Sustainable Technologies
EVALUATION PROGRAM

Supported by Toronto and Region Conservation Authority

Heating & Cooling

Dual-Fuel Heat Pump Home Heating Systems: Analysis of Control Approaches, Utility Costs, and Carbon Emission Reductions

The Sustainable Technologies Evaluation Program (STEP) is a collaborative non-profit research initiative within the Toronto and Region Conservation Authority (TRCA). Among other priorities, STEP leverages partnerships with government, utilities, non-profits, academic institutions, and private companies, to pilot and evaluate emerging low-carbon technologies for buildings with the aim of providing real-world data, analysis, tools, and outreach that informs effective technological responses to climate change.

EXECUTIVE SUMMARY

Heat pumps are the most efficient way to heat and cool a home, and they have drastically lower carbon emissions compared to conventional heating systems. However, the uptake of heat pumps is low for single-family homes in Ontario that are currently heated by natural gas. The primary barriers are related to upfront costs and annual utility costs.

Dual-fuel heat pump systems package a high-efficiency natural gas furnace with a low-cost air-source heat pump and have potential as a better financial investment for homeowners in the near term, while also achieving substantial carbon reductions. This document summarizes analysis of the upfronts costs, annual utility costs, and carbon emissions for an example dual-fuel heat pump system.

It was shown that a dual-fuel system in a nearly average home would have an incremental cost of less than $3,000 compared to a conventional system. Using conservative estimates of cost and performance, it can reduce carbon emissions by 39% while reducing utility costs by nearly $500 in total from 2021 to 2030 due to the rising cost of natural gas from carbon pricing. Smart control approaches that are not yet widely available can drive deeper savings, greater than $1,200 over this time period.

It follows that the potential cost and carbon savings for this technology are significant, but the cost savings are not expected to be larger than the additional upfront costs. A rebate is highly recommended to promote deployment.

A dual-fuel heat pump system (also called a hybrid heating system) looks the same as a conventional furnace and A/C system. The difference is that, in a dual-fuel system, the A/C unit is "upgraded" to an air-source heat pump (ASHP). The ASHP provides both cooling and heating. It is used for heating in milder outdoor conditions, and/or during off-peak time-of-use, when it is more efficient and cost-effective than a furnace. In Ontario and other jurisdictions, this can result in lower utility costs and significantly lower carbon emissions.

INTRODUCTION

The most recent annual carbon emissions inventory from The Atmospheric Fund reports that the Greater Toronto and Hamilton Area is responsible for 49.2 million tonnes of carbon emissions.[1] This is 41% of Ontario's total emissions and equivalent to 6.9 tonnes per capita. Most of these emissions must be eliminated to meet the goal of net carbon neutrality by 2050 so as to reduce the negative impacts of climate change. Within the inventory, buildings are responsible for 43% of the emissions, most of which comes from the natural gas used in the large majority of heating systems in Ontario.

Heat pumps are the most efficient way to heat and cool a home, and they have drastically lower carbon emissions compared to conventional alternatives. However, the uptake of heat pumps is currently low for single-family homes that are located within the natural gas distribution network in Ontario. This is despite a pressing need to transition to low-carbon options.

The primary barriers limiting uptake are related to cost. This includes both the upfront cost of heat pumps and their annual utility costs. A key issue is that most heat pumps are driven by electricity, which is a more costly fuel than natural gas. It follows that, despite a high efficiency, the financial case is often poor when homeowners consider a heat pump against a conventional central air-conditioning (A/C) system and high-efficiency natural gas furnace.

Dual-fuel heat pump systems, which package a high-efficiency natural gas furnace with a low-cost air-source heat pump, have potential as a better financial investment for homeowners in the near term while also achieving substantial carbon reductions. This document summarizes analysis from the Sustainable Technologies Evaluation Program that evaluated the upfronts costs, annual utility costs, and carbon emissions of dual-fuel heat pump systems in comparison to a conventional central A/C system and high-efficiency natural gas furnace.

TECHNOLOGY

Heat pumps can be several times more efficient than a conventional furnace. When a furnace provides heating, it is simply releasing the energy that is contained in natural gas. This means that furnace efficiency (which describes the heat energy output divided by the gas energy input) can never surpass 100%. The heating energy that is supplied by a furnace must *always* be less than the energy that was contained in the natural gas.

A heat pump functions differently. It uses a refrigeration cycle to absorb renewable heat energy that is available in the air or ground and uses it as the primary source of heat energy for a home. The cycle can also be run in reverse to provide cooling. In fact, a heat pump is very similar to an air-conditioner, and in some cases looks exactly the same, only that it can provide heating as well as cooling. The heat pump's refrigeration cycle consumes a small amount of electricity to run but it supplies a much greater amount of heat energy than was consumed. This means that efficiency is significantly higher than 100% - so much so that it is no longer referred to as a percentage and is instead referred to as a "coefficient of performance" or COP. For example, a COP of 3.0 can be thought of as meaning 300% efficient in terms of energy inputs and outputs.

