Answer to Interrogatory of Enbridge Gas on Exhibit M10

M10-EGI-107

Reference:

Exhibit M10, page 3

Preamble:

At page 3, Dr. Howarth and Dr. Jacobson state:

"Further, although GWP100 is still used more frequently in greenhouse gas inventories by governments, this is a political decision dating back to the early 1990s when our knowledge of the critical role of methane in the climate system was quite limited, and the IPCC has noted that "there is no scientific argument for 100 years….".”

Question(s):

(a) Please confirm that the Government of Canada uses the GWP100 in its National Inventory Report, which is used as the basis for setting and tracking Canada's GHG reduction targets in 2030 and beyond.

(b) Do the authors agree that in order to compare the GHG impact of an activity, fuel or technology to the Canadian GHG reduction targets, that a common GWP must be used? Please explain your answer.

Response:

(a) Although most National Inventory Reports use GWP100 as the basis for setting and tracking GHG reduction targets, that does not mean that those same jurisdictions never consider GWP20 figures when making policy decisions, including Canada. Nor does it mean that they *should* disregard GWP20 figures. A 20-year time frame (i.e. GWP20) far better captures the importance of methane as a greenhouse gas and is more useful than a 100-year time frame for analyzing the impacts of blue hydrogen, because it is crucial to eliminate substances like methane whose control can avoid catastrophic short-term damage to the climate. Increasingly over recent years, political leaders around the world have implicitly endorsed GWP20 in their logic and speech, with for example President Biden routinely referring to methane as a gas that is more than 80 times more powerful than carbon dioxide (which is the GWP20 value).

(b) The statement is generally correct but is missing the point. For analyzing the impacts of blue hydrogen (e.g. for policy decisions) a 20-year time frame (i.e. GWP20) far better captures the importance of methane as a greenhouse gas and is more useful than a 100-year time frame, which severely understates the climatic risk posed from methane.

Answer to Interrogatory of Enbridge Gas on Exhibit M10

M10-EGI-108

Reference:

Exhibit M10, pages 4-5

Preamble:

At page 4, Dr. Howarth and Dr. Jacobson states:

"In addition, we performed sensitivity analyses down to a value of 1.54%, the lowest reasonable rate supported by any independent studies."

At page 5, Dr. Howarth and Dr. Jacobson states:

"The leakage rates relied on in that report (0.6% or 0.16%) are not credible and are not consistent with the current scientific understanding of methane emissions from gas extraction."

Question(s):

Please confirm the 2023 paper published in Nature by authors Johnson, Conrad, and Tyner titled "Creating measurement-based oil and gas sector methane inventories using source-resolved aerial surveys", which provides a value of 0.38% methane leakage rate for British Columbia, based on top-down measurements, is a peer-reviewed independent study that contributes to the current scientific understanding of methane emissions from gas extraction.

Response:

There are two errors in this question. First, the figures cited in the questions cover different steps in the gas supply chain. The figure cited in the question from the 2023 Johnson study is for the extraction of the methane alone whereas the figures from our evidence also include transportation and storage. Second, the paper in question is not published in the journal Nature. It is published in a journal called Nature Communications Earth & Environment. These are different journals with far different acceptance rates and different standards for an article to be accepted and published.

The question implies that there is an inconsistency between the 2023 Johnson study and the findings in our paper. That is not the case. The 2023 Johnson paper is in line with studies accounted for in our analysis of methane leakage rates. For further details on the studies that we included in our analysis, see the attached book chapter and peer-reviewed article that I authored (Attachments 1 and 2). The upstream emissions rate in our paper on blue hydrogen was based on the analysis in the book chapter I authored (Attachment 1). I subsequently updated that analysis with more recent data in the peer-reviewed article (Attachment 2). As you can see, the rates of methane emissions are highly variable across the studies that I accounted for.

