**Title: Relative Economics of Sustainable Aviation Fuels, versus competing Biocommodities and uses**

**Lead Author: Michael Lakeman (Boeing)**

**Contributors (alphabetical): Michael Epstein (GE), Nicolas Jeuland (Alfa-Bird/IFPEN), Stephen Kramer (Pratt & Whitney), Kristin Lewis (Volpe), Laurie Starck (Alfa-Bird/IFPEN)**

**Gap/Problem statement:**

As an ever increasing array of technologies are developed to produce aviation biofuels and other bio-based products, priorities must be identified for how to invest in this technology landscape. However, the relative economics of competing uses of biomass resources are not well understood. Therefore technology and commercial investments may currently being made in approaches with little chance of commercial success due to competition in the future.

**Background:**

Considerable effort is going into the research and development of technologies supporting the growth of the aviation biofuel industry. At the same time, a broader bio-based economy is growing, with development of not just other forms of biofuel (diesel and gasoline substitutes) and bioenergy (coal and natural gas substitutes), but also bio-based materials such as bioplastics and renewable chemicals.

As the economy moves towards renewable commodities, increasing demand from a number of different end-uses will be placed on a limited supply of sustainable biomass. Some of the uses of this biomass are complementary. For example, when a plant oil is extracted from an oil seed crop, the oil can be converted into aviation fuel, and the non-oil meal, rich in proteins, can be used to produce other bio-products. What is not clear is just which use that meal will be put to. It could be sold into the animal feed markets, burned for process energy, thermochemically converted to bioplastics, or gasified to go into a bio-based chemical refinery stream. Even less clear is the case of sugar, which is the fundamental biological building block, and heavily in demand for any downstream process that uses biology to create products.

Competition may also occur, not just for feedstocks but also intermediate products. For example, alcohol-to-jet pathways are receiving serious attention from researchers, companies, and end-users. The dehydration of bioalcohols produces reactive olefins which are then oligmerized to produce hydrocarbons, and finally jet fuel. Olefins, however, are valuable intermediates in the production of many other chemicals. It is not clear to which use those olefins are likely to be directed.

In terms of pure efficiency of energy production, there may also be competing uses for biomass among sectors; electricity production from biomass combustion is in fact more efficient in terms of energy conversion than any derived products. Therefore, it is likely that fuels or other bio-based products will have to provide a premium in terms of profit in order to successfully compete for biomass feedstocks.

Some of that premium may come in the form of the cost of carbon, as the substitution benefit for using a bio-based product may differ between sectors, depending on what fossil source and technology is being replaced. For example, electricity as a market is becoming less carbon intensive over time, and therefore a relative carbon premium may be available for displacing liquid petroleum fuels.

Even among liquid biofuels there will be competition. With HEFA production it is possible to produce both diesel and kersoene from the same volume of feedstock. There is a strong synergy between both products, but also an important competition. According to the yield that is targeted for each product (diesel or jet fuel), the unit settings have to be changed. Moreover, it is known that some vegetable oils will allow a higher yield in jet fuel that others. The economic viability of such processes has to take these factors into account. Likewise with the alcohol-to-jet pathway, the competition between the price of a volume of bioalcohol as a fuel, and its value as an input to a jet fuel production facility needs to be clearly understood. Regional differences in supplies of feedstock and demand for different biocommodities will likely affect the analysis.

In the near term the uses for much biomass and many bioresources will be clear, driven by expediency of local transport logistics, requirements of pioneer refineries and the need to drive process technoeconomics by accessing small volume, high value end-uses. However, once commodity-scale production is reached as the bio-based economy matures, feedstocks, by-products, and intermediates are likely to become fungible, tradable, and ratable, leading to decisions around utility being driven by economics (production costs, markets) and not expediency. In order to avoid research, development and demonstration "dead-ends", an understanding of these future competitive dynamics is needed now, to prioritize where to invest in the most advantaged technologies.

**Current Status:**

Much of the technology being developed to produce Biocommodities, including aviation biofuels, are in early stage, precommercial development. The focus is on feasibility, and practicality – answering the questions "can we make this?", "how should we make this more efficiently?", but not tackling the question of "should we make this?" Where competition is acknowledged, and rightly so, is against the petroleum or fossil fuel-based products which the bioproducts are aiming to displace. However, little robust economic analysis has taken place to date *within* the biocommodity arena [author's note: *at least that I am aware of. Extensive literature searches have not turned up any substantial body of research*]

**Solvability and Approaches**

The kind of economic analysis envisioned here requires no new technology development, and should be executable using the current state of the art and tools of a research economist. The output will however rely heavily on assumptions of various technoeconomic parameters for the competing processes, as well as assumptions of how markets for competing end-uses develop over time. As such the output of the analysis will only be as good as the access the researchers have to proprietary data, which can at times be hotly protected. This issue will likely by the largest challenge for successfully addressing the question raised by this white paper.

**Benefits to industry as a whole**

The analysis proposed here would help assist in rationalizing investment decisions, not just for technology development, but across the nascent aviation biofuel industry. By highlighting where competition will be most fierce for limited bio-sourced inputs or intermediates, such a study would have the dual benefits of illuminating pathways for which the business case is threatened, but also suggesting where technical improvements could lead to improved competitiveness. Additionally, there will be benefit to a wider audience, including all those working in areas relating to renewable commodities.