1-PP-ED-1

Reference:

"This electrified option reduces the potential for stranded gas infrastructure investments arising from the shrinking dependence on fossil fuels in a low carbon society."

Questions:

(a) How should the OEB include the avoided cost of stranded assets as a benefit when assessing alternatives like DSM (e.g. an estimated percent of the Enbridge Asset Plan proposed spending)?

(b) Over what period of time are the current gas assets likely to become stranded?

(c) Even if technologies like electric heat pumps are more cost-effective than natural gas to new homes and communities, why is it Enbridge's responsibility to promote those technologies in lieu of additional gas infrastructure?

Response:

(a) This appears to be a regulatory question beyond the scope of this evidence.

(b) As noted in L.ED.1, the federal government[1] and many Canadian municipalities have committed to net zero emissions by 2050, and the International Energy Agency projects that a complete phase out of fuel-based heating systems by 2025 is required to achieve these targets[2] (see p. 7 of L.ED.1).

(c) This appears to be a regulatory question beyond the scope of this evidence.

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[1] Government of Canada. (2021). Government of Canada announces ambitious new greenhouse gas emissions targets. Retrieved from https://www.canada.ca/en/environment-climate-change/news/2021/07/government-of-canada-confirms-ambitious-new-greenhouse-gas-emissions-reduction-target.html

[2] IEA (2021), Heating, IEA, Paris https://www.iea.org/reports/heating

2-PP-ED-2

The December 2021 IESO Annual Planning Outlook indicated an increase in natural gas generation and related GHG emissions. How will Ontarians benefit if end uses are electrified and electricity generation increases emissions through natural gas generation?

Response:

While Ontario's electricity system will rely increasingly on natural gas in the short term, that reliance must decrease in the longer term to meet our climate targets. Some relevant targets include:

- The federal government has committed to achieving a net zero electricity system in Canada by 2035[3].
- Ontario has a climate target of a 30% reduction below 2005 greenhouse gas (GHG) emission levels by 2030[4].
- Our federal targets are for a 40-45% reduction below 2005 levels by 2030 and net zero emissions by 2050[5].
- Many municipalities and businesses are setting ambitious climate targets.
- Financial institutions are looking at the climate impacts of their investment portfolios[6].

These targets are very likely to result in a shift away from the use of fossil fuels in Ontario's electricity supply and a transition toward electrified end uses.

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[3] Liberal Party of Canada. (2021). *Clean electricity: a net zero grid by 2035*. Retrieved from https://liberal.ca/climate/clean-electricity-a-net-zero-grid-by-2035/

[4] Government of Ontario. (2018). Made in Ontario Environment Plan. Retrieved from https://prod-environmental-registry.s3.amazonaws.com/2018-11/EnvironmentPlan.pdf

[5] Government of Canada. (2021). Government of Canada announces ambitious new greenhouse gas emissions targets. Retrieved from https://www.canada.ca/en/environment-climate-change/news/2021/07/government-of-canada-confirms-ambitious-new-greenhouse-gas-emissions-reduction-target.html

[6] Cision. (Oct 15, 2021). *Six of Canada's Largest Banks Join United-Nations-convened Net-Zero Banking Alliance* Retrieved from https://www.newswire.ca/news-releases/six-of-canada-s-largest-banks-join-united-nations-convened-net-zero-banking-alliance-801190199.html

2-PP-ED-3

What barriers (if any) would need to be removed or requirements put in place in order for Enbridge Gas Distribution to deliver programs related to electric ASHPs and HWHPs that reduce/avoid natural gas use and also reduce electricity peaks for A/C?

Response:

As noted in L.ED.1, "Enbridge's decision to exclude fully electrified heat pumps from its proposed program and to subsidize gas heat pump systems does not appear to be justified by the relative cost effectiveness of the systems or a forward-looking need to develop a market. Electric ccASHPs would benefit from a market transformation program aimed at overcoming low consumer and installer awareness of the technology, and misconceptions about their performance and overall cost."

If the question is about barriers and requirements from a regulatory policy perspective, it is beyond the scope of this evidence.

5-PP-ED-4

What requirements should the OEB include in the DSM Framework or DSM decision to ensure that the best technology is promoted vs. a less beneficial technology (e.g. electric vs. gas heat pumps)?

Response:

As noted in L.ED.1, "Enbridge's decision to exclude fully electrified heat pumps from its proposed program and to subsidize gas heat pump systems does not appear to be justified by the relative cost effectiveness of the systems or a forward-looking need to develop a market. Electric ccASHPs would benefit from a market transformation program aimed at overcoming low consumer and installer awareness of the technology, and misconceptions about their performance and overall cost."

Specific OEB regulatory requirements are beyond the scope of this evidence.

5-PP-ED-5

Reference:

"In many cases it is more cost effective to go all electric in lieu of installing new gas infrastructure for an existing community without gas service or to a new residential development"

Question:

The evidence indicates an average grant of $26,700 for Phase 2 of the Natural Gas Expansion Program. It is becoming more costly over time to reach new customers and communities including and additional proposed projects could include a subsidy of well over $130,000 per customer[7]. Please comments on this trend and how it impacts the recommendations in your report.