Air-source heat pumps (ASHPs) use an outdoor fan coil (just like an A/C unit) to absorb heat energy from the outdoor air. When the outdoor air is warmer, it is easier for the heat pump to absorb heat energy. This means that the efficiency (i.e. the COP) of an ASHP increases with the warmer outdoor temperature. Under very warm conditions, the COP can exceed 4.0 or even 5.0, depending on the heat pump. Example COP data is shown in Figure 1. Even though natural gas is a much lower-cost fuel than electricity, the high-efficiency of the heat pump can still make it the lower-cost option in some conditions.

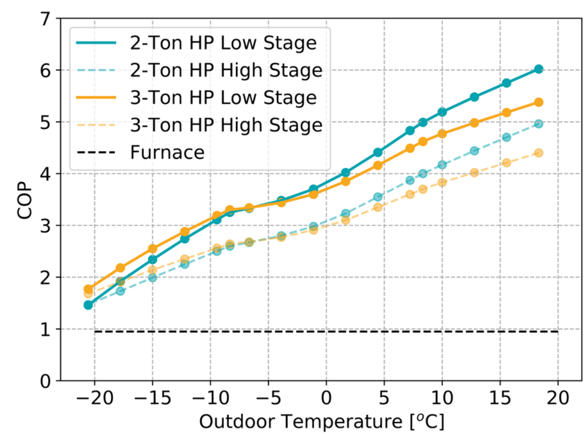

Figure 1. Manufacturer-stated heat pump efficiency data from 2-stage Goodman GSZC16 heat pumps are shown, including data from both a 2-ton and a 3-ton heat pump operating in either the high or the low stage. Different stages are used to closely match the heating demand of the home and reduce equipment cycling.

In many cases, heat pump systems, like cold-climate ASHPs or geothermal systems, are designed to meet the *entire* heating load of a home. This approach produces the highest efficiency and lowest possible carbon emissions. However, it is also normally associated with significantly greater upfront costs than a central A/C system and high-efficiency natural gas furnace.

In terms of utility costs, a geothermal system for a single-family home might break even or produce a small savings because it uses stable ground temperatures as a source of heating. However, at current rates, central *air-source heat pump* systems are expected to cost more to operate than a conventional furnace-A/C arrangement.

While carbon pricing will increase affordability, the financial case is currently often poor for choosing a heat pump instead of natural gas heating for a single-family home. However, note that this is *not* the case away from the natural gas network or for other types of buildings, like multi-family residential buildings, where heat pumps may offer a compelling business case. Dual-fuel heat pumps address these issues by packaging a low-cost ASHP with a high-efficiency natural gas furnace. The heat pump is used primarily when it is the more cost-effective option and otherwise, the natural gas furnace is used. The ASHP is lower cost because it has a lower heating capacity than a full-scale system would require (since it does not need to heat the home in extreme cold - that's when the furnace is used), and it also does not have other features that are commonly incorporated to ensure effective operation in more extreme cold conditions. This makes upfront costs more manageable.

Furthermore, utility costs may be comparable or lower than a furnace-A/C arrangement. This is because the ASHP is used for heating primarily when it is the more cost-effective option. The control logic for dual-fuel heat pump systems may simply switch from the furnace to the ASHP when the outdoor temperature is above an adjustable setpoint value, or it may be "smart" and take into account real-time factors like the outdoor temperature, electricity rate, and equipment efficiency.

DATA AND ANALYSIS

This analysis evaluated the upfront costs, annual utility costs, and annual carbon emissions of a dual-fuel heat pump system compared to a conventional furnace-A/C system. Equipment schedules and invoices for a dual-fuel heat pump system and conventional furnace-A/C have been shared with STEP by homeowners for this analysis. This is shown in Table 1.

Table 1. Example equipment costs from actual installations.

	Equipment	Cost
Dual-Fuel Heat Pump System	**GMVM970603BN** Goodman furnace, modulating gas valve, 60 kBtu, 97% AFUE, 3-Ton ECM variable-speed blower **GSZC160241** Goodman two-stage heat pump, up to 16 SEER, 2 Ton Included: Evaporator coil, installation, accessories, HST	$9,996.51
Furnace and A/C	**TM9E060B12MP12** Luxaire furnace, 95% AFUE, ECM blower, 60 kBtu/hr **TC3B1822S** Luxaire air-conditioner, single-stage, up to 13 SEER, 1.5 Ton Included: Evaporator coil, installation, accessories, HST	$6,893.00

This data was obtained from actual installations but is *not* necessarily representative of all installations. The incremental cost for the dual-fuel heat pump system in Table 1 is $3,000 but it includes a more efficient furnace, blower, and air-conditioning. It is therefore expected, that the additional cost for a dual-fuel system is **less than $3,000** when more comparable equipment is used. For example, contractors report a potential savings of 10 to 15% on the upfront cost of the dual-fuel system if a single-stage furnace and heat pump is used, but this will impact performance and may not always be advisable.

