International Transport Forum Web Debate:

Moving away from fossil fuel: are biofuels the answer?

Introductory Statement by Dan Sperling

Increasing concern about climate change and oil supplies are inspiring new interest in alternative means of transport, including fuels. Many alternatives are in contention, and no clear-cut winner has yet emerged. Some are capable of substantially reducing oil use and greenhouse gases, but are not ready for prime time. Others are economically and technically ready to go, but provide little energy and environmental value. While the future is uncertain, what we can say with confidence is that it is almost definitely going to include a mix of biofuels, electricity, and hydrogen.

The problem is that each alternative is at a different stage of development, and each carries with it a different mix of pros and cons. Even within the category of biofuels there are a vast array of choices.

Ethanol

The most successful biofuel to date – indeed the most successful alternative fuel – is ethanol. Beginning in the 1970s, many small distilleries were built across Asia, Latin America, Africa, and the United States to convert starch and sugar materials into ethanol fuel. Everything from cassava and grapes to fruit-cannery wastes and cheese whey were used as feedstock. Even excess low-quality wine in southern Europe was converted into ethanol fuel (and still is). Out of the vast investments made during those times, only two had staying power: sugar cane in Brazil and corn in the US. Together they account for about 80 percent of all the ethanol produced in the world in 2007.

Brazil's experience is most notable.[1] Back in the 1970s, Brazil was already a large sugar producer, and had a long history of producing ethanol fuel. Brazil had already been blending ethanol into gasoline in proportions of 5 to 25 percent since the 1930s, partly motivated by the desire to offset the volatile sugar market.

When world oil prices soared in 1979 and sugar prices plummeted, it was an easy decision to ramp up sugar-ethanol production. Brazil took it one step further than any other country before or since. The government worked closely with the auto industry to build dedicated ethanol cars, and with fuel suppliers to produce ethanol and supply it at retail fuel stations. Brazil was intent on replacing

[1] Michael Barzelay, *The Politicized Market Economy: Alcohol in Brazil's Energy Strategy*, University of California Press, 1986; and D. Sperling, "Brazil, Ethanol, and the Process of System Change," *Energy* 12:1, 11-23, 1987.

gasoline. By 1984, over 90 percent of the cars being sold in Brazil operated exclusively on ethanol.

Strong policy and large subsidies were not enough, though. When oil prices crashed in 1986, pulling ethanol prices down along with them, and sugar prices soared, sugar-cane producers abandoned ethanol and re-embraced sugar. Ethanol supplies shrunk, and motorists couldn't find fuel for their cars. By the early 1990s, ethanol car sales had evaporated to almost zero. Ethanol continued to be produced, but most was blended in gasoline, usually in 20 percent blends.

In the late 1990s, Brazilian automakers adopted flexible-fuel vehicle technology from the United States. These flex-fuel vehicles (FFVs) can run on any blend of gasoline and ethanol.[2] They are not optimized for the unique attributes of ethanol, but they provide car owners with the flexibility to accommodate fluctuating ethanol supplies. Motorists embraced flex fuel cars. By 2006, about 80 percent of car sales were flex fuel.

Meanwhile, oil prices once again rose, pulling ethanol prices with them. Sugar cane producers again embraced ethanol. Production reached 18 billion litres (5 billion U.S. gallons) in 2006. Sugar-ethanol is estimated to be competitive with oil priced at about $35 per barrel.[3]

Brazil offers policy lessons. It maintained a durable ethanol policy for three decades, mandating a 19% to 25% blend in all gasoline sales, banning private diesel-powered cars, taxing gasoline heavily and, for the first two decades, providing an array of subsidies to the industry. Brazil continued to provide these incentives and subsidies even as the country became a major oil producer and oil prices sagged. It was very costly for a very long time (no one has estimated the total cost). Now, with higher oil prices, Brazil has a winner. The industry is competitive for the first time, and the country has a profitable ethanol fuel industry that is unrivalled in the world.