Response:

Rising costs of connecting new customers to the Natural Gas infrastructure should be an added incentive to find alternatives to natural gas for communities. Our analysis shows that cold climate heat pumps paired with heat pump water heaters are already more cost effective in gas expansion areas (see Table 2 in Exhibit L.ED.1) and further savings would be possible if costs of adding natural gas infrastructure were to increase. Furthermore, as noted on page 11 of Exhibit L.ED.1, "investing in new natural gas infrastructure in these communities with a 40+ year lifespan also risks generating costly assets that may be underutilized or stranded as our society shifts toward greater electrification".

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[7] Example from: EB-2019-0255 EGI Batch 4_Part 1_REDACTED_20201118

6-PP-ED-6

Please explain how the stranding of a natural gas pipeline impacts gas Ratepayers and how that should be considered by the OEB for purposes such as DSM.

Response:

As noted on page 11 of Exhibit L.ED.1, "investing in new natural gas infrastructure in these communities with a 40+ year lifespan also risks generating costly assets that may be underutilized or stranded as our society shifts toward greater electrification". This risk should be considered. It could be quantified in a number of ways and incorporated into cost-effectiveness comparisons.

8-PP-ED-7

(a) What incentive is there for Enbridge to support electric AHSPs or related measures over gas capital expansion?

(b) What requirements are needed to ensure that the best options are identified and pursued?

Response:

(a) Incentives structures are beyond the scope of Dr. McDiarmid's evidence.

(b) Incentives structures are beyond the scope of Dr. McDiarmid's evidence.

10-PP-ED-8

Please provide the TRC Plus test results and assumptions for the hybrid heating system scenario analyzed in the McDiarmid report.

Response:

The NPV cost analysis performed by Enbridge using the NRCan modeling tool was done from a customer perspective, not on a TRC Plus basis (this analysis can be seen on page 5 of Exhibit I.10h.EGI.STAFF.77). Without access to the NRCan modeling tool, we are unable to provide the TRC Plus test results and assumptions for the hybrid heating system scenario.

10-PP-ED-9

(a) Please summarize the net benefits of installing an ASHP or HPHW vs. the comparable natural gas options.

(b) Is an ASHP or HPHW costs effective using the TRC Plus test? If yes, please provide the estimated TRC Plus calculations.

Response:

(a) The net benefits depend on whether the "comparable natural gas options" is referring to a traditional gas equipment, gas heat pumps, or hybrid systems. The benefits for each of those is summarized in L.ED.1. At a general level, the benefits of ASHP and HPHW tend to be:

i. Most cost-effective in some cases (see L.ED.1 for details);

ii. Most consistent with net-zero carbon targets;

iii. Most important for market development;

iv. Greatest likelihood of performance and cost improvements;

v. Best at avoiding need for gas infrastructure that may become stranded and associated cost risks.

(b) Heat pumps are cost effective in a number of scenarios as outlined in Exhibit L.ED.1. This analysis mirrored the TRC Plus test except that it excluded the 15% non-energy benefits adder and did not include an estimate of administrative overhead costs. Note that this analysis relied on Enbridge's avoided cost figures. The live spreadsheet in Appendix B of Exhibit L.ED.1 can be used to recalculate the cost-effectiveness with various assumptions for non-energy benefits and overhead costs.

16-PP-ED-10

If hybrid heating with electric heat pumps where there is a gas furnace is recommended as an interim measure, when should this be reassessed (i.e. in this five year plan or the next)?

Response:

This appears to be out of the scope of the evidence.

10I.ANWAATIN.ED.1

Reference:

Exhibit L.ED.1, p.11

Questions:

The evidence notes that "[i]n many cases it is more cost effective to go all electric in lieu of installing new gas infrastructure for an existing community without gas service or to a new residential development" (p. 11)

(a) In your view, are there benefits or risks of transitioning to all electric for remote and near-remote Indigenous communities currently without gas service?
(b) Please provide any and all analysis regarding the average cost to connect on-reserve new homes to the natural gas system.

Response:

(a) At a general level, the benefits of all electric heating systems (ASHP and HPHW) tend to be:
   i. Most cost-effective in some cases (see L.ED.1 for details);
   ii. Most consistent with net-zero carbon targets;
   iii. Most important for market development;
   iv. Greatest likelihood of performance and cost improvements;
   v. Best at avoiding need for gas infrastructure that may become stranded and associated cost risks.

There are many remote and near-remote Indigenous communities currently without gas service and the risks and benefits for these may differ depending on the characteristics of the community, including housing conditions, existing heating systems (eg. wood vs oil vs propane), source of electricity (eg. grid electricity or local generation), fuel for local electricity generation, and others. Generally speaking, for First Nations not on the gas system, electric heat pumps are likely to be far more cost effective than a gas alternative (see below).

