Review of the Methodology Used in Calculating Fuel Carbon Intensities and of the Use of Three Life Cycle Greenhouse Gas Emissions Models

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<u>Background</u>

This response is based on a request for review of staff reports prepared by the Air Resources Board (ARB) of the California Environmental Protection Agency (Cal/EPA). The staff reports focus on the methodology of estimating life cycle greenhouse gas (GHG) emissions from different crude oils processed in California refineries. In light of my expertise, this review is focussed predominantly on the conclusions in Staff Report 2 titled “Calculating Carbon Intensity Values of Crude Oil Supplied to California Refineries” (Memorandum dated January 21, 2015 from Mr. Jim M. Aguila (ARB) to Dr. Gerald W. Bowes (Cal/EPA), Attachment 2). In addition to the specific comments on Staff Report 2, the review comments also include a general assessment of the material provided for review.

<u>*Conclusion 2: Crude Oil Intensity Values*</u>

Based on staff’s assessment of available government, research literature, and internet sources for each crude source, the ARB staff concludes that the assumptions and input parameters used in OPGEE to calculate CI values for crude oil production and transport are reasonable and the model was applied appropriately under the LCFS.

<u>*Comments*</u>

In my opinion, the OPGEE model used to estimate the life cycle carbon intensity (CI) of various crude oils refined in California refineries is detailed in terms of the different unit operations involved in the production, transportation, and refining processes of crude oils. The model includes a comprehensive framework for the consideration of the characteristics of production wells, crude oils, refining processes, and crude oil transportation. The estimated CI values are reasonable; however, there are important points that should be taken into account when using these estimates. My comments are given below on various aspects of the methodology, input data, and assumptions, and include suggestions for a path forward.

Methodology: As there are many unit operations considered in an estimation of life cycle GHG emissions from the various crude oils refined in California's refineries, the data for these assessments have been either developed or collected from various sources by the ARB staff. Any variation in these assumptions and input data will have an impact on the overall life cycle GHG footprint. Hence it is very challenging to arrive at a single estimated life cycle GHG emissions value for a particular crude oil. The values in the report (e.g., Table 1, Appendix H) are specific estimates for various crudes. It might be useful if the numbers are associated with some uncertainty or range. This would help address the variations in estimated values found in different studies for a particular crude oil.

Effect of GHG emission allocation strategies: The method of allocating refinery and upstream emissions to transportation fuels has a major impact on the life cycle GHG emission results. The process level allocations could be in the form of an energy and/or mass basis. Some of these allocation strategies have been made in an earlier study to understand differences in allocation on refinery levels and sub process levels [1]. In the ARB staff report, there needs to be a justification for the allocation method used. Some consideration should also be given to other allocation strategies, such as the allocation of emissions based on fuel hydrogen content, to study their impact on life cycle GHG emissions. Different existing studies use different allocation techniques and report varying results. A consensus on the allocation strategy is needed to help inform policy formulation and decision making.

Use of GHGenius data and assumptions for heavy crude oil from the Canadian oil sands: An LCA is a highly informative but labor-, time-, and research-intensive method. There are several LCA models available [2-5] that would help reduce the workload to perform an LCA for any pathway by providing the basic framework and database. These models provide varying results based on different assumptions, database inventories, and data sources. There are limitations in using these models for the oil sands-based heavier crudes from Canada that are processed in California's refineries. The limitations are specifically related to the assumptions and methodologies built into the model. The ARB report based on the OPGEE model has considered assumptions and inputs from GREET and GHGenius, and the ARB staff report has specifically used the GHGenius model assumptions and input data for a life cycle assessment of transportation fuels from the oil sands.

GHGenius is based on an estimate of GHG emissions with direct input of process fuel consumed per unit of fuel delivered. The direct relationship between mass and volume is used to proceed from one unit operation to the other. For example, one mass unit of synthetic crude oil (SCO) is assumed to be same as one mass unit of bitumen. This may not always be appropriate as the mass of SCO is always less than bitumen and depends on the upgrading operation. GHGenius considers the API (American Petroleum Institute) gravity relations between feeds to be mass additive, which is not fully justified (the density of crude is additive in volume).

