

Declaration of Dr. Ranajit (Ron) Sahu

1. A copy of my resume is provided in Attachment A to this Declaration.

2. I have over 17 years of engineering and consulting experience, including numerous projects at US various petroleum refineries since 1992 through the present. For these projects, I have, at various times, been retained by the refineries themselves, by community and environmental organizations, and by local regulators. Thus, I have an understanding of the environmental issues at refineries from various perspectives, including those of the operators, the public, public interest groups, and regulators.

3. My background as a Mechanical Engineer, with over 17 years of engineering, environmental, and energy consulting experience provides the academic and experiential foundations of my opinions below.

4. Enbridge is proposing several pipeline expansion projects "...to promote a American solution to energy reliability and security of crude petroleum supply..."¹. These projects generally involve the transport of Canadian tar-sands derived crude oils (or related products) to the US and the concurrent transfer of diluents from the US to Canada. Specifically, in Minnesota, the following projects are proposed:²
 - Alberta Clipper, a new crude oil pipeline from Hardisty, Alberta to Superior, Wis., that will potentially increase capacity of the Enbridge pipeline system by 450,000 barrels per day (bpd) and later be expandable up to 800,000 bpd.
 - Southern Lights, a liquid petroleum pipeline from Chicago through Wisconsin, Minnesota, North Dakota, Manitoba, Saskatchewan and Alberta to bring light hydrocarbons, or "diluents," to Edmonton for distribution to the oil sands area of northern Alberta. This project involves the construction of LSr, a 20-inch crude oil pipeline from

¹ <http://www.enbridge-expansion.com/expansion/main.aspx?id=1296&tmi=1686&tmt=5>

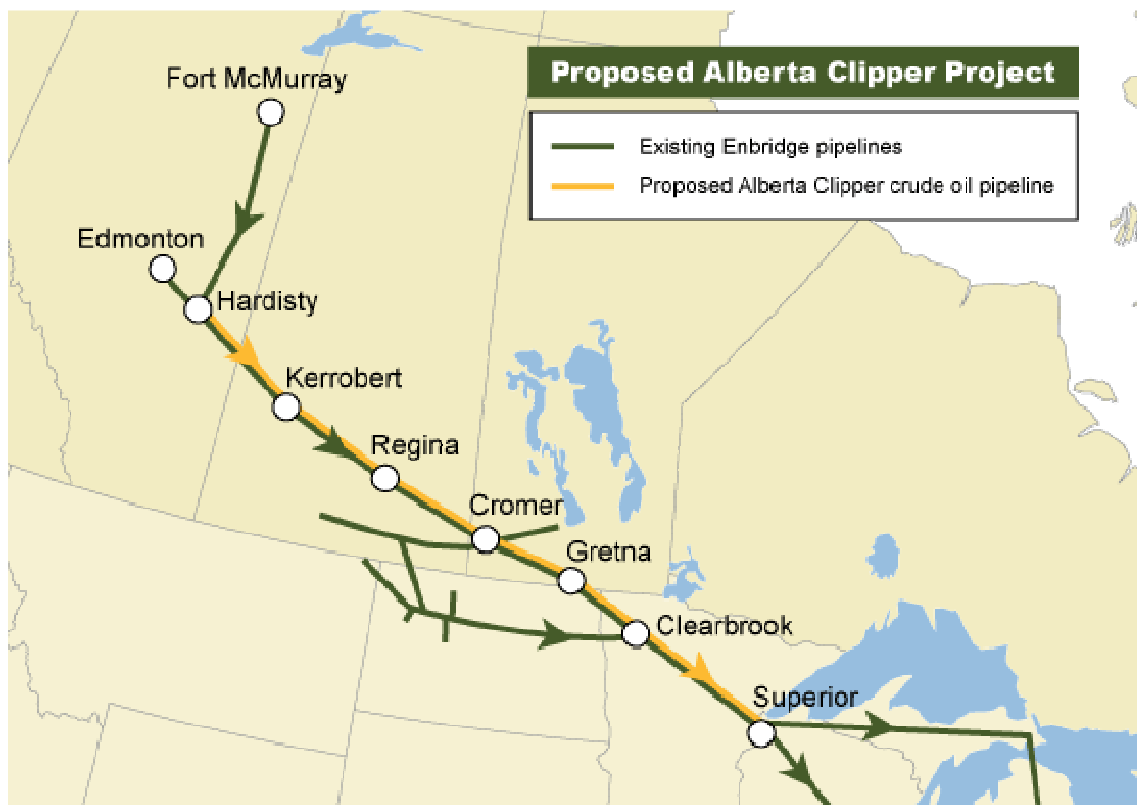
² <http://www.enbridge-expansion.com/expansion/main.aspx?id=1218&tmi=292&tmt=4>

