototype hydrogen equipment and motors are currently being tested. Hydrogen is readily available and more environmentally friendly to burn than gas. On the flip side, it's highly explosive and both storage and distribution systems still need work.

The Toro riding greens mower prototype utilizes a 7 kW hydrogenics PEM fuel cell and a bank of ultra-capacitors in a 48Vdc series-hybrid configuration. Onboard hydrogen is carried in a 26L Dynatek composite compressed gas fuel cylinder capable of containing 0.63 kg of hydrogen at 5,000 psi (350 bar). Field trials have demonstrated it capable of quietly and effectively mowing an entire 18-hole greens route without refuelling.

Other manufacturers of grounds equipment are also exploring fuel cells. Hydrogenics Corporation, a designer and manufacturer of fuel cell technology, announced in Toronto (June 2009) that it has sold six of its 10-kilowatt fuel cell power modules to Deere & Co. for integration and evaluation in off-road vehicle applications including grounds equipment and utility vehicles.

Pound for pound, hydrogen fuel has more inherent energy than gasoline, which could mean higher mileage. One of the main disadvantages is the explosive property of hydrogen. This means that special precautions will have to be taken for pumping and storing. There's no distribution system or standardized method of storage, which is crucial since hydrogen fuel is a gas that must be kept under high pressure.

Significant work still remains to make this a reality. Lots of data must be collected to ascertain the proper power specifications for the fuel cell-hybrid system. Carrying sufficient onboard fuel

is challenging, especially utilizing the large, cylindrical compressed gas tanks. Many of the components are prohibitively expensive, and economies-of-scale must be realized on several fronts to reduce the cost.

Finally, it is unclear how affordable hydrogen fuel systems will work, particularly in applications where the entire fleet consumption may be less than 10-20 kg/day. One solution could be "Hydrogenics On Site Generation" which offers a full line of HySTAT hydrogen station and turnkey hydrogen generating solutions for a wide range of hydrogen generating and refuelling options. Despite obstacles, customer satisfaction and demonstrated technical viability offer hope that some day hydrogen fuel cells might be a common sight on your local golf course. Even though there are some large disadvantages attached to the switch to hydrogen, it will be very beneficial in the long run and will finally eliminate damage to our environment. ♦

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