The heating capacity of the heat pump from Table 1 is shown in Figure 2. A larger 3-ton option is shown as well. Note that a larger heat pump might not always be feasible or may increase costs due to necessary electrical, ductwork and/or equipment upgrades. Also shown is an estimated building heating load. When the building's heating load is greater than the heat pump capacity, the heat pump can no longer meet the load. This means that the furnace *must* be used below a certain temperature, depending on the heat pump capacity. For this system, a 2-ton heat pump could provide enough heating for outdoor temperatures above 1 ºC but a 3-ton could provide enough heating down to -4 ºC. Heat pump sizing has a significant impact on cost and carbon emissions.

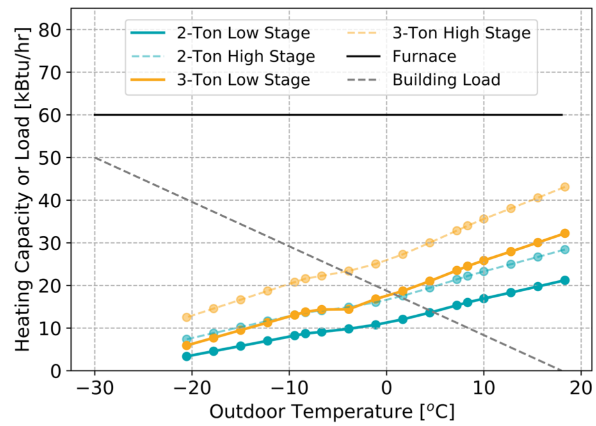

Figure 2. Manufacturer-stated heat pump capacity from 2-stage Goodman GSZC16 heat pumps are shown, including data from both a 2-ton and a 3-ton heat pump operating in either the high or the low stage.

Weather data for a typical meteorological year (TMY) in Toronto was obtained from the Canadian Weather Year for Energy Calculation (CWEC) database. The weather data was used alongside the estimated building load (in Figure 2) to produce Figure 3, which shows the heating energy required for the TMY broken down according to outdoor temperature and time-of-use (TOU) electricity bracket. Actual Toronto weather data from 2011 to 2020 were also analyzed. The relative breakdown of the heating load across different TOUs does not vary greatly year-to-year from the TMY, at most by 2%.

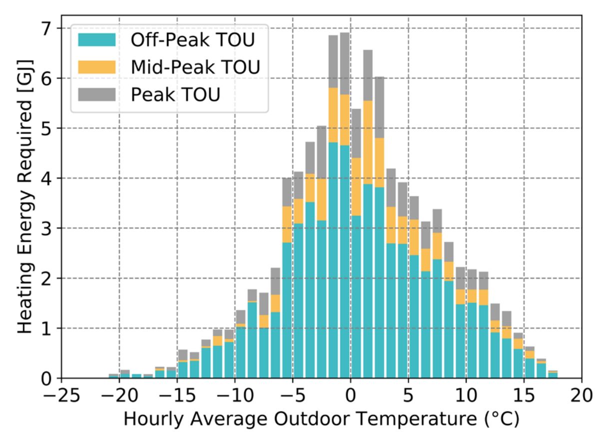

Figure 3. The distribution of the annual heating energy load energy according to outdoor temperature and time-of-use electricity bracket was calculated using weather data for Toronto from the CWEC database and an estimated building load (shown in Figure 2). Note that 66% of the load is off-peak and the remainder is approximately evenly split between peak and mid-peak TOU.

The total annual heating load shown in Figure 3 is 93 GJ. Note that 1 GJ is approximately equal to the energy content of two barbeque-sized propane cylinders. The average household energy consumption in Canada for detached homes is 134 GJ.[2] Natural Resources Canada estimates that 63% of home energy consumption is due to space heating.[3] Average home heating energy can then be estimated at 84 GJ, slightly lower than was assumed in this analysis.

May 2021 utility rates were estimated using the Ontario Energy Board (OEB) online bill calculator. The off-peak, mid-peak, and peak electricity rates were estimated at 9.95, 13.6, and 18.5 cents/kWh, respectively. The current natural gas rate was estimated at 36.4 cents/m^3. However, carbon pricing announced by the federal government in the "A Healthy Environment and A Healthy Economy" plan unveiled in late 2020 will significantly impact natural gas rates. The price of carbon will increase in intervals of 15 $ per tonne per year, rising from 50 $ per tonne in 2022 to 170 $ per tonne in 2030.