There are two Indigenous communities that are part of phase II Ontario's Natural Gas Expansion Program[8]. The cost-effectiveness of all electric heat pumps systems is compared to gas expansion and gas heating systems for homes in these communities in the Tables 1 and 2 below. Electrified heat pump systems are clearly the most cost-effective option in these communities. For these First Nations, it would cost $38,719 to $60,059 less per customer in lifetime capital and operational costs to switch to electric heat pumps instead of converting to gas.

[8] https://news.ontario.ca/en/backgrounder/1000297/ontario-brings-natural-gas-to-43-communities-with-phase-2-of-the-natural-gas-expansion-program

Table 1: Cost-effectiveness of a ccASHP and HPWH compared to a gas furnace, air conditioner and gas water heater in gas expansion area homes in Red Rock First Nation.

	Gas furnace (95%) with SEER 13 AC and EF 0.81 gas water heater in Red Rock First Nation	ccASHP (HSPF 10) and HPWH (EF 3.75)
Natural gas infrastructure investment	$42,794	NA
Upfront equipment costs	$10,500	$15,357
15-yr operational cost	$23,646	$21,484
15-yr operational cost savings	NA	$2,162
Lifetime savings	NA	$40,099
NPV (compared to gas/AC)	NA	$38,719

Table 2: Cost-effectiveness of a ccASHP and HPWH compared to a gas furnace, air conditioner and gas water heater in gas expansion area homes in Mohawks of the Bay of Qunite First Nation.

	Gas furnace (95%) with SEER 13 AC and EF 0.81 gas water heater in Mohawks of the Bay of Quinte First Nation	ccASHP (HSPF 10) and HPWH (EF 3.75)
Natural gas infrastructure investment	$64,134	NA
Upfront equipment costs	$10,500	$15,357
15-yr operational cost	$23,646	$21,484
15-yr operational cost savings	NA	$2,162
Lifetime savings	NA	$61,439
NPV (compared to gas/AC)	NA	$60,059

If the subsidy were used to pay for heat pump conversions instead of gas pipelines, more than two Red Rock First Nation homes could be provided with electric cold climate heat pumps free of charge with the money saved by not connecting a single home to the gas network. This means that twice as many homes could secure cheaper energy bills than the number forecast to convert to gas. In addition, their operational costs would be lower than the gas alternative, as detailed below.

In Mohawks of the Bay of Quinte First Nation, more than four homes could be provided with a cold climate heat pump free of charge with the money saved by not connecting a single home to the gas network. This means that four times as many homes could secure cheaper energy bills than the number forecast to convert to gas. In addition, their operational costs would be lower than the gas alternative, as detailed below.

Furthermore, electric heat pumps would also be more cost-effective to operate than the gas alternative from a customer perspective due to the $0.23 gas surcharge and because gas service tends to already be more costly in remote communities. The average customer would save $22,053 (Red Rock First Nation) or $24,219 (Mohawk Bay of Quinte First Nation) in operational energy costs over 15 years by switching to an electric heat pump over the gas alternative in these two First Nations.[9] If the subsidy were used to pay for heat pump conversions instead of gas pipelines, participating customers would also save the upfront cost of the gas system equipment (up to approximately $10,500 for gas furnace, gas water heater and AC) because the gas subsidy only pays for the distribution pipeline.

[9] 2022 HydroOne variable charges and Union North East (Mohawks Bay of Quinte First Nation) or Union North West (Red Rock First Nation) variable and fixed charges including the gas surcharge were used. Inflation was set at 2%.

10J.OEB STAFF.1.ED.1

Reference:

Exhibit L.ED.1, p.9

Exhibit I.10h.EGI.STAFF.77

Questions:

The report discusses various heat pump heating systems for residential users and notes that hybrid heating systems can help support a low carbon transition in the short term but in the long term, hybrid heating systems that rely on gas are likely to be incompatible with many net zero plans.
Enbridge Gas included some more details of its research into the various heat pump technologies in its interrogatory responses.

(a) Please discuss the implication of missing the opportunity to convert customer heating systems to electric cold climate heat pumps at the time of natural replacement of a traditional gas furnace heating system. As part of your response, please include any analysis that has been completed that shows the GHG emissions that could have been reduced and any cost savings for the customer.
(b) Please briefly discuss if and how your analysis considered additional costs customers may be required to incur to transition from traditional gas furnace heating systems to an electric cold climate heat pump system, such as retrofits to duct systems, and any related issues to correct sizing and balance points.
(c) Please discuss and show the costs to convert from a hybrid heating system to a cold climate electric heat pump in order to help achieve the goal of net zero. In your response, please show the costs and appropriate timing of converting a high efficient natural gas furnace into a hybrid system and later converting that hybrid system to a cold climate electric heat pump vs simply converting from a high efficient natural gas furnace to a cold climate electric heat pump. In what circumstances would the first option be preferable to the second option?
(d) Please indicate in what circumstances, if any, it would be most cost-effective from the customer's perspective to install a gas heat pump system.

Response:

(a) The most cost-effective time to replace a gas system with an electric heat pump alternative is at the time of natural replacement of a traditional gas furnace heating system. Homes that choose to replace their system with another gas-based system may be locked in to continued gas use for the estimated 15-year lifetime of the heating system. Achieving our federal commitment to net zero emissions by 2050 will mean that these homes will face an increasing risk of policies, regulations and/or market forces encouraging early retirement of their gas-based heating systems.

