Hong Jin
Associate Engineer, Biofuels
ConocoPhillips Company
Bartlesville Technology Center
HWY 123 & 60, Bartlesville,
OK 74004
Phone 918.661.4401
Fax 918.662.1097

ConocoPhillips

Anil Prabhu
California Air Resource Board
Tel: 916-327-1501
Email: aprabhu@arb.ca.gov

February 21, 2008

Dear Sir,

Thank you for allowing us the opportunity to provide information for the greenhouse gas (GHG) emissions for renewable diesel pathway. It is our pleasure to work with the California Low Carbon Fuel Standards committee and incorporate renewable diesel fuel into the California GREET model. As you might be aware, there are recent publications by Reinhardt et al at IFEU and Shonnard et al. at Michigan State University on the life cycle GHG emissions for rapeseed NExBTL diesel, and soy Green Diesel (based on the 2006 DOE report submitted by UOP LLC). In addition, there is a paper (under review) by Wang et al. at Argonne National Laboratory that compares the life cycle GHG emissions by petroleum diesel, soy biodiesel and soy renewable diesel.

Significant variations are observed between results of the three studies, primarily due to the difference in the byproduct allocation methods. In the IFEU study, GHG emissions are allocated with substitution method to the byproducts in the life cycle of rapeseed NExBTL diesel, which includes the meal generated during the rapeseed crushing process, as well as the fuel gas (light hydrocarbons) and naphtha during the vegetable oil hydrogenation process. In the MSU study, GHG emissions are allocated to the byproducts (soybean meal and propane) by their mass fractions. Wang et al. proposes a hybrid method for byproduct allocations, the methodology of which is still under review.

In addition, the process energy inputs are different between the studies. Currently there are two commercial processes that convert vegetable oil to diesel-like fuels via hydrogenation, the stand-alone process (i.e., the NExBTL process) and the co-feeding process (the ConocoPhillips process). Energy inputs for the two processes vary significantly primarily for two reasons:

1. Both stand-alone and co-feeding processes require a pretreatment step before the oil feeds are injected into the reactor. However, the level of severity and energy inputs for the pretreatment step are often higher in the stand alone process, because the concentrations of impurities could be detrimental to the hydrogenation catalysts. This is less of a concern for the co-feeding process as the impurities are highly diluted.

2. The products from the stand alone process need to be further isomerized to improve their cold flow properties. These additional steps require extra energy inputs, thus resulting in higher GHG emissions.

At ConocoPhillips, we have conducted internal life cycle assessments for the renewable diesel fuel produced through the co-feeding process, with soybean oil and tallow as the feedstocks. We recognize the upstream inputs for soybean oil production have been established in the California GREET model. Therefore, for soy renewable diesel pathway, we only provide information relevant to the soybean oil conversion process. For tallow renewable diesel pathway, we are in process to verify the upstream inputs for tallow production with Professor Nelson from Kansas State University. We'll submit the information to LCFS committee shortly.

Approximately 5% propane is produced during the soybean oil/tallow conversion process (Table 1). In our study, we allocate GHG emissions to propane as a substitute for natural gas fuel (similar to the IFEU study for NExBTL diesel). However, we shall leave this to the judgment of the LCFS committee.

In our LCA study, the life cycle of soy renewable diesel includes soybean production, soybean transport to crusher, soybean crushing to generate soybean oil, soybean oil transport to a refinery, soybean oil conversion to renewable diesel via hydrogenation reaction (co-processed with petroleum hydrocarbon feeds), and soy renewable diesel transport to blending terminals through pipelines. A hydrogen plant is included in the soybean oil conversion process. Hydrogen is assumed to be generated through steam methane reforming (SMR) process using natural gas as the starting material.

The schematic of soybean oil conversion process is shown in Figure 1. In a typical process, soybean oil is first mixed with the petroleum hydrocarbon feed and hydrogen, then the mixture flows through a heat exchanger (HEX) where it is partially heated by the hot effluent from the reactor (hydrogenation is an exothermic reaction). Following that, a natural gas-fired furnace is used to further preheat the mixed feed to a set temperature before it is injected in the reactor. The product stream from the reactor is sent to the heat exchanger to recover the heat of reaction, and then sent to the diesel pool for shipping and blending. The schematic does not include the petroleum feed, as we assume that the process of petroleum feed is independent of that of tallow.

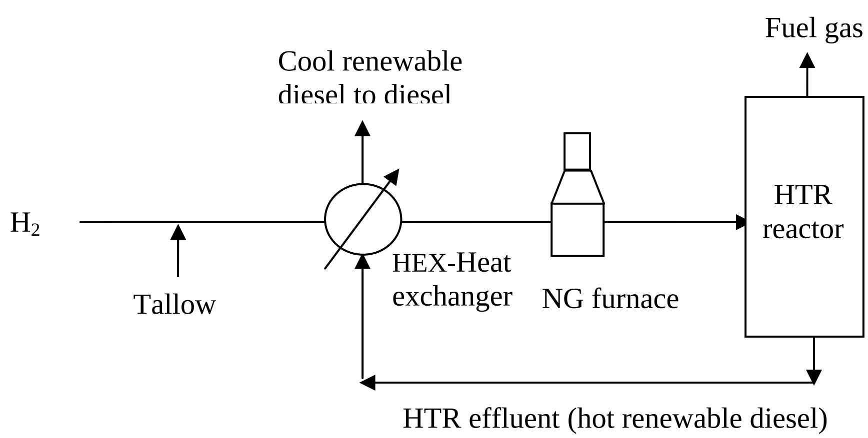

Figure 1 Schematic of co-feeding soybean oil conversion process

The material and energy balances for the soybean oil conversion process (co-feeding process) are summarized in Tables 1a and 1b. Please note the numbers are only representatives of the actual operating data.

Table 1a (left) Material balance normalized to 100 kg vegetable oil feed; Table 1b (right) Energy balance for the conversion of 1 kg soybean oil (lower heating value of vegetable oil is 40 MJ/kg, efficiencies for hydrogen plant, natural gas furnace and heat exchanger are 60%, 90%, and 90%)

Feed	
Soybean oil, kg	100
H_2, kg	3.2
Total, kg	103.2
Product	
H_2O, kg	8.6
CO_2, kg	4.5
CO, kg	0.0
Propane, kg	5.0
Renewable Diesel, kg	85.1
Total, kg	103.2

Feed	
Soybean oil, MJ	40
Natural gas for H_2, MJ	6.4
Natural gas for furnace, MJ	0.2
Total energy input, MJ	46.6
Product	
Propane, MJ	2.3
Renewable Diesel, MJ	37.4
Heat recovered at HEX, MJ	0.5
Total usable energy output, MJ	40.2

There are two stationary emission sources in the co-feeding process, the hydrogen plant and the natural gas furnace (the heat exchanger and the hydrogenation reactor are closed-loop equipment). Emission factors for the hydrogen plants and natural gas furnaces are established in EPA AP-42.

We think the above information is sufficient for the California GREET modelers to add the soy renewable diesel pathway for the co-feeding process. In addition, we could provide the vehicle emission data if they need to be incorporated. Please feel free to contact us if there are any questions or comments regarding the letter. Alternatively, we would be very happy to meet in person at your request.

Look forward to hearing from you soon.

Sincerely,

Hong Jin

Cc: Daniel H. Sinks, Scott A. Mason