Cromer, Manitoba, to Clearbrook, Minn., to replace the capacity of an existing Enbridge line that will be reversed to transport diluent.

5. My opinions in this Declaration will focus mainly on the Alberta Clipper pipeline and its expansion implications. To a lesser extent some of the comments also encompass the Southern Lights project as well. Although there is some expected work (upgrades of three existing pump stations) in Minnesota as a result of a third (North Dakota System Expansion Phase 6 or NDSE6) pipeline, my comments do not address that project.

Figure 1 below shows a map of the pipeline system taken from the Enbridge website and web pages therein.³

Figure 1 – Enbridge Pipeline System including the Proposed Alberta Clipper



³ <http://www.enbridge-expansion.com>

6. Enbridge representatives have described the projects as follows in their testimony:⁴

104 9Q. Please describe the proposed Alberta Clipper Project.

105 8A. The Alberta Clipper project is a new crude oil pipeline that will be integrated with
106 Enbridge's existing pipeline system. The proposed 36-inch pipeline will span 992
107 miles from Hardisty, Alberta to Enbridge's Superior, Wisconsin terminal. From
108 Superior, the pipeline will deliver crude into Enbridge's other pipelines that run
109 east from Superior across the Upper Peninsula of Michigan and that run south
110 from Superior to Chicago and then beyond to serve key refinery markets in the
111 U.S. and eastern Canada. Enbridge has recently completed an expansion of our
112 system between Superior and southern Wisconsin, and is currently undertaking
113 other system expansions between southern Wisconsin and Illinois.

....

129 11Q. Please describe the proposed Southern Lights Diluent Project.

130 11A. The proposed 20-inch Southern Lights Diluent Project is a 189 mile pipeline from
131 Superior, Wisconsin to Clearbrook, Minnesota, where it will connect to an
132 existing Enbridge pipeline. The flow of the existing pipeline will be reversed from
133 Clearbrook to Alberta, Canada and also connect with segments already completed
134 in Wisconsin and to be constructed in Illinois to complete the Southern Lights
135 Diluent Project and connect refineries in the Chicago area with Canadian oil
136 producers.

7. I could not find the exact composition of the heavy crude that is proposed to be transported via the Alberta Clipper pipeline. Although its physical properties such as density and viscosity have been provided, its chemical composition has not. .

8. It is my understanding that a complete environmental assessment of the implications of mining, upgrading, diluents creation/mixing, transportation, and refining of Canadian tar-sand crude has not been made as part of this project assessment. However, it is indisputable that the entire process will require significant amounts of energy. For example, energy is needed to extract the tar sands containing bitumen, regardless of location of such sands; energy is then required for any upgrading that may be needed before the upgraded products are transported for refining; energy is required for the transportation itself, including via pipeline; and energy is required to then refine the shipped products into the usual products from petroleum refineries (such as gasoline, diesel, jet, and other products). Energy use invariably translates to air emissions of various pollutants, depending on the source of the energy – including greenhouse

⁴ Direct Testimony of Mark Sitek and Denise Hamsher, MN OAH Docket No. 8-2500-19094-2 March 11, 2008 and MPUC Docket No. PL9/PPL-07-361

gases such as carbon dioxide. Additionally, other air pollutants can be generated during extraction, upgrading, and refining. In the comments below, I will focus on the refining aspects.

