Biofuels: Alcohol, the fuel of the future? – Part 4

by Chris Meyer, technical journalist

Just after World War 1, it was thought that oil supplies in America would become exhausted in about twenty-five years. The idea of importing oil from the Middle East, then from Persia, or Russia, was considered positively dangerous. And the explosive growth in the number of people buying cars meant that known reserves would be depleted even sooner. Small wonder that alcohol was considered as a possible alternative fuel.

"Midgley and Kettering's interest in ethyl alcohol fuel did not fade once tetraethyl lead was discovered as an antiknock in December, 1921. In fact, not only was ethyl alcohol a source of continued interest as an antiknock agent, but more significantly, it was still considered to be the fuel for high compression engines that would eventually replace petroleum when supplies began to run out" [9].

Today, Thomas Midgely is known as the inventor of two chemical compounds that have caused the world problems: tetraethyl lead, a poisonous anti-knock agent in petrol, and CFCs, claimed to be responsible for damage to the ozone layer. But Midgely's role in investigating ethyl alcohol's potential as a fuel has largely been forgotten.

How Midgely came to discover and develop tetraethyl lead and CFCs is exceeding well told by Bill Bryson, in Chapter 10 ("Getting the lead out") of his best seller, "A short history of nearly everything."

That cannot be repeated here, instead, we touch on something largely forgotten today; how and why Midgely and Charles F. Kettering, Vice President of Research at General Motors, believed in ethyl alcohol as the fuel of the future, even after tetraethyl lead was discovered, and why a lot of research was done at General Motors into this topic, and how General Motors, abruptly decided to drop ethyl alcohol and concentrate only on tetraethyl lead.

Cellulose, the fuel of the future

"From cellulose waste products on the farm such as straw, corn-stalks, corn cobs and similar sorts of material that we throw away, we can get, by present known methods, enough alcohol to run our automotive equipment in the United States" [9].

At first glance, this doesn't seem to be something that Thomas Midgely would ever say. After all, he invented tetraethyl lead, and a few years later, he and Kettering were saying the exact opposite: that alcohol was not suitable for large-scale automotive use. What happened to cause the sudden change?

The first thing we must realise is that, at that time, it was thought that oil supplies in America would become exhausted in about twenty-five years [9]. The idea of importing oil from the Middle East, then from Persia, or Russia, which was then in the throes of a civil war, was considered positively dangerous. And, the explosive growth in the number of people buying cars meant that known reserves would be depleted even sooner.

Small wonder that alcohol was considered as a possible alternative fuel. In fact, the situation then was eerily similar to today, as projections of millions of new motorists in India and China now mean that current oil supplies could be depleted even sooner than predicted. At first, Kettering, Midgely and Boyd, another GM researcher, began to consider what would be involved in a total switch from petroleum to alcohol fuel. And, like current calculations, they showed there was no way the US could grow enough food to produce enough alcohol fuel to completely replace all the oil used.

In 1921, Kettering noted that were [alcohol] to take the place of gasoline, over half the total farm area of the United States would be needed to grow the vegetable matter required [9]. Since then, things have got noticeably worse. Now, even using 100% of the [American] nation's corn crop would supply [alcohol for] only 7% of the fuel consumed by its vehicles [22].

So, strangely enough, many of the conclusions being reached now – that it only really makes economic sense to make alcohol from cellulose, and not from food – were already reached by General Motors researchers in 1921. So, what happened to stop alcohol from being used as a fuel? After all, most countries of the present-day European Union were already using a 5% blend of alcohol with their gasoline in the 1930s, long before most people had even heard the word "biofuels".

The answer comes down to two words: Standard Oil. But before we look at the decision to switch to leaded gasoline, let us first sum up where General Motors was going: or though they were going, and why.

Two ethyls on the horizon

"Thus, during the time Kettering and Midgley researched anti-knock fuels, and especially after tetraethyl lead was discovered, there were two "ethyls" on the horizon for General Motors: Ethyl leaded gasoline, which would serve as a transitional efficiency booster for gasoline, and ethyl alcohol, the "fuel of the future" that would keep America's cars on the roads no matter what happened to the domestic or world oil supply" [9].

In other words, the long-term goal of General Motors researchers was to introduce high-compression engines that would and could use fuel more economically. At first, the fuel would be gasoline, aided by lead additives to stop knocking. And then, when gasoline started to run out, those same high compression engines could then switch to a fuel that did not cause knocking, ethyl alcohol.

