Making it up as you go along

Chemists can make liquid fuel from biomass — or from coal. **Heidi Ledford** weighs up the pros and cons.

Brian Schweitzer, a rancher and the Democratic governor of Montana, has 'folksy' down to a fine art. In a bolo tie, jeans and cowboy boots, Schweitzer shifts seamlessly from jokes about how his border collie, Jag, drinks out of the toilet to analyses of energy policy in which every complex problem gets its down-to-earth soundbite, from pumping carbon dioxide into the ground ("It came from those rocks, we're just sending it home") to public perceptions of coal as a dirty source of energy ("To a lot of people, coal is a four-letter word").

Put these aperçus all together and you have a pitch for turning coal into oil, an idea Schweitzer and his constituents have 240 billion reasons to take seriously. With 8% of the world's reserves, Montana has enough coal to make 240 billion barrels of diesel fuel, which is in the same ball park as all of the proven reserves claimed by Saudi Arabia.

Schweitzer is far from alone; many politicians and businessmen are now eyeing a chemical process called the Fischer–Tropsch synthesis as a way of converting solid hydrocarbons or natural gas into liquid fuel. The great advantage is energy security: Fischer–Tropsch technology allows domestic coal to replace foreign oil, which is pretty attractive if you're sitting in Washington DC or Beijing, let alone Billings, Butte or Bozeman. Another potential advantage is environmental: the fuel produced by Fischer–Tropsch methods can be made to burn more cleanly than diesel. It could thus ease the adaption of cars with efficient diesel engines in countries, such as the United States, that have so far been resistant to such technology.

The obvious drawback, though, is also environmental. The process of converting coal into liquid and using it for transportation releases nearly twice as much carbon dioxide as burning diesel made from crude oil does. In a world conscious of climate change, that excess carbon is a problem. "If you make liquids from coal and don't capture carbon dioxide in the process, you're effectively doubling emissions," says Eric Larson, a research engineer at Princeton University's Environmental Institute in New Jersey.

One way round this problem might be to take the carbon dioxide and bury it underground. Another would be to replace fossil-fuel feedstock with biomass. That is in some ways an attractive option — but it is also, as yet, an immature technology.

Expense is another issue. To date, Fischer–Tropsch has always been rather costly, and thus something people normally start to do only when they have no alternatives. Its first major use was during the Second World War, when the blockaded Nazis produced about 90% of their diesel and aviation fuel with the technologies originally developed by Franz Fischer and Hans Tropsch at the Kaiser Wilhelm Institute for Coal Research in 1923. South Africa began liquefying coal in response to apartheid-era sanctions, and in part as a result of its investment back then, continues to derive about 30% of its fuel from liquefied coal.

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Around the bend: is there a feasible future for liquid fuels made from coal?

To make liquid fuel from coal, you first shatter the long hydrocarbon chains into a mixture of hydrogen and carbon monoxide using high temperatures and intense pressure. This is also the first step for the "integrated gasification combined cycle" plants, seen by many as the future of coal-fired generation — a technology that has many synergies with coal-to-liquids. In Fischer-Tropsch synthesis, the gas is not burned but channelled to a reactor where catalysts reunite the carbon and hydrogen to form hydrocarbon chains of varying lengths, including diesel and petrol. During both phases — gasification and liquefaction — some carbon is given off as carbon dioxide.

Because contaminants such as mercury and sulphur can inhibit the reaction, companies have a built-in incentive to remove impurities from the gas before liquefying it. And the choice of catalyst allows the make-up of synthetic fuel to be tailored to an extent. As a result, diesel produced by the Fischer–Tropsch process is quality stuff. It contains less sulphur and fewer contaminating aromatic compounds, such as benzene and toluene, and releases fewer particulates when burnt than regular diesel fuel does.

Capturing carbon

But none of that solves the carbon dioxide problem. In the United States, all coal-to-liquid plants on the drawing board would include carbon capture followed by, in most cases, sequestration, says Lowell Miller, director of the US Department of Energy Office of Sequestration, Hydrogen, and Clean Coal Fuels. That includes the 22,000-barrel-a-day operation near the town of Roundup that Schweitzer has proposed. But the Natural Resources Defense Council (NRDC), a US-based environmental group, says that even if 90% of that carbon were captured, producing and using coal-derived fuels would still release 8% more carbon dioxide than petroleum-derived fuels[1]. "Even if you do carbon sequestration, at best coal-to-liquid methods are still no better than crude oil in terms of lifecycle emissions," says David Hawkins, director of the NRDC's Climate Center. "And if we are building a new industry to make transportation fuels, we need to build an industry that produces fuels that are significantly lower in carbon dioxide emissions."

In China — which, like the United States, is not bound by the Kyoto Protocol, and which has vast coal reserves — carbon sequestration is less likely. Yong-Wang Li, director of Synfuels China in Shanxi, says that there are two proposed coal-to-liquid industrial plants under consideration in China and that, at present, neither proposal contains plans for sequestering carbon.

The advantage of using plant biomass as a feedstock from which to make synthetic fuel, on the other hand, is that no sequestration is necessary — the emitted carbon is carbon that came

from the air in the first place. If one were to add sequestration to a biomass-to-liquids plant, the result could be 'carbon negative', in that the net effect on the atmosphere would be to draw down the level of carbon dioxide as some of the carbon dioxide fixed by the plant would be sequestered into the planet's crust. What's more, Fischer–Tropsch methods could complement, at the very least, some other biomass technologies.