9. It is my understanding that an assessment of air quality emissions from refining, including an assessment of greenhouse gas emissions, has not been conducted nor is part of the record. Large amounts of pollutants, including greenhouse gases, will result from the refining of the increased supply of heavy crude delivered through the Alberta Clipper pipeline. While exact information is not readily available on which refineries will receive the increased supply, Enbridge has identified refineries in Minnesota and the Midwest that will likely process and refine this heavy crude. With exact locations, accurate estimates for such emissions can be performed with better information as to the products that will be transported and the disposition of these products (i.e., refining locations and the types of refinery processing that will be required). Nonetheless, even in the absence of such specific information, initial estimates of such emissions can be created.

10. While the record does not address the nature of the products that will be transported in the Alberta Clipper pipeline, a reasonable universe of such products and their properties can be inferred. Since these are the products that will be refined, I focus my attention on this pipeline. The tar-sands derived bitumen must be diluted with a lighter hydrocarbon stream to meet the specifications required for shipping in pipelines. The mix of bitumen and diluents is often referred to as “DilBits.” DilBits are blends of bitumen and condensate, typically natural gas condensate. They normally contain 25 – 30 % condensate and 70 – 75 % bitumen by volume. The most common streams are Cold Lake Blend (CLB), Bow River (BRH), and various Lloyd blends (LLB, LLK, WCB).⁵

Additionally, to address the shortage of diluents, producers have started to market SynBits, blends of sweet synthetic (i.e., upgraded) crude and bitumen. SynBits are typically 50% synthetic

⁵ Gary R. Brierley, Visnja A. Gembicki and Tim M. Cowan, Changing Refinery Configuration for Heavy and Synthetic Crude Processing. “...WCS is a somewhat unique in that it has a proprietary formula developed by EnCana, Talisman, Canadian Natural Resources Limited (CNRL), and Petro-Canada. They wanted to reduce the large number of heavy crudes being marketed from Western Canada, and achieve consistency in the heavy crude blends being shipped from Canada. Each batch contains specified amounts of the following crudes; LLW, LLC, CLB, CSB, MKH, and BR. As such, each batch contains condensate, hydrotreated synthetic crude (OSA), heavy conventional crude, medium conventional crude, Cold Lake bitumen, and Athabasca bitumen. Each batch is blended to meet the following specifications; API gravity of 19 - 22°, carbon residue of 7 – 9 wt%, sulfur of 2.8 – 3.2 wt%, and a total acid number (TAN) of 0.7 – 1.0 mg KOH/g.”

crude and 50% bitumen, by volume. The most common SynBits on the market today are Christina Lake Blend (CSB) and MacKay Heavy (MKH).⁶

Finally, there are further combinations such as SynDilBits which are actually blends of condensate, hydrotreated synthetic crude, and bitumen. They typically contain about 65% bitumen, with the remaining volume split between the two diluents streams. The most common of these streams are Wabasca Heavy (WH) and Western Canadian Select (WCS).⁷ In particular, WCS may well become the new marker heavy crude from Western Canada. For example, Platts lists WCS and Cold Lake as standard tradable crudes from Western Canada.⁸

While the exact amounts of products that will be carried by the Alberta Clipper pipeline is not disclosed, it is likely that it will consist of products mentioned above. Further, given the push toward diluents transport, it is likely that DilBits may be more likely to be transported than SynBits or SybDilBit, although some of these are choices dependent on diluents availability, local (i.e., Canadian) upgrading capacity constraints, and economic factors.

11. The Southern Lights Diluent pipeline will carry diluents from US refineries back to Canada and the environmental air quality impacts of this pipeline, in addition to the impacts from the pumping itself, should also include an assessment of the emissions associated with the production of diluents, especially, if additional diluents are required to be produced. This will require assessments of the particular refineries and processes that will be used in diluents production.

12. Regardless of the type of product that may be transported, it will doubtless consist of significant levels of bitumen. For example, compared to the standard West Texas Intermediate (WTI) crude "...DilBits and WCS have about three times the volume of resid material than WTI, 50% more Vacuum Gas Oil (VGO), but only half the distillate range material, and half the naphtha..."⁹ Technologies for upgrading heavy crude feedstocks such as these tar sand bitumens

⁶ Brierly et al.