But Brazil is not an energy model. The Brazilian situation is unique. It is not replicable. When it launched its ethanol initiative in 1980, Brazil already had an efficient low-cost sugar cane industry. It also had abundant land, a favorable climate, a large domestic auto industry, no domestic oil supplies, and strong R&D capabilities in farming and ethanol production. Over the years, sugar farming and ethanol production were made steadily more productive. Sugar cane yields have increased and production processes have become more efficient. Innovations such as co-generation of electricity with unused stalks and leaves (called

[2] In contrast with the situation in the United States, where cold weather restricts the maximum percentage of ethanol in the fuel blend to 85% (and even as low as 70% in Minnesota), FFVs in Brazil can run on any blend ratio, including pure anhydrous ethanol.
[3] IEA, Biofuels (2004).

bagasse) further reduced the cost of production and in some cases even generated additional revenue from selling excess electricity back to the grid.[4]

No other country in the world benefits from such a favorable set of circumstances. There is no other country where it makes sense to convert large amounts of sugar or starch crops into ethanol – including the United States.

The US corn-ethanol story in some ways shadows the Brazilian experience. The United States also began subsidizing ethanol production in the 1970s. Corn (maize) was the lowest-cost feedstock available, not sugar cane, and it quickly came to dominate fuel-ethanol production. The subsidies started out in 1978 – equivalent to 40 cents per gallon (10.6 cents per litre) of pure ethanol – and continued to grow thereafter. They were needed because ethanol derived from American corn turned out to be substantially more expensive to produce than ethanol derived from Brazilian sugar-cane. Corn uses much more energy for farming, and the way it is currently harvested (collecting only the kernels from the field and leaving the residue behind) does not deliver nearly as much crop residue to the distilleries that could be used as boiler fuel or to co-generate electricity.

America's corn-ethanol lobby has been extraordinarily successful. Subsidies for (corn) ethanol have soared, and stiff tariffs have discouraged the importation of Brazilian ethanol. The only comprehensive studies on the subject carried out to date have found that total support for ethanol in the United States amounted to over $5 billion in 2006, and can be expected to grow for the indefinite future.[5] This $5 billion included $3 billion for a 51 cent per gallon subsidy, about $1 billion for corn crop subsidies, and additional subsidies from a variety of other federal and state programs. The subsidies amounted to over $1.50 for every gallon of gasoline-equivalent ethanol produced in 2006 (about 4.5 billion gallons were produced, and ethanol has 2/3 the energy content of an equivalent volume of gasoline). That is huge. If a subsidy of this magnitude were made available more broadly, a large range of alternative fuels would become competitive with gasoline.

Unfortunately, the combustion of ethanol emits about the same quantity of conventional pollutants as gasoline (in modern computer-controlled engines). What is worse is that corn ethanol also has little or no greenhouse gas (GHG) benefit. Corn farming is energy intensive. It uses large amounts of fossil energy for fertilizer and harvesting. The fermentation-distillation plants also require

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[4] Costs steadily dropped over the past 30 years, the result of steady improvements aided by continuing investments in research. See José Goldemberg, Suani Teixera Coelho, Plinio Mário Nastari, and Oswaldo Lucon, "Ethanol Learning Curve – the Brazilian Experience," Biomass and Bioenergy 26 (2004) 301-304.

[5] Doug Koplow, "Biofuels at What Cost? Government Support for Ethanol and Biodiesel in the US," Global Subsidies Initiative of the International Institute for Sustainable Development, Geneva, Switzerland, October 2006; and Doug Koplow, "Biofuels at What Cost? Government Support for Ethanol and Biodiesel in the US—2007 Update," Global Subsidies Initiative of the International Institute for Sustainable Development, Geneva, Switzerland, October 2007.

considerable energy, often burning coal – in contrast to the Brazilians who use waste *bagasse* material for energy in their processing plants and in some cases even generate surplus electricity they sell back to the grid. The calculations of net energy use and greenhouse gas emissions are highly complex and can vary considerably depending on where the corn is farmed, how the protein-rich co-product is used, how far the fuel is transported, and so on. A careful review of the many studies on this topic concluded that corn ethanol would reduce GHG emissions about 13% relative to gasoline made from conventional oil.[6] More sophisticated analyses that also consider the sequestering effect of soils and plants conclude that the net effect is probably about zero – zero greenhouse gas benefit -- and that it might even be worse than gasoline.[7]

And then there is one last issue: diverting corn to fuel distorts agricultural markets and raises food prices. In 2006-07, the diversion of corn to fuel contributed to the sharp (50%) increase in corn prices — not just in the United States but also internationally from historical levels of around $2.25 per bushel to about $3.75. The price effects reverberated far afield. Beef prices increased because cattle are fed corn, farmland prices doubled in many areas, soy prices increased as fields were diverted to corn, and corn tortilla prices more than doubled in Mexico, provoking riots.