What is knocking? It occurs when the burn or explosion of fuel spreads too irregularly after ignition. Instead of one flame front spreading uniformly in what is basically a controlled explosion inside the piston, several different flame fronts develop where they shouldn't, and cause the explosion to proceed far more quickly – and unpredictably – than planned for.

The result is a sudden down thrust of a piston, which ruins the steady, regular thrusts essential to spinning a crankshaft smoothly. And, if not stopped, knocking can soon ruin the engine as well. Knocking is not a problem with a low-compression engine, or with a diesel engine. But it is a huge problem when one is trying to improve the fuel efficiency of an engine by increasing the compression.

As Kettering and Midgely had discovered
through their pioneering research, there were two ways to solve it. One, the high percentage direction, was to add alcohol to the gasoline, mixing it in various proportions of 5% or higher or even use pure alcohol (methanol or ethanol) as a fuel, as no knocking resulted. Modern lead-free petrol typically uses methanol, ethanol or even benzene to stop knocking.

Or, one could use far smaller concentrations of a special additive compound, the low-percentage direction. This compound, originally iodine (far too expensive) and later tetraethyl lead, effectively dampens the smallest, irregular explosions and allows one steady burn to develop properly.

In chemical terms, this compound absorbs just enough of the free radicals, particularly oxygen radicals that developed during combustion, and leaded gasoline? The exact reasons are not very clear. All that Kovarik says is that, in late 1920, Midgely was more interested in meeting Standard Oil Co. officials than with Hibbert, who was researching a process to convert cellulose into ethyl alcohol alcohol alcohol [9].

Clearly, Kettering was no longer worried about American oil supplies drying up. In another paper, Kovarik notes that Kettering did not think gas was discarded when oil supplies proved to be plentiful and TEL [Tetra ethyl lead] proved to be profitable in the mid-1920s [10].

Whatever the reasons were, the consequences were profound. General Motors formed an alliance with Standard Oil and the Du Pont Corporation, creating the Ethyl Corporation. In 1925, making this highly poisonous chemical resulted in a public outcry, following the deaths of some 17 workers and injuries, from lead poisoning, of at least 149 [10]. Why the resulting public health enquiry did not ban TEL is a story in itself [10]. The result was that by the mid 1930s, the motor ing industry in the United States had largely standardised on leaded gasoline.

Only sixty years later were the public health dangers of leaded gasoline recognised, and lead banned. In a sense, General Motors current problems can be traced to the adoption of leaded gasoline, because it marked the trend towards the "gas guzzler", large, uneconomical cars that consumed ever more cheap, leaded petrol, that became the quickest way for the automotive industry to make profits. Alcohol as the fuel of the future had joined electric cars, hybrid cars, and a need for better fuel efficiency as things that no longer really mattered.

While the USA turned increasingly to leaded petrol after 1925, most other industrialised nations turned to bio-alcohol: This was especially true for Europe, where most countries routinely blended bio-alcohol with their gasoline between 1925 and 1937. And this brief period is worth looking at, for it shows how bio-alcohol was used extensively in industrialised countries as a fuel, without affecting food prices in the slightest.

How to produce bio-alcohol without affecting food prices?

"By the mid-1920s ethyl alcohol was routinely blended with gasoline in every industrialised nation except the United States. 10% to 25% alcohol blends were common in the Scandinavian countries, where alcohol was made from paper mill wastes; in France, Germany and throughout continental Europe, where alcohol was made from surplus grapes, potatoes and other crops; and in Australia, Brazil, Cuba, the Philippines, South Africa, and other tropical regions, where it was made from sugar cane and molasses" [9].

Can biofuels be produced without affecting food prices? The answer appears to be yes: if they can be made from surplus agricultural crops or waste products from industry like paper mill wastes. And, if one could somehow repeat what most of Europe managed to do between 1925 – 1937. Exactly how this could be achieved is far beyond the scope of this article, but many of the practical measures introduced then could doubtless be applied again, allowing for the changed times.