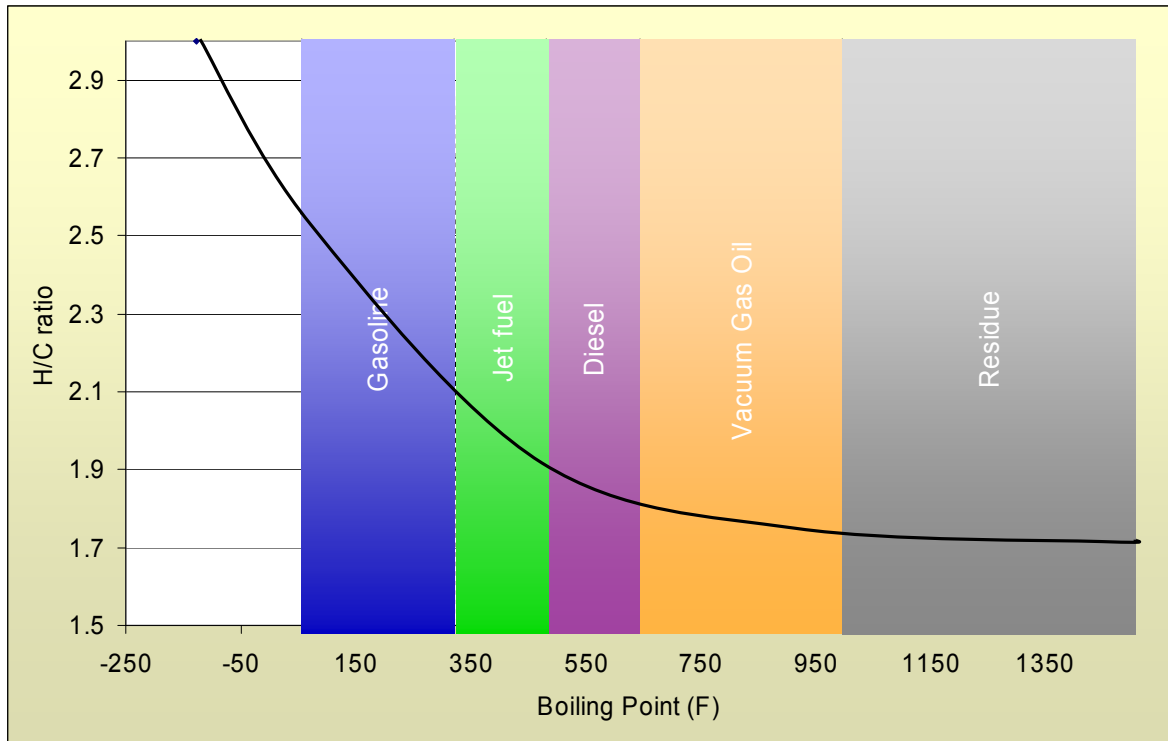
⁷ Ibid.

⁸ From "Methodology and Specifications Guide," Crude Oil, Platts, October 2008. Platts defines Western Canadian Select (WCS) as: Injection at Hardisty. API gravity is 19-22 and sulfur content is 2.8-3.2%. Platts defines Cold Lake as: Injection at Hardisty. API gravity is 19.9 and sulfur content is 3.25%.

⁹ Ibid.

into conventional products in a refinery, can be broadly divided into processes that either involve carbon rejection and hydrogen addition, at the molecular level. Basically, this is because the hydrogen (H) to carbon (C) ratio of bitumen or residue is far smaller than that needed for products such as gasoline, jet, diesel, etc. This is shown in Figure 2 below.