In sum, corn ethanol is expensive and provides no net environmental benefits. The main societal benefit is a small reduction in oil imports, gained at substantial cost.

Only one cogent argument can be made on behalf of corn ethanol, other than serving the interests of the corn lobby: that even given corn ethanol's shortcomings, corn ethanol could be a stepping stone to more promising biofuels.

Cellulosic and Other Biofuels

More promising biofuels do exist, but they are even more expensive to produce. These are fuels made from the vast array of cellulosic plant materials: grasses, woody material, municipal trash, and crop residues. These materials can be converted into ethanol or any number of other liquid and gaseous fuels. They are

[6] Farrell, A. E., R. J. Plevin, B. T. Turner, A. D. Jones, M. O'Hare, and D. M. Kammen. 2006. Ethanol can contribute to energy and environmental goals. *Science* 311 (5760): 506-8.

[7] Soil sequestration is an issue because expanded biofuel production means bringing more land into intensive cultivation. These lands by definition are less intensively farmed. They might be prairies or rainforests. These lands have been sequestering carbon in the soil for years. When it is broken up for intense cultivation, large amounts of carbon are released. The quantity of these releases are not well understood but early evidence suggests it is a large percent of total lifecycle emissions for a biofuel. See Farrell, Alexander E. and Daniel Sperling (2007) A Low-Carbon Fuel Standard for California, Part 1: Technical Analysis. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-07-07; part 2; and Delucchi, Mark A. (2006) Lifecycle Analyses of Biofuels. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-06-08.

attractive in part because they are abundant.[8] Much more cellulosic material can be harvested at less cost from a plot of land than corn. And cellulosic material can be grown on marginal lands, not just rich farm land. The key remaining uncertainty is the cost of processing these materials into fuel. Because very little R&D funding has been devoted to these processes, they are at an early stage of development.

In 2006, a number of demonstration and pilot plants were being built around the US. Wall Street investors and Silicon Valley venture capitalists were starting to pour money into biofuels, principally corn ethanol but also cellulosic startup companies. In May 2006, Goldman Sachs invested $27 million in Iogen, a Canadian company building a plant in Idaho, to convert wheat straw into ethanol. Vinod Khosla, co-founder of Sun Microsystems and famed venture capitalist was pouring funds into a variety of corn and cellulosic ethanol investments. Even BP, Shell, ConocoPhillips, and Chevron, the oil giants, started investing in a range of biofuels. In 2006, Chevron committed about $40 million over five years to University of California, Davis and Georgia Tech; BP offered $500 million over 10 years to UC Berkeley, University of Illinois, and Lawrence Berkeley National Laboratory; and ConocoPhillips offered $22.5 million over eight years to Iowa State University. In all these cases, the funding was to find new ways of producing biofuels for transportation.

Biodiesel: The Populist Choice

Biodiesel is a relative late-comer to the alternative fuel scene. Unlike ethanol, which is used in gasoline spark ignition engines, biodiesel replaces diesel fuel. Diesel accounts for about 20 percent of transport fuel use in the US and almost 70 percent of transport fuel in Europe. Biodiesel is the only prominent non-fossil alternative for diesel engines. For this reason, and because it is made from renewable feedstocks, it has gained considerable attention. Its potential is quite limited, however.

Biodiesel is derived from animal fats or plant oils. Currently it is mostly made from dedicated plant oil crops, such as soybeans in the United States, rapeseed (canola) oil in Canada and Europe, and palm oil in Asia, and from frying oils discarded by fast food restaurants. US biodiesel production was 850 million litres (225 million U.S. gallons) in 2006, accounting for less than 0.5 percent of diesel fuel consumption. In the European Union, production reached 4.9 billion litres in

[8] Virtually every study on ethanol and biofuels highlights the potential attractions of cellulosic fuels. These include William Morrow, W. Michael Griffin, and H. Scott Matthews, "Modeling Switchgrass Derived Cellulosic Ethanol Distribution in the United States," Environmental Science and Technology 9 VOL. 40, NO. 9, 2006, 2877-2886; and Perlack, R. D., Wright, L. L., Turhollow, A. F., Graham, R. L., Stokes, B. J. and Erbach, D. C. (2005) *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply* (Oak Ridge Natl. Lab., Oak Ridge, TN), ORNL Publ. No. TM-2005_66.. For the state of the art in cellulosic processing, see US DOE, Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda, DOE/SC-0095, Washington, DC, June 2006.