Table 1 below shows the lifetime greenhouse gas (GHG) emissions and carbon taxes from natural gas use that a customer would avoid if they chose to switch to a fully electrified system rather than a gas-based system at the time of natural replacement of a traditional gas furnace heating system.

Table 1: Carbon tax and GHG emissions associated with natural gas consumption.

Gas system	Lifetime carbon cost from natural gas	Lifetime GHG emissions[10]
Gas furnace	$10,560	50.9 t
Gas water heater	$1,937	9.3 t
Gas heat pump	$9,667	40.3 t
Gas hybrid heat pump system	$1,299-$6,118	6.3 t - 29.5 t

(b) Our analysis did not include considerations of
   i. Any upgrades to ductwork that may be required to accommodate additional air flow
   ii. Any electrical panel upgrades
   iii. Any building envelope upgrades that are recommended to reduce the heating/cooling load and improve sizing and balance points

(c) There are many unknowns associated with transitioning from a hybrid heating system to a cold climate electric heat pump. Replacing just the gas furnace with an electric alternative that can also pair with the heat pump part of the hybrid system may not be feasible due to a variety of factors, including: the design and size of the heat pump system, compatibility of the smart controls for switching heating sources, the configuration of the ducting, and others. In these cases, switching from a hybrid heating system to a cold climate heat pump would involve replacing both the furnace and the existing heat pump.

The hybrid heating system modeled by Enbridge Gas is marginally more cost-effective over its lifetime than a ccASHP if the furnace is at its end of life (see Exhibit I.10h.EGI.STAFF.77 Table 1). If other upgrades are required to install a ccASHP (e.g. to the ducting or to the electrical panel), a hybrid system may be preferred from a cost perspective.

If the gas furnace is not at the end of its life when the hybrid system is installed and the heat pump system must be replaced if the system is to be fully electrified, then the hybrid system is likely to only be cost effective if the gas furnace is relatively new. Since we do not have access to the NRCan modeling tool that Enbridge Gas used, we cannot be more specific than this.

However, as noted in Exhibit L.ED.1: "It is not clear what type of heat pump Enbridge Gas proposes to use in their Low Carbon Transition program and how it will be sized."

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[10] Emission factor taken from Government of Canada. (n.d.) *Emission factors.* http://data.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/Emission_Factors.pdf

(d) Gas heat pumps are not cost-effective when analyzed using customer-facing prices. They generate net costs of -$3,993. In comparison, electric heat pumps are cost-effective using customer-facing prices from a lifetime savings perspective. They generate net savings of $11,474 per customer compared to traditional gas equipment and $13,431compared to gas heat pumps (see Table 1 below).

Projections of customer electricity and natural gas prices were not included in Enbridge Gas's Interrogatory Responses. We therefore used January 1, 2022 residential fixed and variable natural gas prices obtained from Enbridge Gas in Toronto[11],[12] and residential time-averaged time of use and variable electricity prices from Toronto Hydro[13]. Prices were increased by 2% per year to account for inflation and the carbon tax portion of the natural gas price was set to increase by $15/t/yr, consistent with the analysis in Exhibit L.ED.1. HST and the Ontario electricity rebate were included in the costs.

Table 1: Customer costs of gas furnace, water heater and air conditioner, a gas heat pump and air conditioner, and a ccASHP with a HPWH.

	Gas furnace (95%), gas water heater (EF 0.81) and SEER 13 AC	**Gas heat pump (120%) with SEER 13 AC**	**ccASHP (HSPF 10) with HPWH (EF 3.75)**
Upfront cost	$10,500	$18,250	$15,357
15-yr operational cost	$27,135	$21,342	$16,3069
15-yr NG fixed costs	$5,505	$5,505	NA
15-yr operational/NG fixed cost savings	NA	$5,793	$16,331
Lifetime savings	NA	-$1,957	$11,474
NPV[14] (compare to gas furnace scenario)	NA	-$3,993	$1,869

The spreadsheet with the complete calculations is attached (Exhibit L.ED.1.IR.Attachment_A). This can be used to look at other scenarios.

[11] Enbridge Gas. (2022). *Rate 1*. Retrieved from https://www.enbridgegas.com/-/media/Extranet-Pages/residential/myaccount/rates/rate-1-marketer-en.ashx?rev=ae532bd9abb44ef3b4c48c16b394dcfc&hash=9CD5F8B6CC76F2C4FD4ED05B695C0251
[12] NOTE: to keep the analysis simple, the Delivery to use charge for the first 30-85m3/mo was used.
[13] Toronto Hydro. (2022). *Residential rates and charges*. Retrieved from https://www.torontohydro.com/for-home/rates
[14] Discount rate of 6.08% used

10J.OEB STAFF.2.ED.1

Reference:

Exhibit L.ED.1, p.9

Question:

The report briefly discusses the cost-effectiveness of heat pumps for commercial customers.
a) Please indicate and discuss if it would be cost-effective for Enbridge Gas to include commercial customers in its Low Carbon Transition program, to incentive and educate commercial customers and energy contractors to install cold climate electric heat pump systems.