Figure 2 – H/C Ratios of Various Mixtures¹⁰

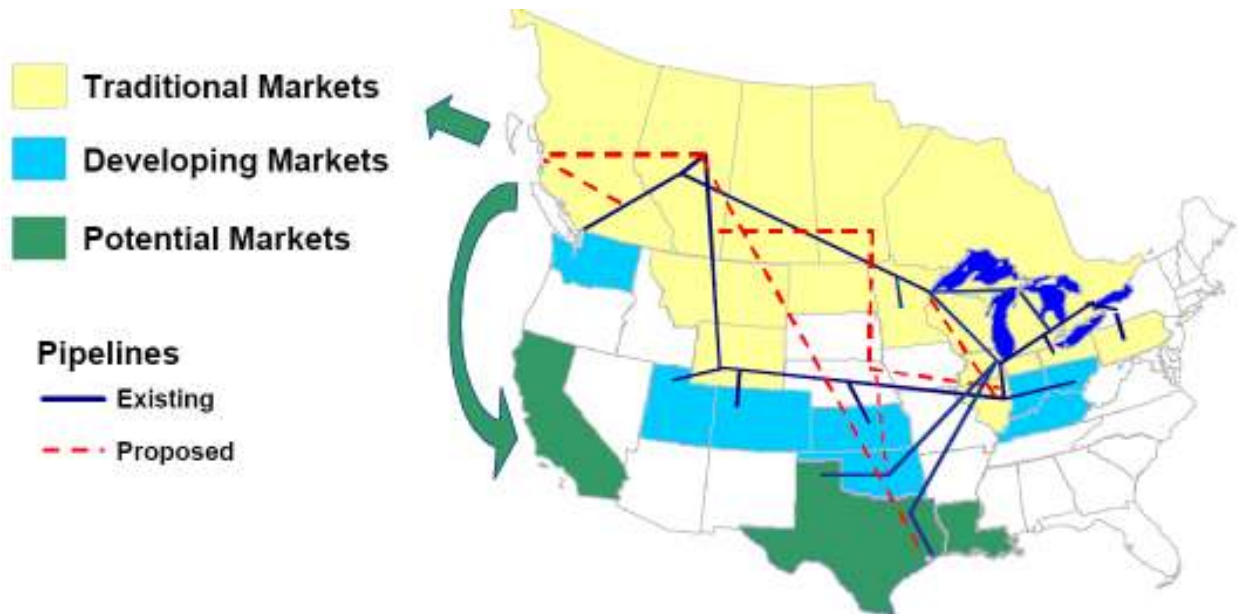


Carbon rejection processes are those...in which hydrogen is redistributed among the various components, resulting in fractions with increased hydrogen/carbon atomic ratios (distillates) and fractions with lower hydrogen/carbon ratios (coke). ...Hydrogen addition processes involve the reaction of heavy crude oils with an external source of hydrogen and result in an overall increase in the hydrogen/carbon ratio. Within these broad ranges, all upgrading technologies can be subdivided as follows:

¹⁰ Bruce, G.B., Bitumen to Finished Products, presentation to Canadian Heavy Oil Association Technical Luncheon, Calgary, Nov. 9, 2005.

13. Much of the products that will be transported via the Alberta Clipper pipeline will likely be refined in the US Midwest.¹³ Figure 4¹⁴ below shows the target refining markets. Most of these refineries will need additional coking and cracking upgrades in order to handle the composition of DilBits as inputs. Finally, it is more than likely that significant amounts of hydrogen will also be required, as discussed earlier.