2006 (compared to just 1.6 billion litres of ethanol) and accounting for around 2% of diesel consumption.

Biodiesel production lends itself to small facilities and local initiatives. The basic technology is so simple that it can be — and is in some cases — produced in people's kitchens. The fuel itself is similar to conventional diesel, and can be burned in today's diesel engines in mixtures up to 20 percent. With only small engine modifications, higher blend proportions are possible, though it can reduce engine durability and cause problems in cold weather.

Biodiesel's actual attractions, beyond being simple to make and easy to transport, are modest, with mixed health and safety impacts.[9] Most pollutants are reduced, though a key one, nitrogen oxides, tends to increase slightly. The exhaust is carcinogenic, just like its conventional diesel relative, but overall toxicity is reduced. With waste oils, huge reductions in greenhouse gases are achieved, but with oil crops, the greenhouse gas benefits are modest, and in some cases possibly even inferior to diesel made from petroleum.[10]

Most importantly, the oils from which biodiesel are made have become expensive, and are likely to remain so.[11] It is one thing to use small amounts of used cooking oil to power a few vehicles. Doing so is quite compelling. The feedstock is essentially free and otherwise causes a disposal problem. Using it connects with our desire to make a personal contribution to our mounting energy problems. But consider that a typical fast food restaurant generates less than 40 litres (10 U.S. gallons) per day of waste oil. That isn't nearly enough to power even the cars of the restaurant's employees. It is, figuratively speaking, a drop in the bucket.

Worse, the high cost of making biodiesel from dedicated crops – whether soy, palms, or other plants — is unlikely to diminish. At current prices (over $900 per tonne) the plant oils by themselves cost well over $0.75 per litre ($2.80 per U.S. gallon) in most cases. Add in processing, distribution, and retailing costs, and it easily exceeds $1 per litre ($3.80 per gallon). It can only compete with diesel fuel when crude petroleum is selling at about $150 or more per barrel.[12] In contrast with other alternative fuels, these costs are unlikely to recede much in the future.

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[9] NREL, "Impact of Biodiesel Fuels on Air Quality and Human Health," Summary Report, May 2003, NREL/SR-540-33793, www.nrel.gov/docs/fy03osti/33793.pdf

[10] See IEA, Biofuels (2004). There is considerable uncertainty about the release of N_2O from farming of soy. N_2O is a very powerful greenhouse gas, and considerable amounts seem to be released when fertilizers are used with nitrogen fixing plants such as soy. One estimate, probably considerably overstated , suggests that biodiesel made from soy will result in more than twice as much greenhouse gas emissions as with conventional diesel fuel on a lifecycle basis. See also Delucchi, Mark A. (2006) Lifecycle Analyses of Biofuels. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-06-08. Emissions are also very high in cases where rainforests are planted and plant matter is burned to remove it so that more crops can be planted.

[11] Manuel Frondel and Jörg Peters, "Biodiesel: A new Oildorado?" *Energy Policy* Volume 35, Issue 3, March 2007, Pages 1675-1684. Also, see International Energy Agency, Biofuels for Transport, Paris, 2004.

[12] .

That is because plant oils are a long-established agricultural product and account for most (80%) of the total cost of the fuel. Large-scale production will not substantially reduce unit costs. Biodiesel survives in the United States mostly because of a $1 per gallon ($0.26 per litre) federal subsidy, and the substantial tax breaks and production incentives offered in several U.S. states. In Australia, Canada, the EU and Switzerland, its future survival depends on the continuation of subsidies, tax breaks and renewable-fuel mandates.

Farther into the future, there are some interesting biodiesel opportunities. One is algae. Certain species of algae can produce large amounts of lipids. If some way could be found to farm algae in large facilities at low cost, then this might prove a future source of biodiesel. Alternatively, chemical processes can be used to gasify cellulosic materials and then synthesize the gases into diesel-like liquids (sometimes referred to as BTL). Research is underway to reduce costs for both fuel pathways.

So with this as a backdrop, let's now hear from you.

A few questions to get the debate going:

1. **Are countries right to set volume-based targets for biofuels?**

2. **Which of the biofuels hold the most promise for the transport sector?**

3. **Are subsidies designed to reduce CO_2 emissions best used for biofuel production; if not where should they be targeted?**