Response:

The proposed commercial Low Carbon Transition program is intended to support market development of technologies that may be cost-effective in the future. The program objectives are:

> "• increasing awareness in the marketplace;
> • training design engineers to identify appropriate applications for and specify these solutions into existing businesses; and,
> • supporting the uptake of the technology into the market through the provision of incentives to customers to offset the increased cost of the solution as compared with current standard alternatives." (Exhibit E,Tab 3, Schedule 1, p6).

As noted in the report (Exhibit L. ED.1), the current cost-effectiveness of including commercial customers in its Low Carbon Transition program is difficult to assess due to multiple factors that affect upfront and operational costs: building type, energy use, energy costs, and others[15]. However, commercial businesses and governments have ambitious climate targets that will require decarbonization of building operations[16],[17],[18]. Realizing those goals will require a growing work force able to advise on, install and maintain cold climate electric heat pump systems. This is consistent with Enbridge Gas' objectives for its commercial Low Carbon Transition program.

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[15] Nadel, S., and C. Perry. (2020). Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges. Washington, DC: American Council for an Energy-Efficient Economy. aceee.org/research-report/b2004
[16] Government of Ontario. (2018). Made in Ontario Environment Plan. Retrieved from https://prod-environmental-registry.s3.amazonaws.com/2018-11/EnvironmentPlan.pdf
[17] Government of Canada. (2021). Government of Canada announces ambitious new greenhouse gas emissions targets. Retrieved from https://www.canada.ca/en/environment-climate-change/news/2021/07/government-of-canada-confirms-ambitious-new-greenhouse-gas-emissions-reduction-target.html
[18] Cision. (Oct 15, 2021). *Six of Canada's Largest Banks Join United-Nations-convened Net-Zero Banking Alliance* Retrieved from https://www.newswire.ca/news-releases/six-of-canada-s-largest-banks-join-united-nations-convened-net-zero-banking-alliance-801190199.html

10J.ANWAATIN.ED.1

Reference:

Exhibit L.ED.1, pp. 7-9

Preamble:

The evidence indicates that residential heat pumps and electrification are recommended and key to Ontario and Canada's lower carbon transition. The evidence notes that "[e]lectric heat pumps are explicitly recommended as the main mechanism for reducing emissions from residential heating systems by a growing number of influential groups". (p. 8).

Question:

(a) Please discuss and provide any and all analysis performed regarding potential savings associated with reduced charges under the Greenhouse Gas Pollution Pricing Act as a result of installing fully electric Air Source Heat Pumps compared to Gas Heat Pumps or hybrid heating systems.

Response:

Table 1: Carbon tax and GHG emissions associated with natural gas consumption.

Gas system	Lifetime carbon cost from natural gas	Lifetime GHG emissions[19]
Gas furnace	$10,560	50.9 t
Gas water heater	$1,937	9.3 t
Gas heat pump	$9,667	40.3 t

Since the carbon tax is paid by the electricity generator, it is embedded in the avoided cost of electricity values provided by Enbridge Gas. Without access to the data used to estimate the avoided cost of electricity values, we were unable to determine the carbon tax contribution for electricity.

[19] Emission factor taken from Government of Canada. (n.d.) *Emission factors.* http://data.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/Emission_Factors.pdf

10J-BOMA-5-ED

Reference:

Exhibit L.ED.1 page 16

Preamble:

"There are four options for commercial buildings considered in this review: a) Air source heat pumps (ASHPs) with electric backup heating, b) hybrid heating systems that use an ASHP with a natural gas furnace as backup, c) ground source heat pumps (GSHP) that are also fully electrified, and d) gas heat pumps of various configurations (GHP: e.g. absorption, engine driven and thermal compression technologies)."

Question:

1. Has consideration been given to electric heat pumps which recycle internally generated heat (without necessarily being supplemented with air- or ground-source heat), which are increasingly used to great effect in hospitals (such as Humber River and Mackenzie Vaughan) and being considered for commercial office buildings as part of net zero planning?

Response:

Electric heat pumps that recycle internally generated heat were not considered in this analysis. However, these heat pumps have the potential to operate at net zero emissions, have greater potential to reduce energy than gas heat pumps, have greater potential to reduce GHGs than gas heat pumps, and would therefore be an appropriate technology for a Low Carbon Transition program.

10J-EGI-1-ED.1

Reference:

Exhibit L.ED.1, page 13

Preamble:

It is not clear what type of heat pump Enbridge Gas proposes to use in their Low Carbon Transition program and how it will be sized. Their models in Exhibit I.10h.EGI.STAFF.77 use an HSPF 10 system which is designed for cold climate use but models the same 3 ton unit in two homes with very different heating loads. As a consequence, the balance point (where a heat pump is no longer able to meet the full heating load) is -14.3°C in the newer post '80s home and -1.6°C in the older pre '80s home with higher heat loss.