Figure 4 – Markets for Canadian Tar Sands Crudes



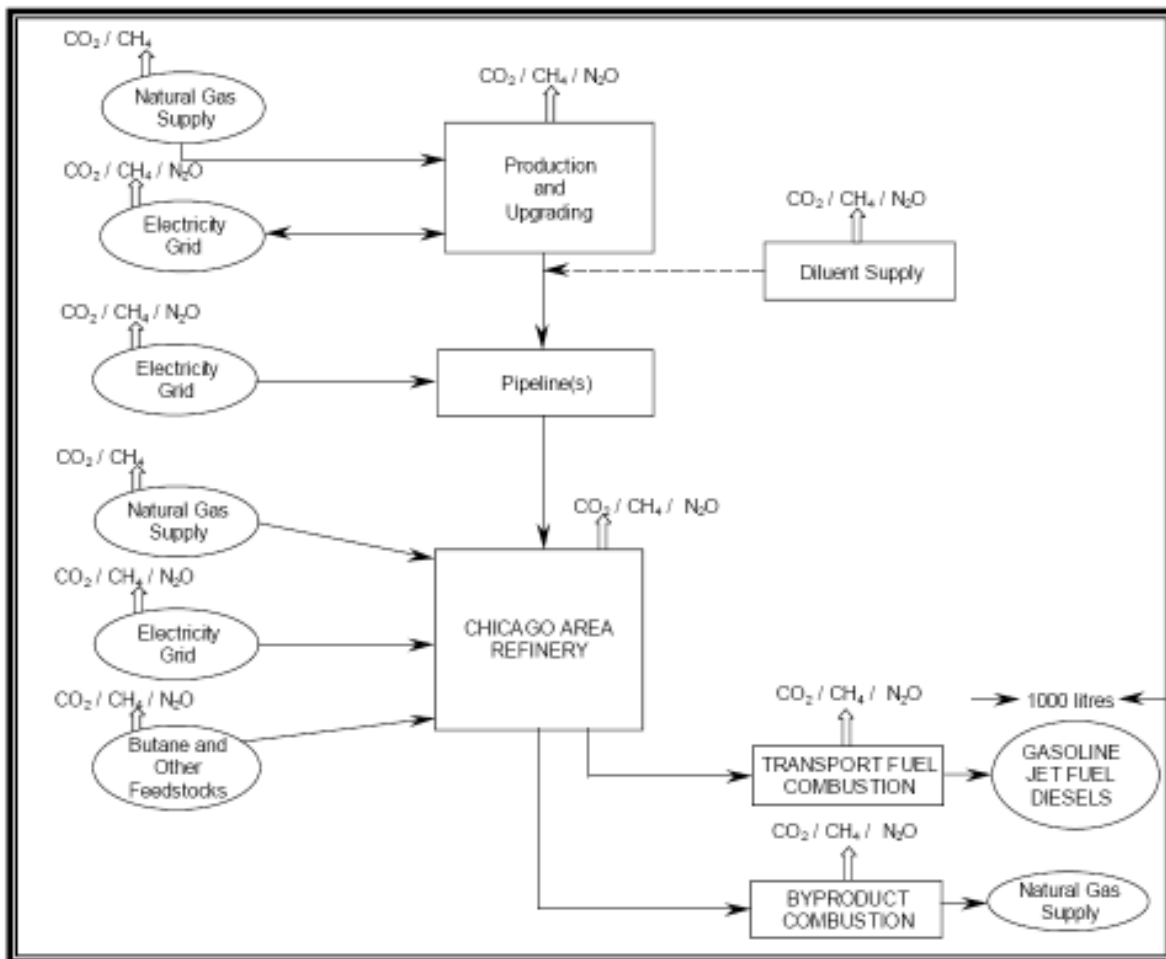
14. Based on the background materials above, it is my opinion that there are several approaches to estimating greenhouse gases from the refining of products that will be delivered to US refineries by the Alberta Clipper pipeline. Again, the accuracy of the estimates will obviously be better if more process detail is available.

¹³ Herein, the term “Midwest” means refineries in Petroleum Administration Defense District (“PADD”) 2, which includes Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Ohio, Oklahoma, Tennessee, and Wisconsin. See <http://tonto.eia.doe.gov/oog/info/twip/padddef.html>.

¹⁴ From “Pricing of Canadian Oil Sands Blends,” Edmonton CFA Society Investing In Alberta’s Oil Sands Conference, Edmonton, Alberta, June 8, 2006 by Purvin and Gertz, Inc.

A prior study¹⁵ is available that attempts to profile greenhouse gas emissions from the refining of heavy crude/bitumen as compared to alternate input crudes. This study considers the greenhouse gas emissions from a range of processes that will be required to produce, upgrade, transport, and refine heavy crude at a typical “Chicago Area Refinery.” The processes considered are shown below in Figure 5. Greenhouse gases including CO₂, methane (CH₄) and nitrous oxide (N₂O) were included in the analysis. While the assumptions considered in the analysis may not be completely valid, it is likely that this type of study can be adapted to provide estimates of greenhouses from the refining of products transported by the Alberta Clipper pipeline.

