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The Potential for Aviation Biofuels—Technical, Economic, and Policy Analysis

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For a number of reasons, the aviation sector may be the most promising for expansion of the cellulosic biofuels industry (Tyner, 2012). The European Union is planning to implement a carbon tax on airplane takeoffs and landings in the EU (EU Business, 2013). Several U.S. aviation companies have expressed strong interest in renewable fuels (Midwest Aviation Sustainable Biofuels Initiative (MASBI), 2013). There are alternatives for the ground fleet that have emerged in recent years such as compressed or liquefied natural gas or electric vehicles. However, these options and ethanol are not viable in aviation. U.S. civilian aviation consumes over 21 billion gallons of jet fuel per year (U.S. Energy Information Agency - Department of Energy, 2014), so it is a sizeable market. For all these reasons, evaluating the technical and economic potential of aviation biofuels has merit. We do that here by summarizing the results of a techno-economic analysis done for the fast pyrolysis process to produce drop-in hydrocarbons, including jet fuel.

Fast pyrolysis is one of the thermochemical processes that goes directly to a mixture of hydrocarbons instead of ethanol. The projected fuel cost is in the same range as current fossil fuels, but the uncertainty in projected cost is very high. Given that uncertainty, it is useful to examine policy options that might help reduce private sector risk in biofuel investments.

Techno-economic Analysis

This section relies in part on a recent techno-economic analysis of corn stover biofuels (Petter & Tyner, 2014). The objective was to estimate the distribution of outcomes from investments in a fast pyrolysis conversion technology.

The technical assumptions were primarily from Brown, Thilakaratne, Brown, & Hu (2013). We replicated the breakeven cost in terms of $/gallon of gasoline equivalent (GGE) from Brown et al. before adapting the engineering analysis to an economic analysis. In so doing, we assumed a 2.5% inflation rate, adjusted some of the key parameters, and added uncertainty in feedstock costs, hydrogen prices, conversion yields, and fuel prices. Technical details are shown in Table 1.

Table 2 is the share in total cost net present value (NPV) of the capital, feedstock, and hydrogen components. The total NPV of all costs was a bit over $1 billion.

Table 1: Selected Technical Parameters

Item	Value
Production capacity	58 million gallons per year
Capital cost	$429,000,000
Debt-equity ratio	50%
Debt interest rate	7.50%
Real rate of return on equity	10%
Inflation rate	2.50%
Plant life	23 years

Table 2: Cost Shares for Key Pyrolysis Cost Components

Item	Cost share (%)
Capital cost incl. working capital	30.3
Feedstock	34.4
Hydrogen	21
Other operating cost	14.3
Total	100

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Uncertainty in future fossil fuel prices was handled in two ways. First, the expected gasoline price was fixed at \$2.68/GGE, which is the economic breakeven price at a 10% real rate of return with no project financing. In other words, it is the price that drives NPV to zero with a 10% return. The breakeven financial price was \$2.62/GGE (again at a 10% rate of return), but there was a 41% chance of a loss at that price. In the second case, the gasoline price was set to increase over the assumed plant life of 23 years at the rate contained in the U.S. Department of Energy's base price projection (U.S. Department of Energy, 2013) for crude oil with a random component added.

The mean feedstock and hydrogen prices were \$83/MT and \$2.06/gal, respectively. Jet fuel would be about 15% more costly to produce, so its breakeven could be around \$3.01/gal. However, any thermochemical process like fast pyrolysis is likely to produce a mixture of products including diesel, gasoline, jet fuel, and naphtha. The analysis accounts for all products produced. It uses \$/GGE to provide a single metric for the base economics and analysis of policy options. The diesel production was converted to a gasoline equivalent using the historical relationship between diesel and gasoline prices, and their respective energy contents.

Policy Options

If there were no policy incentives provided, private sector investments would not likely go forward as there is a 41% chance of loss for any private sector investor at current oil prices. This probability of loss emerges from all four uncertain variables, but future crude oil price is by far the most important factor in driving the investment uncertainty. Assuming the increasing price forecast of the second case, the probability of loss is reduced to 15%. Next, we consider two policy options.

Reverse Auction

Given that future oil price is an important determinant of riskiness of an investment, a reverse auction may be attractive to potential investors. In a reverse auction, military or civilian purchasers of jet fuel would offer to buy a fixed quantity of the fuel each year for some stipulated period of time, say 15 years. The qualified bidder with the lowest bid wins the contract (thus, reverse auction).

Another advantage of this option is that it is well known that a major barrier to biofuels investment is the lack of off-take contracts. An off-take contract is a long-term contract between a buyer and a seller with the price and quantity terms delineated in the contract. It is very difficult or impossible to obtain financing without a contract for the fuel being produced. A reverse auction also solves this problem.