Question:

a) Please confirm a 3 ton (36,000 BTU) heat pump was used in your analysis? If not, please specify the heating rating of the equipment modelled in the analysis

Response:

The analysis does not directly rely on assumed heat pump capacity (i.e. tons or BTUs). The analysis does rely on assumed heat pump costs and home heating requirements, which would be correlated with the heat pump capacity. For consistency with Enbridge's own analysis, Enbridge's own figures were used as found in I.10h.EGI.STAFF.77, which appears to have used a 3 ton capacity.

10J-EGI-2-ED.1

Reference:

Exhibit L.ED.1, page 22

Preamble:

Enbridge Gas and Union Gas avoided cost values (from 1.5.EGI.ED.16) for gas and electricity were averaged. The carbon price schedule outlined by the federal government was used until 2030, after which it was assumed that the price would continue to rise at the same rate ($15 per tonne per year).

Question:

a) Please confirm the carbon tax of $15/ton/year after 2030 used for the analysis is not based on any currently announced policy. Please provide references for Federal Government information if not confirmed.

Response:

The assumed carbon price is consistent with currently announced policy. The currently announced policy includes a carbon price increasing until $15 each year until 2030, a net-zero target in 2050, and interim carbon targets. The goal of achieving net zero emissions by 2050 will require continued emissions reductions from increasingly difficult measures beyond 2030. The carbon tax will very likely continue to rise beyond 2030. The assumed increase of $15/ton/year continues the currently announced trend.

10J-EGI-3-ED.1

Reference:

Exhibit L.ED.1, page 22

Preamble:

The operational costs for space heating were calculated for every year using:

$$\text{annual operational heating or cooling cost} = \frac{\text{heating or cooling load}}{\text{efficiency}} * (\text{total avoided cost per kWh or m3})$$

The total operational cost of the HPWH system is includes the cost of generating the heat absorbed from the air by the water heater in winter and the air conditioning energy avoided due to this heat absorption in summer. Since the HPWH also loses heat while in standby, these values are reduced by 5%. The formula used was:

$$\text{HPWH operational cost} = (\text{avoided cost of electricity}) * ((\text{water heat load})/(\text{HPWH efficiency}) + \left(\frac{0.5 * (\text{water heat load})}{\text{ccASHP efficiency}} - \frac{0.5 * (\text{water heat load})}{\text{ccASHP cooling efficiency}}\right)$$

Questions:

(a) Please provide the source of this formula.

(b) Please confirm, is this an industry accepted calculation to account for the heating penalty and cooling benefit of electric heat pump water heaters in conditioned spaces of a home?

Response:

(a) This formula was developed using the following logic:
   i. All heat extracted by the HPWH increases the ASHP heating load in winter
   ii. All heat extracted by the HPWH reduces the ASHP cooling load in summer
   iii. It was assumed that the ASHP operates in heating mode for roughly half of the year and in cooling mode for roughly half of the year

   If the impact of HPWH on internal heating/cooling load is disregarded or discounted, this would have the effect of improving the cost effectiveness of HPWHs. Therefore, the assumption of including 100% of this impact is a conservative one that likely lowers the cost-effectiveness of HPWHs in comparison to real world scenarios where only a portion of the impact would be felt because most HPWHs are situated in a utility room that can maintained at a colder temperature in the winter because they are not occupied and may have excess heat from the furnace and ducting.

(a) The author is not aware of an industry accepted calculation for the heating penalty. The calculations are similar to those used by Sustainable Technologies Evaluation Program (they assumed heating for 2/3 of the year and cooling for 1/3)[20]. A Canadian field study of heat pump water heaters showed that furnace energy use increased by an average 6.6% in winter[21]. This value is similar to the 7.8% increase in heating load that we get using our approach.

[20] Sustainable Technologies Evaluation Program. (2017). *Technical Brief: Evaluation of an air source heat pump water heater.* Retrieved from https://sustainabletechnologies.ca/app/uploads/2017/11/ASHPWH_Tech-Brief2.pdf
[21] CMHC. (2014). *The Impact of heat pump water heaters on whole house energy consumption*.

10J-EGI-4-ED.1

Reference:

Exhibit L.ED.1 – Appendix B

Preamble:

Analysis of Enbridge Gas' low carbon transition program for cost-effectiveness and climate alignment.

Questions:

(a) The EB-2021-0002, Exhibit I.10h.EGI.STAFF.77 Tables 1 & 2 analysis uses a 3 ton heat pump. This equipment requires backup heating to supplement the electric heat pump. As indicated in figure 26 from the NRCan sizing guide, a back up system is required to meet heating demands below the balance point where the heat load exceeds the heat pump capacity. Please confirm if backup heating was considered in your analysis? If not, why not? Confirm the overall system efficiency will decrease if electric backup is used in the analysis for temperatures below the balance point resulting in a higher annual electrical heating costs for an all electricity fueled system. If not, please state all assumptions/rationale.

(b) If an electric heat pump water heater is used, additional heating load is required from the home heating system to make up for the energy drawn from the inside air by the HPWH to heat the domestic hot water.
  i. Please confirm if the additional heating load required was included in the total design home heating load calculation?
  ii. Confirm the home heating load is increased due the additional load from the HPWH.
  iii. Confirm this will increase the balance point temperature resulting in theelectric backup heating system coming on sooner to provide home heating needs. If any portion of the above is not confirmed please state the assumptions and/or rationale.