The key appears to be the idea of using surplus crops, instead of producing crops in competition with foods. Of course, the immediate problem is what happens when there are no surplus crops any more. This was the situation after 1937, as Europe shifted gears and prepared for war. Industrial production thereafter shifted away from producing alcohol to producing war materials. Crop failures in 1938 and 1939 also helped to eliminate surpluses. But for 12 years producing alcohol for blending into fuel enjoyed considerable success in Europe because of two different measures: tax incentives encouraging this, and regulations enforcing it. Hungary, Poland and Brazil followed the French and Italian examples with mandatory alcohol and gasoline blends in national fuels in the 1920s and 1930s, while the tax incentive approach was adopted by many other European nations such as Switzerland, Sweden, Germany (the United Kingdom) and Czechoslovakia [9].

France and Germany, two key members of the European Union, had both known insecure oil supplies during World War I. Germany had gone further, with alcohol obtained from agriculture providing fuel for every motor car in the empire and most of the German transportation system after 1915 [9].

But it was the Second World War that showed that burning wood could do far more than generate heat. It could also be used to drive cars and trucks: an idea, strangely enough, that is being rediscovered as research into advanced biofuels continues.

Running on empty

"In occupied Denmark during World War II, 95% of all mobile farm machinery, tractors, trucks, stationary engines, and fishing and ferry boats were powered by wood gas generator units. Even in neutral Sweden, 40% of all motor traffic operated on gas derived from wood or charcoal. All over Europe, Asia and Australia, millions of gas generators were in operation between 1940 and 1946" [15].

What do you do when, suddenly, no petrol is available and you somehow have to keep cars, lorries, engines, ships and tractors running? This was the situation that many countries found themselves in soon after the outbreak of World War II, in 1940. It was almost as if the worst fears of Charles Ketttering had come true overnight, and the world had suddenly run out of oil. Actually, in 1940, lots of oil was still available, but war had created the same result: oil suddenly became virtually unobtainable.

While alcohol for fuel was no longer available in large quantities, wood was. And when petrol supplies disappeared in 1940, older people remembered what they had used before petrol – gas: fuel gas, used since 1840 in Europe for heating and lighting. Wood gas is very similar to fuel gas, except for its source. While fuel gas was usually made in the 19th century by heating and reducing coal and peat in a gasworks, wood gas was be made from wood chips in a far smaller bin heated by charcoal, in what was known as an Imbert gasifier.

The main gases formed – carbon monoxide (CO) and hydrogen (H2) burn reasonably well in both petrol and diesel engines, forming carbon dioxide and water. Called synthesis gas, this mixture of CO and H2 is also produced on a huge scale today by heating coal, and used to form a variety of hydrocarbons, including octane, at Sasol's gasifier.

But the Imbert gasifier was far simpler, and was mass produced during World War II by many European automotive
companies, including General Motors, Ford, and Mercedes Benz [15]. However, it had disadvantages. Besides having somewhat low efficiency, operating it meant shoveling in chunks of wood chips, and lighting all this by means of charcoal. Almost like having to get a braai or barbecue ready every time you wanted to use the car.

Also, danger was never very far away. The gasifiers produce carbon monoxide, an extremely poisonous gas, and sometimes exploded. Small wonder then that, once petrol again became available in 1946, the use of these generators was quickly discontinued. But, they did keep millions of cars, lorries, engines, tractors and ships moving during the difficult war years. And, ironically, we may yet see these generators again in the future, but in a different form.

While still a long way off from large-scale use, researchers have recently announced the first direct conversion of plant cellulose into gasoline components [21]. Instead of breaking down the cellulose into its component sugars and then producing alcohol, the cellulose is chopped up, rapidly heated in the presence of solid catalysts, and then rapidly cooled. The resulting liquid can be used “as is” for a high octane gasoline blend or further treated to form the remaining fuel components. Some researchers have claimed they can even produce jet fuel this way. So, just maybe, a variant of the old nineteenth century fuel gas process could, two centuries later, be used to produce fuel for cars, trucks, modern aircraft and maybe even fighter aircraft. And the idea of using “switchgrass or poplar trees grown as energy crops, or forest or agricultural residues such as wood chips” to drive cars and run engines suddenly does not seem so new, as after all, millions of people were basically doing that between 1940 – 1946.

In the next article, let us briefly look at so-called “good” and “bad” biofuels: and why bad economics can give even the best of fuels a bad name. And, some very basic points about global warming, economics and agricultural yields that are often forgotten in all this.

References