ENBRIDGE

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March 30, 2021

BY RESS AND EMAIL

Ms. Christine Long
Board Secretary
Ontario Energy Board
2300 Yonge Street, 27th Floor
Toronto, ON M4P 1E4

Dear Ms. Long:

Re: Enbridge Gas Inc. (Enbridge Gas)
Ontario Energy Board File No.: EB-2020-0091
Integrated Resource Planning Proposal
Updated Undertaking Response

Consistent with the Ontario Energy Board's ("OEB" or "Board") Procedural Order No. 9 (dated March 5, 2021), on March 16, 2021 Enbridge Gas filed responses to undertakings received during the Oral Hearing in the above noted proceeding held from March 1-4, 2021.

On March 25, 2021, Environmental Defence ("ED") wrote to Enbridge Gas requesting that the Company file an updated response to undertaking J2.2. Enbridge Gas has considered the additional context set out by ED in its request and has updated its original response at Exhibit J2.2 attached. In the process of completing this updated response, the Company discovered three minor discrepancies included in the calculations included in its original response and is hereby correcting those errors as well (updates have been marked). These discrepancies do not change the conclusion of the Company's original response.

If you have any questions, please contact the undersigned.

Sincerely,

(Original Signed)

Adam Stiers
Technical Manager, Regulatory Applications

cc.: D. Stevens (Aird & Berlis)
M. Parkes (OEB Staff)
M. Millar (OEB Counsel)
EB-2020-0091 (Intervenors)

ENBRIDGE GAS INC.

Undertaking Response to ED

To provide a list of what studies are saying regarding the price of green hydrogen as a cost per cubic metre of equivalent natural gas. To include the calculations used to get from the cost per kilogram to the cost per equivalent natural gas cubic metre in the underlying studies.

Response:

The most appropriate means to complete this response is via comparison on the basis of units of energy for each fuel. Therefore, GJ and kwh have been used.

The government of Canada's (Natural Resources Canada) Hydrogen Strategy For Canada, released in December 2020 (the "Hydrogen Strategy") reflects a forecast to have an,

> …[e]stablished supply base of low carbon intensity hydrogen with delivered prices of **$1.50 - $3.50/kg** [1]

Based on the numbers set out within the Hydrogen Strategy forecast:

1kg of H_2 at 1 atm and 0^0C = ~11.126Nm^3
1m^3 of H_2 = 0.012GJ
1GJ = 278.8kwh

At $1.50/kg:
Conversion to $/$m^3$ = $1.5/kg x 1kg/11.126$m^3$ = **$0.135/m³** /U
Conversion to $/GJ = $0.135/$m^3$ x 1m^3/0.012GJ = **$11.23/GJ** /U
Conversion to $/kwh = $11.23/GJ x 1GJ/278.8kwh = **$0.0403/kwh**

At $3.50/kg:
Conversion to $/$m^3$ = $3.5/kg x 1kg/11.126$m^3$ = **$0.315/m³**
Conversion to $/GJ = $0.315/$m^3$ x 1m^3/0.012GJ = **$26.21/GJ**
Conversion to $/kwh = $26.21/GJ x 1GJ/278.8kwh = **$0.094/kwh**

Therefore, the equivalent cost per cubic meter of hydrogen is $0.135/$m^3$ - $0.315/$m^3$ or in energy units $11.23/GJ - $26.21/GJ or $0.040/kwh to $0.094/kwh. In comparison,

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[1] NRCan, HYDROGEN STRATEGY FOR CANADA – Seizing the Opportunities for Hydrogen – A Call to Action, December, 2020, p. XVIII **[emphasis added]**; https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf

natural gas trades in Ontario at approximately $3/GJ or $0.117/$m^3$, subject to market conditions at any specific point in time.

Canada's Hydrogen Strategy indicates that the future cost of hydrogen will be lower than that of electric air source heat pumps (ASHP) and electric resistive heating based on the assumption that cost will be reflective of the cost of natural gas today which is lower than that of ASHP.[2]

> For both hydrogen and the alternative fuels, the costs shown reflect the total cost to the customer including production and distribution. The values are presented in $/GJ-equivalent, which takes into account the efficiencies of FCEVs and BEVs relative to ICE vehicles and air source heat pumps (ASHP) relative to electric resistive. As a heating fuel, hydrogen is more expensive than natural gas, but this value does not account for the increased costs of natural gas due to carbon. Over time, the delivered costs of all of the available fuels are likely to change. As a point of comparison, the figure shows the expected cost of natural gas used for heating for which the carbon emissions have been offset through direct air capture (DAC)…[3]

Similar estimates have also been made by The Hydrogen Council,[4] and the International Energy Agency.[5]

UPDATE

Enbridge Gas is not currently aware of any established price for green hydrogen in Ontario. However, the government of Canada's Hydrogen Strategy report, in Figure 16 at page 58, estimates that the cost for hydrogen produced from electrolysis using dedicated renewable electricity sources to range from approximately $3.25/kg to $7.50/kg ($0.87/m^3 to $2.02/$m^3$ on a natural gas equivalent basis),[6] and the cost for

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[2] NRCan, HYDROGEN STRATEGY FOR CANADA – Seizing the Opportunities for Hydrogen – A Call to Action, December, 2020, p. 100; https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf.