A single study, such as the 2023 Johnson study, should not be relied on to come to general conclusions regarding methane emissions rates associated with gas extraction. There is too much variation among studies for that to be reliable. Therefore, in my papers I have estimated methane emissions rates based on weighted-averages of multiple studies that have used aerial measurements. If I had used a straight mean or median, instead of a weighted average, the results would have produced higher emissions rates. See the attachments for details.

The fact that some top-down studies find relatively low emissions rates does not prove that low emissions rates are possible across the industry in the future. There are too many variables and uncertainties to be able to say the results of any one study are actually reflective of the current reality or that those results could be achieved in the future on average across the industry. There are a number of factors that can contribute to higher or lower emissions rates in any one study. They include:

- **Temporal variation:** Emissions can vary significantly over time. For instance, the level of activities such as drilling and hydraulic fracturing can have a significant impact. Production levels can also increase or decrease due to market forces or other factors.
- **Measurement methodology:** The outcomes of a study are quite sensitive to the assumptions and methodologies used. There is no single scientifically accepted standard for measuring methane emissions from gas extraction. In addition, papers often do not include each and every assumption made, which hinders efforts to compare results, determine why some are higher and lower, and determine which are most accurate.
- **Operators and regulatory enforcement:** The actions of operators and their regulators can impact emissions.
- **Location:** Geology and other location-specific factors could impact emissions.

The number of variables and the modest number of well-done top-down studies make it difficult or impossible to determine which studies are most representative of the actual reality. Nor is it possible to attribute the differences to factors that are amenable to mitigation by operators versus those that are not.

Answer to Interrogatory of Enbridge Gas on Exhibit M10

M10-EGI-109

Reference:

Exhibit M10, pages 9-11

Preamble:

At pages 9 and 10, Dr. Howarth and Dr. Jacobson states:

"Top–down estimates use information such as from satellites or airplane flyovers that characterize an integrated flux. The mean value of estimates from 20 different studies in 10 major natural gas fields in the United States, normalized to gas production in those fields, indicates that 2.6% of gas production is emitted to the atmosphere.[16] This is a good estimate for the upstream emissions that occur in the gas fields. Methane is also emitted from storage and transport to consumers, and the data in the top–down study of Plant et al[23] suggests this is an additional 0.8%.[16, 24]"

Question(s):

a) Please provide the average methane emission rate for each of the production/extraction, gathering and boosting, processing, transmission, storage, and distribution segments as they contribute to a total rate of 3.5%, and how these rates were derived for each segment.

b) What timeframe does the estimated average US methane emission rate of 3.5% represent? In what year, were the specific measurements that inform the methane emission rate collected? Please provide this information according to production/extraction, gathering and boosting, processing, transmission, storage, and distribution segments.

c) Please discuss the specific processes (e.g., extraction, gathering, processing) represented in the 2.6% methane emission rate for the "upstream" natural gas supply chain, and confirm that methane emission rates were normalized to production in 2015. Please discuss the use of 2015 production volumes as it relates to the year of observation from the studies used to estimate methane emissions rates.

d) Please discuss each method of top-down methane emission measurement undertaken by authors Peischl et al. (2013, 2015, 2016, 2018), Karion et al.(2015), Caulton et al.(2014), Barkley et al.(2017), Ren et al.(2019), Schneising et al. (2014, 2020), Zhang et al. (2020) and how comparable the results are between the various aerial and satellite measurement methods undertaken in each study and how other potential anthropogenic or biological sources of methane were excluded from these measurement methods. Please discuss the variability of methane emission rates for the Marcellus basin between studies conducted by Barkley et al. (2017), and Ren et al. (2019).

e) Please confirm the 0.8% of methane emissions representing storage and transportation was based on aerial measurements conducted by Plant et al, of Northeastern US urban centers in 2018 and which segments of the natural gas supply chain (i.e., storage, transmission, distribution, end-use) are represented by the data collected, and how the measurement method allows for attribution to each distinct segment of the natural gas supply chain and excludes other anthropogenic or biological sources of methane?

f) Please discuss why the results of the Plant et al. study area were scaled to the United States, when Plant describes the study areas as "old and leak prone" and when Howarth (2020) indicates "This estimate may or may not apply to the entire United States" and how these results may compare to Ontario, and the relevancy of methane emissions in the distribution system when a blue hydrogen facility is most likely to be supplied at the transmission level?

