Evidence regarding stage 2 analysis and gas alternatives for greenhouses

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I have been asked to review Enbridge's estimates of the savings that would accrue to its customers as a result of using natural gas instead of an alternative fuel and conduct my own analysis in this regard. As detailed below, Enbridge's analysis does not account for key factors, most notably the option of heating with highly efficient electric heat pumps. Enbridge estimates that customers would save by being able to use gas, when in fact gas would be considerably more expensive than the most cost-effective alternatives.

I have also been asked to provide high-level comments on alternatives to gas for greenhouses. This work is addressed in the second section and demonstrates that there are technically viable alternatives that can replace all or some of the need for natural gas or other fossil fuels in Southern Ontario's new construction greenhouses and many of these are already in use.

1. Review of Enbridge Gas' stage 2 analysis of the economics of natural gas and electrified alternatives for customers in the Ontario Panhandle

This work reviews and remodels Enbridge's estimates of the savings that would accrue to its customers as a result of using natural gas instead of another fuel. Enbridge Gas did not consider heat pumps as the electric fuel alternative, which are approximately three times more efficient than gas heating. When appropriate adjustments are made to Enbridge's cost comparison spreadsheets, the 20-year net present value (NPV) from using natural gas fuel instead of the most cost-effective alternative is negative $84 million for the Ontario Panhandle. My own model, which also includes up-front costs, finds that a residential homeowner who chooses electric heat pumps over gas systems for space and water heating can expect to save $6,792 over the equipment's 15-year lifetime (NPV).

Electric Heat Pumps

Electric Heat pumps are systems that use electricity to move heat. They can provide both heating and cooling by either moving heat into a space or out of a space. Moving heat is far more efficient than generating heat. Air source heat pumps can be 210% to 390% efficient over the winter season in Ontario's climate, while ground source heat pumps can be 320% to 500% efficient in the heating season[1]. The technology has improved significantly in recent decades and newer cold climate air source heat pumps can extract heat efficiently at temperatures as low as -30°C[2]. Heat pump water heaters are also available to provide hot water for domestic uses. There is growing global demand for electric heat pump systems for space and water heating because of their high efficiencies, potential for low carbon heating, and lower operational costs in many areas[3].

Analysis using Enbridge Gas Spreadsheet

My analysis using Enbridge Gas' spreadsheet shows that the use of alternative fuels results in higher costs for customers who choose to use natural gas for space and water heating over alternatives when electric heat pumps are considered[4]. The 20-year NPV for using natural gas over electricity for residential customers is negative $67 million (see Table 1). The 20-year NPV for using natural gas over alternatives is negative $84 million for all buildings modeled (see Table 1). In other words, by choosing electric heat pump-based systems instead of natural gas systems in residential and commercial buildings, building owners could collectively save over $80 million over 20 years in variable energy costs. These values are greater on a 40-year NPV basis (see Table 1).

[1] Government of Canada. (2021). Heating and cooling with a heat pump. Retrieved from https://www.nrcan.gc.ca/energy-efficiency/energy-star-canada/about/energy-star-announcements/publications/heating-and-cooling-heat-pump/6817#f1

[2] Mitsubishi Elecgric. (n.d.). *The cold climate heat pump advantage* Retrieved from https://cdn.agilitycms.com/mesca/productdownloads/mem-202103-e-zuba-brochure-final.pdf

[3] Grand View Research. (n.d.) Heat pump market size, share & trends analysis report by technology, by application, by region, and segment forecasts, 2022-2030. Retrieved from https://www.grandviewresearch.com/industry-analysis/heat-pump-market

[4] Enbridge's cost comparison spreadsheet is attached to the response to Environmental Defence interrogatory #14.

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Table 1: Net Present Value of the Variable Costs of using Natural Gas Versus Alternatives per Updates to Enbridge Gas's Spreadsheet

Building type	**NPV for gas versus electricity**	
	20-years	**40-years**
Residential	($67 million)	($108 million)
Small and large commercial	($17 million)	($29 million)
Industrial	($0 million)	($1 million)
Total	**($84 million)**	**($136 million)**

My analysis differs in three key ways from that of Enbridge Gas[5].