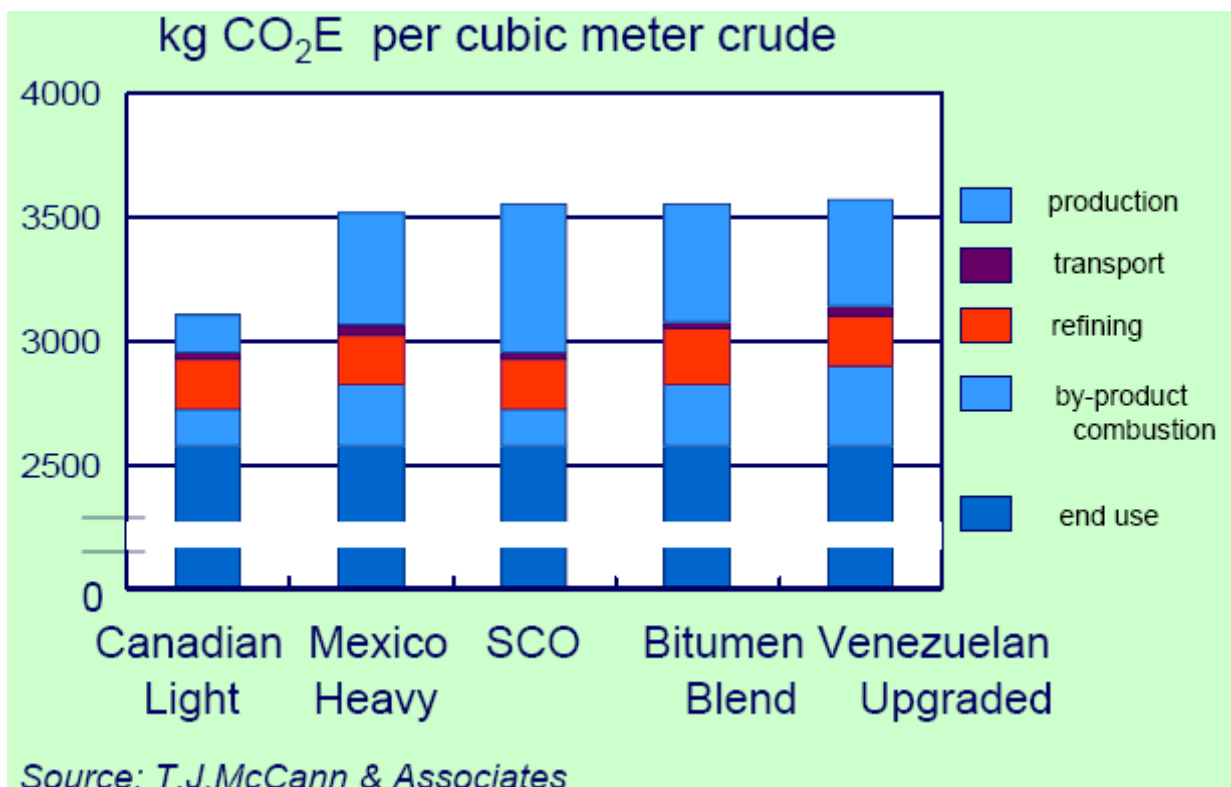
Figure 5 – Processes Considered in McCann 2001 Study



¹⁵ “Typical Heavy Crude and Bitumen Derivative Green House Life Cycles in 2007,” T.J.McCann and Associates, 2001.

15. As a result of the study above, the CO₂ equivalent emissions per cubic meter of crude refined is provided in Figure 6 below. As can be seen from the Figure, roughly 200 kg equivalent CO₂ is emitted for every cubic meter of “Bitumen Blend” refined. For the entire life cycle, the figure is a little greater on 3500 kg CO₂ equivalent. Using the ultimate pipeline capacity of 800,000 barrels per day, the CO₂ equivalent from refining alone is approximately 18.77 million kg per day (over 7.5 million tons per year) and the CO₂ equivalent emitted from the life cycle is approximately 328.5 million kg per day (approximately 132 million tons per year).

Figure 6 – CO₂ Equivalent Emissions from Refining etc.