Response:

(a) That is not possible because the analysis was done on multiple studies based on top-down measurements. It is a meta analysis.

(b) See the attachments to the previous interrogatory response for the date of the studies included in the analysis.

(c) As noted in (a), a breakdown is not possible. Yes, the figures were normalized to 2015.

(d) A description of each of the top-down methods used in the 11 studies would be onerous and would add little or nothing to what can be gleaned from the papers themselves. Also, see the response to the previous interrogatory for a discussion of the inherent challenges in comparing study results and study methodologies.

I have not conducted a detailed comparison of the methane emission rates for the Marcellus basin between studies conducted by Barkley et al. (2017), and Ren et al. (2019). However, I can speak generally to there being differing methane emissions rates from studies for the same location over time, including the Marcellus basin. For examples of studies that find different emissions rates for the same fields at different times, see the book chapter and peer-reviewed paper that I authored, which are attached to the previous interrogatory. The previous interrogatory response also discusses why it is very difficult to determine why that variance occurs. Factors may include, for example, changes in the level of activities such as drilling and hydraulic fracturing and differing measurement methodologies.

(e) The 0.8% value is indeed derived from top-down, aerial overflights reported in the Plant et al. 2019 paper. It includes all sources of emissions from natural gas systems within these northeastern US cities. As with all top-down studies, it is not possible to sub-divide the emissions into particular aspects of the natural gas system. The Plant et al. study was able to separate methane emissions from natural gas from other anthropogenic and biogenic sources of methane, since they also measured ethane levels. Ethane is co-released with methane from natural gas systems but is not found in biogenic emissions or anthropogenic emissions such as those from landfills and wastewater treatment plants.

(f) Plant et al. summarized how their estimate for methane emissions from northeastern US cities compared to the official inventory of the US EPA for that same region. I used this information to scale to the US as a whole, as described in two papers. See footnotes 16, 23, and 24 in the Howarth and Jacobson 2021 paper. The Plant et al. paper does indeed describe the gas distribution systems in the northeastern US as "old and leak prone." And in my 2020 paper, which was focused just on the State of New York, I sidestepped the question of whether or not the Plant et al results should be considered representative of the entire US. There are a paucity of reliable studies with which to determine this, but most studies in fact show much higher rates of emissions than reported by Plant et al for northeastern US cities, including studies in Indianapolis, Indiana, and Los Angeles, California. See Table 2 in my December 2022 paper, which shows an average downstream emission rate from cities of 2.2%, and ranges from 1.7% to 3.5%. See attachment 2 to the previous interrogatory. The downstream leak rate of 0.8% used in our blue hydrogen papers is significantly less, and should probably be considered very conservative. As with other values we used in the Howarth and Jacobson 2021 paper, we chose to be conservative.

Although the 2019 Plant study covers cities with old and leak prone pipelines, that is the case for most cities. Again, the additional studies noted in my December 2022 paper show high leak rates.

The actual leak rates will depend on where a blue hydrogen facility is situated. A facility located closer to the end-user and farther from the gas fields will likely have experience higher upstream losses, other things equal, and vice versa. The upstream leak rate will not be determined solely based on whether the gas enters distribution pipes, but also how long it must be carried in transmission pipes and whether storage facilities are used along the way.

Answer to Interrogatory of Enbridge Gas on Exhibit M10

M10-EGI-110

Reference:

Exhibit M10, page 10

Preamble:

At page 10, Dr. Howarth and Dr. Jacobson states:

"Note that in addition to some methane being lost between production and consumption due to leaks, methane is also burned by the natural gas industry to power natural gas processing and transport. This is important to consider, since we want to evaluate how much methane is emitted for the methane in natural gas that is consumed in producing hydrogen. In 2015, natural gas production in the United States was 817 billion m^3, while consumption was 771 billion m^3,[25,26] (converting cubic feet to cubic meters). Using this information, we can estimate the methane emission as a percentage of gas consumption as follows:

(3.4% of production) ∗ (817×109 m^3⁄771×109 m^3)
= 3.5% of consumption."