In a reverse auction, potential biofuel suppliers bid for the right to supply a pre-specified quantity and type of biofuel for delivery each year for the term of the contract. Thus, with the reverse auction, for both the biofuel supplier and for the purchaser, the price of the biofuel under contract is known with certainty for the contract quantity and duration. In this scenario we forecasted the result of a forward contract at a fixed price for 45 million gallons per year. The facility always produces more than this amount, and we assumed the additional production volume is sold at the market price for that year.

The analysis of the reverse auction showed that the probability of a loss falls from 41% with constant crude oil prices on average to 13% with the reverse auction. The 13% is due to the remaining uncertainty in feedstock costs, conversion yields, and hydrogen prices, and the fact that all production beyond the 45 million gallon contract was assumed to be sold at the uncertain market price.

We also tested this scenario using the rising Department of Energy (DOE) crude oil price forecast. Using that forecast, the probability of loss went to zero. It is also important to consider the government cost of implementing such a reverse auction policy. The estimated net present value of the government's cost was \$4.8 million for this version of the reverse auction.

Capital Subsidy

In another scenario, we used a capital subsidy of \$5 million. This scenario has about the same expected cost as the reverse auction scenario. For the increasing price case, the reverse auction probability of loss was zero, yet the capital subsidy still had a 14% probability of a loss. Thus, when the reverse auction and capital subsidy have the same expected cost to the government, the reverse auction is far more effective at reducing risk for potential private sector investors. In essence, the government is absorbing the risk because its subsidy cost could be higher or lower, depending on what happens to crude oil prices in the future.

Key Points

There are several important conclusions that emerge from this analysis:

- First, uncertainty abounds in the process of converting corn stover or other cellulosic feedstocks to biofuel. This analysis has quantified many of the important sources of uncertainty, but not all.
- The sources of uncertainty that were quantified were feedstock costs, conversion yields (feedstock to biofuel), hydrogen prices, and fossil fuel prices. While all these factors are important, the future fossil fuel price is, by far, the most important source of uncertainty.

- To reduce private sector risk, a reverse auction resulting in a long-term off-take contract may be a viable option. In our analysis, the reverse auction resulted in a substantial reduction in private investor risk.
- We compared the reverse auction policy with a capital subsidy policy since governments seem to prefer capital subsidies in some form (such as a direct capital subsidy or a loan guarantee). We found that a capital subsidy having the same expected government cost as the reverse auction did not reduce private sector uncertainty nearly as much as the reverse auction. In other words, the reverse auction is a much more efficient and effective policy instrument than capital subsidies.

Big Picture

Stepping away from the details of the analysis, a big-picture conclusion also emerges. Thermochemical conversion technologies such as fast pyrolysis may be close to being economic, considering only expected cost; however, the variance due to that cost and future fossil fuel prices is large enough to deter private-sector investment especially in early plants. Once investment risk is taken into consideration, it is clear that private investments will not be forthcoming without off-take contracts. A reverse auction would result in such an off-take contract.

It will be difficult to get these contracts for the first few plants in the private sector because the likely contract price would be higher than the equivalent fossil fuel prices. Since these plants produce a mixture of products, there would need to be contracts or swapping mechanisms for all the plant outputs. Commercial airlines are only interested in jet or aviation fuel. The U.S. Navy may be interested in both jet fuel and diesel.

The bottom line is that the technologies with the assumptions used in this analysis may be getting very close to being competitive over the likely 20-year production horizon of any commercial plant. However, there are no financing mechanisms available at present to get the industry moving.

The Navy, DOE, and the U.S. Department of Agriculture (USDA) have created a partnership to get some early aviation biofuel plants built. The program hopes to enable the Navy to procure biofuels under provisions of the Defense Production Act (Else, 2009). Under this partnership, companies are being selected based on submission of techno-economic and greenhouse gas analyses. The selected companies will receive capital subsidies from DOE and feedstock subsidies from USDA that, hopefully, will get the product price down low enough to be competitive with fossil fuels.

Unfortunately, the length of contracts envisioned at present is one year with a possibility of 3-5 years available. The packages of incentives may or may not work to get plants built and producing aviation biofuels for the Navy. While this innovative partnership is to be commended for helping to get the industry moving, the analysis in this study suggests that a reverse auction would stimulate private investment at a lower total cost to the government while providing greater risk reduction for private sector investors.

We believe there is significant potential for aviation biofuels for both civilian and military applications. The techno-economic analysis suggests the fast pyrolysis process with hydrogenation of the bio-oil is getting close to being economic. Now we need a policy environment that is conducive to stimulating investment in advanced biofuel production facilities.

For More Information

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