16. Assessments have also been done for the likely emissions of greenhouse gases due to the additional refining of similar crudes via other pipelines, where more process detail is available. For example, the Keystone pipeline is expected to provide 591,000 barrels per day of heavy crude to several, specified, Midwest refineries. Based on the expected use of hydrogen required to convert heavy crude to transportation fuels (estimated to be roughly 860 cubic feet of hydrogen per barrel) and the incremental vacuum distillation and coking capacities needed, the

increase in emissions is expected to be in the range of 1.5 to 5.4 million metric tons per year, as carbon equivalent.¹⁶

17. These are not the only means of estimating emissions of greenhouse gases from refining operations. As more process detail is available (i.e., details of refinery processes that will be used to refine these heavy crudes), more refined calculation procedures can be used. As an example, the American Petroleum Institute (API) has developed methodologies for such calculations.¹⁷ More recently, the California Air Resources Board (CARB) has been developing greenhouse gas estimation methodologies for refineries.¹⁸ CARB's methodology considers the following refining processes, emissions sources, and greenhouse gases:

- A. Stationary Combustion
 - a. Carbon dioxide
 - i. Non-standard fuels
 - ii. Natural gas
 - iii. Other fuels
 - b. Methane and Nitrous oxide
- B. Co-generation plants
- C. Process emissions
 - a. Hydrogen plants
 - b. Catalytic cracking
 - c. Sulfur recovery
 - d. Asphalt production
- D. Fugitive Emissions
 - a. Wastewater treatment
 - b. Flaring

18. As noted earlier, greenhouse gases are not the only pollutants that will be emitted from the refining of heavy Canadian tar-sands derived crudes. At a minimum, due to their bitumen portion which is heavy, tar-like and contains significant amounts of aromatic and asphaltene compounds, corrosive organic acids, as well as high levels of sulfur, nitrogen, and metals, these crudes are not a good fit for refineries designed for light sweet crudes. They need conversion (such as cracking and coking capacity discussed earlier) to handle bottoms, significant

¹⁶ Karras, G., Declaration in Civil Action No. 08-1363 (RJL) in NRDC v. U.S. Dept. of State and TransCanada Keystone Pipeline, LP.

¹⁷ Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industries, American Petroleum Institute, February 2004. Available at http://www.api.org/ehs/climate/new/upload/2004_COMPENDIUM.pdf.

¹⁸ Mandatory Greenhouse Gas Reporting for the California Petroleum Refinery and Exploration and Production Sectors: Draft Regulation Concepts, The Petroleum Refinery Sector, California Air Resources Board, July 17, 2007. See also, Final Draft Discussion Paper for a Petroleum Refining Greenhouse Gas Accounting and Reporting Protocol, California Climate Action Registry, July 9, 2007.

hydroprocessing, and they will produce significant by products such as sulfur and coke.¹⁹ Air emissions, including those of sulfur compounds (such as sulfur dioxide, hydrogen sulfide, sulfuric acid, etc.), metals (e.g., vanadium and nickel), and oxides of nitrogen will be produced in significant quantities.

19. As one example, flaring emissions can be large and significant. Flaring is the combustion of excess gases and entrained liquids in a “flare” – typically an elevated open flame. While flares are intended to be safety devices to provide “relief” in the case of unplanned emergencies by providing a pathway to exhaust large quantities of potentially combustible gases in a short amount of time, they are also used as pathways to discard excess or relief gases in non-emergency situations.

20. Flaring incidents (i.e., size, frequency, and durations) can depend on several factors. These include the age of the refinery, the original design basis of the flares and any modifications made, the metallurgy used in piping and vessels, the types of catalysts used, the design and actual catalyst degradation rates, as well as the operating philosophy of the refinery with regards to turn-arounds, relief gas system design, and fuel gas system design, and the balance between the relief and fuel gas systems.

21. Available data indicate that flaring emissions are significant and often much greater than routine emissions from refineries. There is also evidence that flaring emissions can increase, unless carefully mitigated (via design and operating practices) when processing heavier crudes. This can be deduced by careful analysis of data from the Bay Area²⁰ and from US Gulf Coast refineries.

22. In summary, it is my opinion that emissions of greenhouse gases and other pollutants from the life-cycle assessment of tar-sands derived crudes, including those pertaining to refining of

¹⁹ Bruce, G.B., Bitumen to Finished Products, presentation to Canadian Heavy Oil Association Technical Luncheon, Calgary, Nov. 9, 2005.

²⁰ <http://www.baaqmd.gov/enf/flares/>

such crudes, can be developed based on the increase in such crudes that will be processed via pipelines such as the Alberta Clipper.

Attachment A

Sahu Resume