Question(s):

a) Is the 817 billion m^3 of 2015 natural gas produced in the U.S. based on marketed production, and if not, confirm what this value represents?

b) Please provide the 2015 dry production of natural gas in the U.S. and discuss which phase of production (dry or marketed) best reflects the final stage of natural gas production (i.e., post producers gate) entering the transportation and storage phases of the natural gas lifecycle.

c) Please comment on how the ratio of production[1] to consumption[2] accurately represents gas used in processing and transporting natural gas, and how this ratio is influenced by importing and exporting natural gas. Please indicate to what degree this ratio has changed over the last 20 years, or is expected to change in the future.

Response:

(a) The value is based on marketed production, as stated in footnote #25 in Howarth and Jacobson 2021 associated with this calculation.

[1] U.S. Energy Information Administration. U.S. Dry Natural Gas Production. https://www.eia.gov/dnav/ng/hist/n9070us2a.htm
[2] U.S. Energy Information Administration. U.S. Natural Gas Total Consumption. https://www.eia.gov/dnav/ng/hist/n9140us2a.htm

(b) According to the US DOE site referenced in footnote #25: "EIA uses three different concepts to measure natural gas production. Gross withdrawals are the full volume of compounds extracted at the wellhead, which includes all natural gas plant liquids and nonhydrocarbon gases after oil, lease condensate, and water have been removed. Marketed natural gas production, which is used in this analysis, excludes natural gas used for repressuring the well, vented and flared gas, and any nonhydrocarbon gases. Dry natural gas production equals marketed production minus natural gas plant liquids." From this, it is clear that marketed production (which is the value we used) is the most appropriate measure for the natural gas sold into the gas transportation and storage system.

(c) We chose 2015 for our analysis in our paper for several reasons, but one is that natural gas imports and exports from the US were nearly identical in that year. In earlier years, the US was a net importer of gas. In later years, the US has been a net exporter of gas. Since exports and imports were in near balance in 2015, the difference between production and consumption provides a reasonable estimate for gas used by the industry to power pipeline compressors, etc. To apply such an approach in earlier or later years would require a correction for the net import or export of gas.

Answer to Interrogatory of Enbridge Gas on Exhibit M10

M10-EGI-111

Reference:

Energy Science & Engineering, Comment on “How green is blue hydrogen?”, March 29, 2022.[3]

Energy Science & Engineering, Blue hydrogen must be done properly, June 23, 2022.[4]

Royal Society of Chemistry. On the climate impacts of blue hydrogen production. November 21, 2021.[5]

Question(s):

Please confirm the above referenced papers are also peer reviewed studies on the GHG emissions from blue hydrogen production.

Response:

Confirmed. Note that our reply to the comment on our paper (the first item listed above) was also peer reviewed. Note also that a number of the authors of the above papers have conflicts of interest. For instance, although they do not declare this as a conflict of interest, the authors of the second paper listed above are all employed by Equinor ASA and most are shareholders in Equinor ASA through the internal share savings program. Equinor is the largest gas producer on the Norwegian continental shelf, and the second-largest gas supplier in Europe.[6]

For our rebuttal to the comment listed in the question, see our reply (Exhibit M10, page 19).

[3] Energy Science & Engineering, Comment on “How green is blue hydrogen?”, March 29, 2022. https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.1126
[4] Energy Science & Engineering, Blue hydrogen must be done properly, June 23, 2022. https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.1126
[5] Royal Society of Chemistry. On the climate impacts of blue hydrogen production. November 21, 2021. On the climate impacts of blue hydrogen production - Sustainable Energy & Fuels (RSC Publishing) DOI:10.1039/D1SE01508G
[6] https://www.equinor.com/energy/natural-gas.