(c) Confirm that replacing a furnace with a heat pump sized to meet peak heating load without additional heating backup may not adhere/meet manufacturers installation requirements for 2 reasons:
  i. Minimum airflow specification - existing duct work may not accommodate the heat pump max airflow specifications,
  ii. Proper cooling - cooling sizing selection limit as identified in CSA F280-12 is 125% of the cooling load. If not confirmed please state any assumptions or supporting rationale.

Response:

(a) Yes, backup heating was accounted for in the analysis. Most cold climate ASHP systems have a built-in electric resistance heater that provides backup heat below the balance point. Energy used by this auxiliary heating system is included in the manufacturer’s reported HSPF values.

From Air-Conditioning, Heating and Refrigeration Institute: "For all heat pumps, HSPF accounts for the heating delivered and the energy consumed by auxiliary resistive elements when operating below the balance point." (p101)[22]

(b) i. Confirmed. The additional ASHP heating load required to supply the heat for the HPWH was included in the analysis. The reduced cooling load in summer due to removing ambient heat for the HPWH was also included. See 10J-EGI-3-ED.1 for details.

ii. Confirmed. The heating load increases due to the additional load from the HPWH.
iii. The effect on the balance point temperature was not included in the analysis as this was assumed to be very small.

(c) As noted in response (a), most cold climate air source heat pumps have built in electric resistance heaters to provide backup heating when temperatures fall below the balance point, and heat pump efficiency values include energy used by these auxiliary heaters. It was assumed that the cold climate heat pumps modeled by Enbridge and in our analysis included a built in electric resistance heater.

i. Some homes may require upgrades to ducting systems to accommodate the air flow from a cold climate heat pump system.
ii. NRCan's ASHP sizing and selection guide[23] describes how cold climate ASHPs (variable stage) should be sized based on heating loads, not cooling loads. The sizing approach that considers the 125% of cooling load value is recommended for ASHPs that are not cold climate rated (often single stage or 2-stage), and which are intended for use in homes where the objectives are primarily cooling or a balance of cooling and mild weather heating with a backup heating system for colder days.

[22] AHRI. (2012). *Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment* Retrieved from https://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/ANSI%20standards%20pdfs/ANSI.AHRI%20Standard%20210.240%20with%20Addenda%201%20and%202.pdf
[23] NRCan. (2020). *ASHP Sizing and Selection Guide.* Retrieved from https://www.nrcan.gc.ca/sites/nrcan/files/canmetenergy/pdf/ASHP%20Sizing%20and%20Selection%20Guide%20(EN).pdf

10J-EGI-5-ED.1

Reference:

Exhibit L.ED.1 – Appendix B

Preamble:

Analysis of Enbridge Gas' low carbon transition program for cost-effectiveness and climate alignment.

The results in ED_Sub_McDiarmidEvidenceAppendixB_20211201 were adjusted to begin in 2023 to align with the analysis provided by Enbridge in EB-2021-0002, Exhibit I.10h.EGI.STAFF.77.

Questions:

(a) Are the adjusted results calculated correctly if the start date is 2023 instead of2025?

The results in ED_Sub_McDiarmidEvidenceAppendixB_20211201 were adjusted to maintain carbon tax constant at $170/ton after 2030. The adjusted 2023 start date from a) was also in addition to the carbon tax adjustment past 2030.

(b) Please confirm the updated results are correct.

The manufacturers HSPF rating has historically been based on AHRI Standard 210/240 however on January 1 2023 this will be changed to USA DOE "Appendix to M1 subpart B, Part 430 of Title 10" as outlined in Amendment 17 of the Canadian Energy Efficiency Act (i.e. proposal). These new standards including new MEPS that will result in higher AC efficiency regulation and lower HP efficiency regulations, in addition to new test condition which will lower the overall HSPF rating of heat pumps. The results in ED_Sub_McDiarmidEvidenceAppendixB_20211201 were adjusted by a conservative HSPF reduction of 1.

(c) Please confirm the updated results which are inclusive of a) & b) adjustments are correctly calculated.

(d) Further as it relates to the HSPF reduction of 1, would you agree that in the "ENERGY STAR® Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment Eligibility Criteria Draft Version 6.1" on page 6 that it stipulates that the HSPF value tested using the new HSPF 2 test method will result in a significant drop in HSPF value compared with the current test methodology.

Response:

(a) The results are calculated correctly.
(b) The updated results are correctly calculated, although they do not include inflation.

(c) Confirmed, the updated results are correctly calculated.
(d) As stated in the "ENERGY STAR® Program Requirements Product Specification for Central Air Conditioner and Heat Pump Equipment Eligibility Criteria Draft Version 6.1" document, the testing criteria for heat pumps in the US will be changing in 2023 and the seasonal heating efficiency will be reported as HSPF2 to reflect the changed test procedures. In Canada, NRCan is considering amending its test standards to better align with those in the US and is considering making the -15'C test point mandatory and requiring HSPF2 values to be based on climate region V[24].