1. The original spreadsheet did not account for differences in efficiencies of heating systems. The weighted average efficiencies of the space and water heaters for residential and commercial buildings were incorporated into the unit prices[6] (see the attached spreadsheet for details). This change is significant because air-source heat pumps can achieve efficiencies of 300% and above[7] while conventional natural gas, heating oil and propane heating equipment have efficiencies below 100%. Table 2 shows the costs per unit of heat energy when adjusted for residential heating system efficiencies. I based the efficiency of electric space heating on air-source heat pump efficiencies because they are more common than ground-source heat pumps. However, ground-source heat pumps are far more efficient (up to 500%).
2. I adjusted fuel costs to reflect the full October 2022 costs in the Ontario Panhandle area. All customer costs that are charged per unit of fuel are included (this may include supply, delivery, transportation, storage, and all applicable taxes).
3. I have assumed that the applicable residential and commercial customers (which are 95% to 98% new construction) would choose heat pump space heating systems and electric water heaters[8] over heating oil and propane systems because their higher efficiencies mean significantly lower operational costs (see Table 2). No changes were made to the alternatives for industrial buildings because fuels may be used for non-heat applications where heat pumps do not apply.

Table 2: 2022 Residential heating costs adjusted for heating system efficiencies (cost per heat output)

Fuel	**$/MJ**	**Gas $/MJ**	**Diff $/MJ**
Heating Oil	89.8	25.3	**64.5**
Propane	71.7	25.3	**46.4**
Electricity	17.5	25.3	**(7.8)**

[5] All changes are noted in the adjusted spreadsheet and highlighted with a green background.
[6] The efficiencies of the space and water heaters were weighted based on their relative contribution to total residential or commercial building energy use according to NRCan data. See the adjusted spreadsheet for details.
[7] https://www.hrai.ca/uploads/userfiles/files/Dunsky__HRAI_Benefits%20of%20GSHPs_(2020-10-30)_F.PDF
[8] I have assumed heat pump water heaters in residential buildings and electric resistance heaters in commercial buildings.

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Detailed Analysis of Residential Savings Potential

Enbridge Gas' analysis was not able to account for many factors that affect the long term price of purchasing and operating heating systems in residential buildings. These factors include upfront costs, fixed customer charges for connection to the gas line, savings from the greater cooling efficiencies of heat pumps over air conditioners, and the heating penalty/cooling benefit from heat pump water heaters. The model used in my evidence for Enbridge's DSM proceeding (EB-2021-0002) incorporates these factors and was used as the basis for this analysis. Enbridge Gas values were used as much as possible in this analysis.

An average homeowner in the Panhandle area can save $6,792 (NPV) over the 15-year lifetime of space and water heating systems by choosing electric heat pumps over conventional gas systems (see Table 3).

Table 3: Average Customer Costs – Gas versus Electric Heating

	Gas furnace (95%), gas water heater (EF 0.81), and SEER 13 AC	**Heat pump (HSPF 10) and heat pump water heater (EF 3.75)**	**Cost savings with gas systems**
Upfront cost	$10,500	$15,357	**$4,857**
15-year operational cost	$26,878	$15,665	**($11,213)**
15-year NG fixed costs	$4,715	NA	**($4,715)**
15-year total cost	$42,093	$31,022	**($11,071)**
15-year NPV savings	NA	NA	**($6,792)**
20-year NPV savings*	NA	NA	**($8,341)**
40-year NPV savings*	NA	NA	**($13,457)**

*The 20-year and 40-year savings account for the multiple installations of the equipment (assumed 15-year lifespan).

When all projected new residential installations are modeled, the 20-year and 40-year NPV for natural gas savings relative to electric heat-pump-based alternatives are negative $48 million and negative $82 million respectively.

The break-even cost for gas-based residential heating systems compared to electric heat pumps using my spreadsheet is 0.27$/m^3 on a 20-year NPV value basis. The gas supply cost would have to fall by 67% to achieve this break-even point.