[3] NRCan, HYDROGEN STRATEGY FOR CANADA – Seizing the Opportunities for Hydrogen – A Call to Action, December, 2020, pp. 76-77; https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf

[4] Hydrogen Council, Path to Hydrogen Competitiveness – A cost perspective, January 20, 2020, p. 21; https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf

[5] https://www.iea.org/data-and-statistics/charts/global-average-levelised-cost-of-hydrogen-production-by-energy-source-and-technology-2019-and-2050

[6] The following units are used:

- 1kg of H_2 at 1 atm and 0ºC = ~11.126Nm^3
- Energy content of CH_4 = 38.53 MJ/m^3
- Energy Content of H_2 = 12.78 MJ/m^3

Calculation of the estimated cost for electrolysis hydrogen ("H_2") using renewables in 2020 in equivalent natural gas ("CH_4") units:

- ($3.25/kg H_2) x (1kgH_2/11.126Nm^3)= $0.29/$m^3$ H_2; to

hydrogen produced from electrolysis using grid electricity to range from approximately \$4.25/kg to \$8.40/kg (\$1.14/m^3 to \$2.26/m^3 on a natural gas equivalent basis)[7].

In its response to ED's interrogatories in Enbridge Gas's Low Carbon Energy Project proceeding (EB-2019-0294) at Exhibit I.ED.6 g), the Company provided an estimate of the probable cost to produce hydrogen in Ontario (per m^3 and GJ) via power-to-gas (electrolyser) based on a hypothetical scenario where a new 20 MW plant operated using grid electricity during off-peak hours at a cost ranging from \$0.038/kWh to \$0.044/kWh was scheduled to come online.[8] Under this hypothetical scenario the estimated cost for producing hydrogen over the life of such a facility was estimated to be:

- \$44 to \$55 per GJ; or
- \$0.56 to \$0.70 per m^3.

On a natural gas equivalent basis, these costs range from approximately \$1.60/m^3 to \$1.99/m^3.[9] Of course, the actual cost of hydrogen production by electrolysers in Ontario

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- (\$7.50/kg H_2) x (1kgH_2/11.126Nm^3)= \$0.67/m^3 H_2.

Calculation of ratio of 1 unit of CH_4 to 1 Unit of H_2 based on energy content:

- (38.53 MJ/m^3 CH_4) ÷ (12.78 MJ/m^3 H_2) = 3.01 units of CH_4 :1 Unit of H_2

Calculation of equivalent CH_4 cost for the same unit of H_2:

- (\$0.29/m^3 H_2) x (3.01 CH_4/H_2)= \$0.87/m^3; to
- (\$0.67/m^3 H_2) x (3.01 CH_4/H_2)= \$2.02/m^3.

[7] The following units are used:

- 1kg of H_2 at 1 atm and 0ºC = ~11.126Nm^3
- Energy content of CH_4 = 38.53 MJ/m^3
- Energy Content of H_2 = 12.78 MJ/m^3

Calculation of the estimated cost for electrolysis hydrogen ("H_2") using grid electricity in 2020 in equivalent natural gas ("CH_4") units:

- (\$4.25/kg H_2) x (1kgH_2/11.126Nm^3)= \$0.38/m^3 H_2; to
- (\$8.40/kg H_2) x (1kgH_2/11.126Nm^3)= \$0.75/m^3 H_2.

Calculation of ratio of 1 unit of CH_4 to 1 Unit of H_2 based on energy content:

- (38.53 MJ/m^3 CH_4) ÷ (12.78 MJ/m^3 H_2) = 3.01 units of CH_4 :1 Unit of H_2

Calculation of equivalent CH_4 cost for the same unit of H_2:

- (\$0.38/m^3 H_2) x (3.01 CH_4/H_2)= \$1.14 /m^3; to
- (\$0.75/m^3 H_2) x (3.01 CH_4/H_2)= \$2.26/m^3.

[8] These hypothetical costs only represent the cost of producing hydrogen via electrolysis, they do not include associated storage and/or distribution costs. This also assumes that the amount of electricity required to operate equipment is approximately 4.7 kWh/m^3.

[9] The following units are used:

- 1kg of H_2 at 1 atm and 0ºC = ~11.126Nm^3
- 1m^3 H_2 = 0.012GJ
- Energy content of CH_4 = 38.53 MJ/m^3
- Energy Content of H_2 = 12.78 MJ/m^3

Calculation of the estimated cost for electrolysis hydrogen ("H_2") using grid electricity in 2020 in equivalent natural gas ("CH_4") units:

- (\$44/GJ H_2) x (0.012GJ H_2/1m^3 H^2)= \$0.53/m^3 H_2; to
- (\$55/GJ H_2) x (0.012GJ H_2/1m^3 H^2)= \$0.66/m^3 H_2.

Calculation of ratio of 1 unit of CH_4 to 1 Unit of H_2 based on energy content:

- (38.53 MJ/m^3 CH_4) ÷ (12.78 MJ/m^3 H_2) = 3.01 units of CH_4 :1 Unit of H_2

Calculation of equivalent CH_4 cost for the same unit of H_2:

- (\$0.53/m^3 H_2) x (3.01 CH_4/H_2)= \$1.60/m^3; to

in the future will be dependent upon a number of factors including the scale of any plant, the cost of electricity, and the time of day that the plant operates.

- ($0.66/$m^3$ H_2) x (3.01 CH_4/H_2)= $1.99/$m^3$.