Diesel fuel is one of the main sources of energy for bitumen extraction through surface mining. The estimate of diesel required in the OPGEE model, which is based on the GHGenius model, is almost 100 times higher than the values used in the GREET model and up to 7 times higher than the results of another recent study [6]. This assumption needs to be justified in the report as it has an impact in the overall GHG emissions.

The assumptions in the OPGEE model based on GHGenius regarding electricity production and export from the oil sands are only partially justified. This model uses Alberta's grid electricity ratio for electricity production and electricity export from the oil sands. This assumption is not clear as most of the electricity production in the oil sands is on site and from natural gas. And the extra electricity exported displaces Alberta's grid electricity, of which 53.1% is from coal, 37.4% from natural gas, and the rest from other resources such as hydro, wind, and biomass [7]. This assumption on Alberta's grid electricity ratio for electricity production and export has a significant impact on the overall life cycle GHG emissions of oil sands-based crudes and hence needs further justification.

Steam Assisted Gravity Drainage (SAGD) is another method of bitumen extraction in the oil sands. One of the key limitations to SAGD in the ARB report (as this is based on GHGenius model) is in the area of electricity and steam generation. The consideration of the cogeneration of electricity and steam is very limited. The limited consideration does not represent the actual scenario in oil sands SAGD operations. The use of cogeneration in SAGD operations is expected to increase in future, and this increase will have a significant impact on the overall life cycle GHG emissions.

The upgrading of bitumen produced from the oil sands is an energy-intensive process. The requirement of energy is dependent on the techniques used for upgrading. Most of the energy requirement comes from conventional sources of energy (e.g., natural gas and electricity). Coke, which is one of the by-products of the upgrading process, could be used for energy, but its use depends on the different industrial operations. The majority of the coke is stockpiled and not combusted. This stockpiling should be considered in a life cycle GHG emissions assessment as it has a significant impact on the overall estimated values.

Upgrading operations consume significant quantities of hydrogen to convert bitumen to SCO. There are very limited details on the amount of hydrogen consumed for upgrading bitumen from in situ recovery, and for upgrading bitumen from surface mining there is very limited information found in GHGenius.

Fugitive emissions: The emissions over the life cycle of the production, processing, and use of the various crude oils are an important factor and have an impact on overall GHG emissions. There has been very limited effort to estimate these emissions. The OPGEE estimates these emissions based on the development of bottom-up parameter-based models; however, a real life measurement of these emissions is needed for a credible estimate. The fugitive emissions for different crudes could vary significantly as there are differences in the extraction, production, transportation, and processing of these oils. The emissions could differ significantly for the conventional and non-conventional sources of crude oils.

Biomass use for energy and fuels: Different jurisdictions use different sources of biomass to produce energy and fuels. These could be agricultural or forestry sources. The life cycle GHG footprint for various biomass feedstocks (e.g., wheat straw, corn stover, bagasse) depends on the jurisdiction where they are grown and also on the feedstock itself. These life cycle GHG footprints depend on the inputs (e.g., fertilizer, fuels) for biomass production, harvesting, collection, transportation, and conversion. It is very challenging to estimate these parameters for different jurisdictions. The use of different biomass for electricity generation could have an impact on the electricity generation grid mix for various jurisdictions. Hence this should be added as a cautionary note, and a range of life cycle estimates, as stated earlier, may be more appropriate.

Changing the electricity generation mix with time: The electricity grid GHG emissions for a particular jurisdiction depend on the type of fuels used to produce electricity. The type of fuels could vary significantly from one jurisdiction to another. The electricity grid mix changes continuously with changes in the amount and type of fuel used to produce electricity. For example, in Alberta, recently there has been a significant increase in natural gas-based power generation compared to coal-based power generation. There has also been a significant increase in wind power generation. These sources of power are continuously changing the grid intensity as natural gas- and wind-based electricity have lower GHG footprints than does coal power generation. This lowering of the grid intensity would have an impact on the life cycle GHG emissions of bitumen-based crude oil. There needs to be a system under the LCFS to account for this.

Future LCA footprints: In the current ARB report, the focus is on life cycle GHG emissions from the different crude oils that are processed in California's refineries. In future, and keeping in mind the current water availability issue in California, it would be important to also look at the life cycle water footprints of the different crude oils processed in California refineries. This could involve the development of methodologies to estimate the life cycle water consumption coefficients for various crude oils.

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