    It is anticipated that HSPF2 values will be lower than their HSPF counterparts. However, as noted in Exhibit L.ED.1, ASHPs with HSPF values of 13.2 in climate zone V already exist[25], and with ongoing improvements in heat pump efficiency, it seems likely that ASHPS with the efficiencies used in Exhibit L.ED.1 will be readily available even when assessed using the HSPF2 criteria.

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[24] https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/planning-and-reporting/central-air-conditioners-and-heat-pumps/23613
[25] NRCan. (n.d.). *Heat pump list*. Retrieved from https://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.download-telecharger&appliance=HP_SS

10J.SEC.1.ED

Reference:

Exhibit L.ED.1, p. 6

Question:

Please confirm the conclusion, from these figures, that, if the lifecycle cost of a ground source electric heat pump is three to five times the cost of a conventional gas furnace/AC/gas water heater, it is expected that the ground source system will be the more cost effective option.

Response:

That is not necessarily the case. The cost effectiveness of a ground source heat pump relative to a gas system is more complex and was not part of our analysis. See the response to 10J.SEC.2.ED.

10J.SEC.2.ED

Reference:

Exhibit L.ED.1, p. 10 et seq.

Question:

Please provide tables 1 through 4 in Excel format, with all formulae intact. Please provide a similar Table for ground source heat pumps.

Response:

Please refer to Appendix B: Tables and interactive spreadsheet from Exhibit L.ED.1.

It is not possible to provide the tables in an Excel format with all formulae intact as the calculations are complex and draw from multiple variables. In the interactive spreadsheet, the user can use their values to calculate the outcomes used in this report. The formulae used for this analysis can be seen in Exhibit L.ED.I, Appendix A.

The following tables were prepared using Dunsky's values of $27,500 as the upfront cost for a GSHP, an HSPF of 12.6[26], and an assumed SEER of 20 and water heating COP of 3.7 (based on the HSPF efficiency of the GSHP). This analysis assumes that the Dunsky GSHP can also provide for all of the hot water needs. Since GSHP equipment have a 25-year timespan (the loop systems have lifespans of 50 years or more)[27], the analysis was performed over 25 years and included two installations of gas equipment. The results can be seen in Tables 1-4 below.

Over a 25-year timeframe the GSHP is more cost effective than both the hybrid and the gas heat pump systems in this analysis.

The spreadsheet used to calculate these tables is attached (Exhibit L.ED.1.IR.Attachment_B) and can be adapted to address other scenarios, such as an analysis that accounts for the 50-year lifespan of ground source loop systems.

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[26] Dunsky Energy Consulting. (2020). *The Economic Value of Ground Source Heat Pumps for Building Decarbonization.* Retrieved from https://ontariogeothermal.ca/downloads/dunsky--hrai-benefitsofgshps--2020-10-30-.pdf/
[27] https://www.energy.gov/energysaver/geothermal-heat-pumps

Table 1: Cost-effectiveness of a GSHP compared to a gas furnace and air conditioner over 25 years.

	Gas furnace (95%) with SEER[28] 13 AC	GSHP (HSPF 12.6)
Upfront cost	$16,000	$27,500
25-yr operational cost	$43,330	$28,453
25-yr operational cost savings	NA	$14,877
Lifetime savings	NA	$3,377
NPV (compared to gas/AC)	NA	-$5,661

Table 2: Cost-effectiveness of a GSHP compared to a gas furnace, air conditioner and gas water heater in gas expansion area homes over 25 years.

	Gas furnace (95%) with SEER 13 AC and EF 0.81 gas water heater	GSHP (HSPF 12.6)
Upfront cost, including NG infrastructure investments	$47,700	$27,500
25-yr operational cost	$50,586	$32,691
25-yr operational cost savings	NA	$17,895
Lifetime savings	NA	$38,095
NPV (compared to gas/AC)	NA	$27,257

[28] SEER is the Seasonal Energy Efficiency Ratio. It measures the average efficiency of moving heat out of a home over the entire cooling season.

Table 3: Cost-effectiveness of a GSHP compared to a gas furnace, air conditioner, and gas water heater in new homes over 25 years.

	Gas furnace (95%) with SEER 13 AC and EF 0.81 gas water heater	GSHP (HSPF 12.6) and
Upfront cost, including NG connection	$24,300	$27,500
15-yr operational cost	$50,586	$32,691
15-yr operational cost savings	NA	$17,895
Lifetime savings	NA	$14,695
NPV (compared to gas/AC or gas/AC/DHW)	NA	$3,857

Table 4: Cost effectiveness of a GSHP compared to a gas heat pump with an air conditioning system over 25 years.

	Gas heat pump (120%) with SEER 13 AC	GSHP (HSPF 12.6)
Upfront cost	$36,500	$27,500
25-yr operational cost	$39,988	$32,691
25-yr operational cost savings	NA	$7,297
Lifetime savings	NA	$16,297
NPV (compared to gas/AC)	NA	$11,139