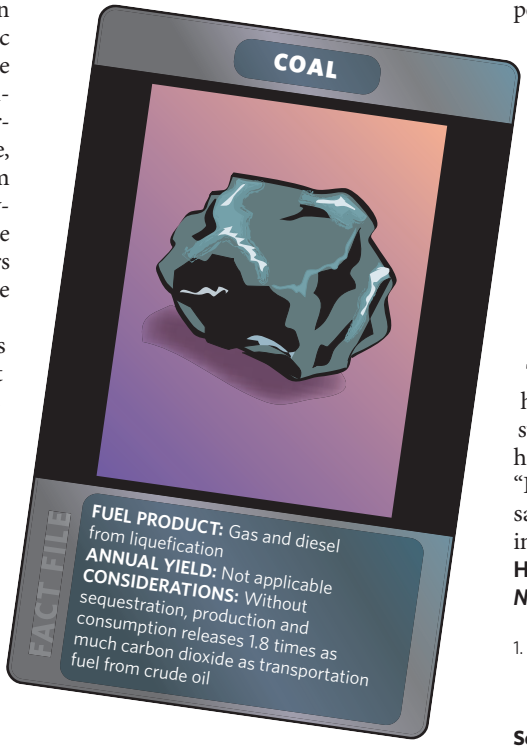
Plant material that contains too much lignin and not enough cellulose for use in cellulosic ethanol projects (see page 673) could still be used in a Fischer–Tropsch system. The technique could open up the possibility of using forest thinnings and other sources of wood waste, or even the lignin-rich residue left over from cellulosic ethanol production, says David Dayton, a senior scientist at the National Renewable Energy Laboratory in Golden, Colorado. Others think that Fischer–Tropsch could outcompete the fermentation of cellulose more generally.

But the technology for gasifying biomass currently lags well behind the development of such methods for coal. The Netherlands has invested a lot of research into the process, but still operates only demonstration-scale biomass-only plants. Choren, a German company, and Shell are building a commercial plant in Freiberg, which will produce 15,000 tonnes per year (110,000 barrels per year) of what Choren calls SunDiesel. Construction of five 200,000-tonnes-per-year facilities that will use wood and agricultural waste is scheduled to begin in 2008. By far the biggest undertaking of its kind to date, the total output from this project would still be enough to supply only about 4% of Germany's projected diesel needs in 2015.

The other big issue is cost. Several US demonstration coal-to-liquid plants, established during the spike in oil prices during the 1970s, closed without leading to further commercial development after oil prices fell in the early 1980s. Miller and Jim Bartis, a policy analyst at the RAND coroporation in Santa Monica, California, both think that oil prices must be above $50–$55 a barrel (159 litres) for coal-to-liquid plants to make long-term economic sense. With oil prices currently just under $60 a barrel that's already an uncomfortably snug fit – and there's no guarantee of prices staying at that level.

Biomass boost

Nevertheless Chevron, Shell and Exxon have all invested in development of Fischer–Tropsch technologies, as has the biggest US coal company, Peabody Coal, which is working on Schweizer's Roundup plant with Rentech of Denver, Colorado. "Some of the big players are willing to take a low rate of return just to establish a technology position," says Bartis. "Once you build a first plant, you're going to learn by doing, and subsequent plants are going to cost less." Another strategy is to concentrate on people who might pay a premium for domestic hydrocarbons. Syntroleum of Tulsa, Oklahoma, recently provided samples of its natural-gas-derived jet fuel, made with technology licensed from Exxon Mobil, to the US Air Force for testing.



For biomass, the situation is worse. Robin Zwart of the Dutch Energy Research Centre in Petten hopes that upcoming improvements in efficiency will drive the price down, but says that oil prices will still have to exceed $70–80 per barrel to make liquid fuels from, for example, willow trees economical. That said, carbon taxation or emissions trading would give a boost to biomass-based systems that are unavailable to coal-to-liquid systems.

That is why, until biomass supply and technology are scaled up, there is still the appealing option of spiking coal feedstock with biomass. Coupled with carbon sequestration, this would reduce greenhouse gas emissions without requiring much change to existing technology, says Robert Williams, a researcher at Princeton University's Environmental Institute. Williams has calculated that a mixture of 89% coal and 11% biomass could reduce carbon emissions by 19% relative to using the same process with coal only.

Because they can't yet make money, current Fischer–Tropsch projects often involve a complex mix of industry partners and government subsidies. Sasol of South Africa, a veteran in the easier gas-to-liquids game, considers government subsidies crucial. Sasol is conducting feasibility studies for coal-to-liquid projects in China and India, and has partnered with oil giant Chevron in Europe. But it is waiting to see what develops with government subsidies, according to chief executive Pat Davies, before committing to any US projects.

So far, the US federal government has proposed tax credits for coal-to-liquid programmes, and provides grants to interested companies. States are also pitching in: Pennsylvania, for example, is guaranteeing $465 million in loans and $47 million in tax credits for a proposed plant in Schuylkill County. Elsewhere in the world — in China, India and the Philippines, for example — liquefaction projects have received pledges of strong government support. And in Germany, biomass-derived fuels are exempt from the heavy taxes levied on other fuels.

Miller says he is optimistic that Fischer–Tropsch fuels could finally establish a foothold in the United States. But 30 years of studying coal-to-liquid technology has taught him to temper his enthusiasm with caution. "I've been in this business for a long time," he says, "and I'll believe it when the shovel goes into the ground." ■

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1. Williams, R. H., Larson, E. D. & Jim, H. 8th International Conference on Greenhouse Gas Control Technologies, Trondheim, Norway, 19-22 June 2006.

See Editorial, page 654.

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