This analysis includes the upfront cost of heating system equipment. Installation prices can vary due to many factors but air-source heat pumps cost would have to be 68% higher before gas becomes as cost-effective as electricity for heating. Heat pumps prices, however, are expected to come down as their market share increases and economies of scale take effect[9].

The outcomes modeled here may be seen as conservative for a number of reasons:

[9] Jadun, Paige, Colin McMillan, Daniel Steinberg, Matteo Muratori, Laura Vimmerstedt, and Trieu Mai. 2017. Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-70485. https://www.nrel.gov/docs/fy18osti/70485.pdf

1. The Panhandle region of Ontario has a more moderate climate than much of the rest of Ontario and it is therefore likely that heat pumps will perform at higher efficiencies than those modeled here.
2. Most of the new residential connections anticipated by Enbridge are for new builds (92-95%) where the upfront cost of heat pumps may be lower than the values previously modeled by Enbridge due to economies of scale for installation in new developments.
3. The analysis is based on air-source heat pumps whereas ground-source heat pumps are far more efficient and may be particularly cost-effective in new construction.
4. For existing buildings, homeowners can receive up to $5,000 in grants for qualifying heat pump systems, which reduces the 20-year NPV for natural gas savings from negative $40 million to negative $72 million.
5. Finally, if the carbon price were to increase at the current rate of $15/tonne/year between 2030 and 2050, as assumed in the IESO decarbonisation pathway study[10], the 20-year NPV for natural gas savings would decreases from negative $48 million to negative $80 million.

This analysis demonstrates that electric heat pumps are in fact lower cost to own and operate than conventional natural gas alternatives on average in the Ontario Panhandle. Residential homeowners can see lifetime savings of $6,792 (NPV) compared to those gas systems, with the savings increasing each year as carbon prices increase. Those savings could even be higher if ground-source heat pumps are installed in new construction or if heat pump technology continues to increase in efficiency and decrease in price.

[10] IESO (2022). *Pathways to Decarbonization*. Retrieved from https://www.ieso.ca/en/Sector-Participants/Engagement-Initiatives/Engagements/Pathways-to-Decarbonization

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2. Analysis of Alternatives to Natural Gas for New Construction Greenhouses in Ontario

This work provides high-level comments on alternatives to gas for greenhouses. Details and examples of ground-source heat pumps and other low carbon alternatives that have proven viable in Southern Ontario or other similar climates are described.

Ground-source heat pumps (aka geoexchange) move and concentrate heat from the ground for heating and move excess heat from the greenhouse back into the ground for cooling while also providing dehumidification. This technology is commercially available for greenhouse applications[11]. Summerstreet Industries in Nova Scotia is in the process of building a year-round greenhouse that will be heated using ground source heat pumps[12], and there are examples of greenhouses with this technology in the United States[13]. When used in sealed (ie not vented) and well insulated greenhouse structures, the heating and cooling requirements can often be balanced[14].

In Southern Ontario, existing conventional greenhouses (ie not sealed or well insulated) generally require more heat in winter than is restored in summer through cooling. Engineers working for the greenhouse industry recommend pairing ground source heat pumps with a secondary heat source or adding extra heat to the ground using solar collectors[15]. Solar collectors combined with ground-source heat pumps have proven to be highly effective for space heating in a community near Calgary Alberta (heating efficiencies of 1800%-3000%)[16], but to my knowledge the technology has not yet been applied to greenhouses. Greenhouses also use supplemental carbon dioxide to stimulate photosynthesis. This carbon dioxide is often sourced from burning fuels but can also be purchased[17].

Ground-air heat transfer (GAHT aka climate battery, earth air heat exchange) is a simpler system that takes advantage of ground heat. Pipes are buried under the greenhouse and by moving air or water through the pipes, heat can be stored underground in summer and used in colder weather. This technology is commercially available for the greenhouse industry[18], and has proven to be technically viable in Ontario with supplementary heating on the coldest days[19].

Biomass can also be used as a direct replacement for gas in greenhouses. Burning biomass generates both heat and carbon dioxide, but can also be used to generate electricity for the greenhouse in a

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[11] Ceres. (n.d.) Ecoloop™/Sunchamber™. Retrieved from https://ceresgs.com/environmental-controls/ecoloop-sunchamber/
[12] Liz LaPier, Manager of Community Development at Summerstreet Industries
[13] Ceres. (n.d.) Ecoloop™/Sunchamber™. Retrieved from https://ceresgs.com/environmental-controls/ecoloop-sunchamber/
[14] Ceres. (n.d.) Ecoloop™/Sunchamber™. Retrieved from https://ceresgs.com/environmental-controls/ecoloop-sunchamber/
[15] Chiu. G. (2022). Power from the ground up. Greenhouse Canada. Retrieved from https://www.greenhousecanada.com/power-from-the-ground-up-the-geothermal-spectrum/
[16] Mequita, L., et al. (2017). Drake Landing solar community: 10 years of operation ISES Solar World Congress 2017. Retrieved from https://www.dlsc.ca/reports/swc2017-0033-Mesquita.pdf
[17] Dunn, B. Poudel, M. (2017). Greenhouse carbon dioxide supplementation. Oklahoma State University. Retrieved from https://extension.okstate.edu/fact-sheets/greenhouse-carbon-dioxide-supplementation.html
[18] Ceres (n.d).GAHT® system. https://ceresgs.com/environmental-controls/gaht/
[19] Ceres (2022). A greenhouse for cold climates, eh? Retrieved from https://ceresgs.com/greenhouse-for-cold-climates/

combined heat and power configuration. Several large Southern Ontario greenhouses use biomass for heat, carbon dioxide and sometimes power[20]. Willow biomass pellets have been proposed as a low carbon alternative to fossil fuels in Ontario's greenhouses[21], and the Ontario Greenhouse Vegetable Growers lists natural gas and wood as the typical heating fuels for greenhouses[22]. A 240 acre biomass-fueled combined heat and power greenhouse is being planned for Ontario[23].

It should be noted that greenhouses are likely to experience increased pressure to reduce their reliance on fossil fuels as our society works to achieve its climate targets. Canada has a goal of becoming net zero emissions by 2050[24] and many groups are developing climate-friendly food labels[25],[26]. A tomato grown in an Ontario greenhouse is responsible for 3.2 kg of greenhouse gas emissions for every kg of tomato[27], but a field tomato trucked from Mexico to Canada is responsible for approximately 0.3 kg of emissions[28].

Many new construction greenhouses may choose to use multiple heating sources, seek sources of industrial waste heat and carbon dioxide[29] or to implement energy efficiency measures (e.g. insulated panels, thermal curtains, sealed environment) to reduce total dependence on natural gas and future-proof their businesses against decarbonization pressures and rising fuel prices.

In conclusion, there are indeed technically viable alternatives that can replace all or some of the need for natural gas or other fossil fuels in Southern Ontario's new construction greenhouses and many of these are already in use.

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[20] Ontario Greenhouse Vegetable Growers. (n.d.) Case Studies. Retrieved from https://www.ogvg.com/_files/ugd/5ef796_e27e9eab784c4482b7bd162404e12897.pdf, https://www.ogvg.com/_files/ugd/5ef796_35340c3b90d1431d9eb30f76261d867e.pdf

[21] Dias, G. M. et al. (2017). Life cycle perspectives on the sustainability of Ontario greenhouse tomato production: Benchmarking and improvement opportunities. Journal of Cleaner Production. 140(2): 831-9. https://doi.org/10.1016/j.jclepro.2016.06.039 .

[22]Ontario Greenhouse Vegetable Growers https://www.ogvg.com/how-we-grow

[23] Chiu. G. (2022). Power from the ground up. Greenhouse Canada. Retrieved from https://www.greenhousecanada.com/power-from-the-ground-up-the-geothermal-spectrum/

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