To take this into account within the analysis, the estimated utility rates for 2025 were generally used, with estimated rates for 2030 also considered at the end of this white paper. The estimated 2025 natural gas rate was the current rate adjusted to include the additional federal carbon charge. It was 47.2 cents/m^3. The electricity rate estimates for 2025 included a 2% per year cost escalation to the current values to yield 10.8, 14.7, and 20.0 cents/kWh.

Table 2. Summary of control approaches that were considered.

Control Strategy	Description
Lowest Carbon Emissions	The heat pump is selected to operate whenever it has sufficient capacity (see Figure 2). This only requires that the system switches between the heat pump and the furnace at a preset outdoor temperature, and is accomplished with an outdoor relay rather than a smart controller. Note that this approach could select the heat pump even when it is uneconomical and could result in greater utility costs than using the furnace alone.
Lowest Utility Costs	For the different TOU brackets and outdoor temperatures, the lowest cost option (of either heat pump or furnace) is always selected. This requires a smart controller that considers the heat pump and furnace efficiency against the real-time outdoor temperatures and utility rates. Note that larger utility cost savings are produced at the expense of greater carbon emissions.
Constant Switchover Temperature	The system uses an outdoor temperature relay to switch between furnace and heat pump at a preset outdoor temperature chosen by the homeowner. This is a simple approach that allows the homeowner to balance utility costs and carbon emissions to their preferences but is less effective than "Adjustable Smart Control." "Lowest Carbon Emissions" control is a special case of this approach where the lowest possible outdoor temperature is selected.
Adjustable Smart Control	"Adjustable Smart Control" adds an additional factor - referred to in this document as the "smart factor" - to the "Lowest Utility Costs." It allows the heat pump to continue operating until it was more expensive than the furnace by some preset value. As an example, if the smart factor was set to 10%, the control system would stop operating the heat pump, and switch to the furnace, when the cost of heat pump operation exceeded that of the furnace by greater than 10%. This approach would allow a homeowner to balance cost and carbon more optimally but it requires a smart controller.

Table 3. Summary of parameter estimates used in calculations.

Parameters	Description
Electricity Rates	The marginal off-peak, mid-peak, and peak electricity rates were estimated at 10.8, 14.7, and 0.20 cents/kWh, respectively, based on the OEB rate calculator and assuming a 2% per year cost escalation to 2025.
Natural Gas Rate	The marginal natural gas rate was estimated at 47.2 cents/m^3 based on the OEB online bill calculator tool and federal carbon pricing schedule for 2025.
Electricity Emission Factor	The marginal emission factor for the winter season was estimated at 0.119 kg CO_2e per kWh. This value was taken from recent analysis from The Atmospheric Fund.
Natural Gas Emission Factor	The natural gas emission factor was estimated at 1.89 kg CO_2e per m^3 based on Canada's National Inventory Report.
Base Case Furnace Efficiency	Base case furnace efficiency was estimated at 95% based on the cost comparison provided in Table 1.
Dual-Fuel Heat Pump Capacity and Efficiency	Manufacturer-stated heat pump efficiencies and capacities from Figure 1 and Figure 2 were used. Different scenarios derated heat pump efficiency values by 10 to 30% to take into account the fact that real-world values are expected to be lower. Both 2-ton and 3-ton heat pumps were considered.
Dual-Fuel Furnace Efficiency	A furnace efficiency of 97% was assumed based on the cost comparison provided in Table 1.
Weather	Typical meteorological year weather data from the CWEC database for Toronto was assumed.
Building Load	Building load data corresponding to the equipment provided in Table 1 was assumed. It was assumed to be linear and equal to 0 kBtu/hr at 18 ºC and 34 kBtu/hr at -15 ºC.

The marginal emission factor for electricity was obtained from The Atmospheric Fund.[4] It was 0.119 kg CO_2e per kWh for the winter season based on their most recent reporting. The emission factor for natural gas was obtained from Canada's National Inventory Report. The efficiency data from Figure 1 was used. However, this data is overly optimistic in terms of real-world performance because it does not include effects like defrosting or cycling. The uncertainty surrounding real-world performance was taken into account by derating the COP curves by between 10 and 30%. For example, if the COP is 3.0 for a certain outdoor temperature in Figure 1, a 30% derate would bring this value closer to 2.0. STEP estimates the derate in most installations would be 20 to 30%, but more data is required for a definitive answer.

The analysis proceeded by applying the capacity, efficiency, and utility cost data of the furnace or heat pump to the heating load data provided in Figure 3. Different control approaches were considered to determine whether the heat pump or furnace would be operating for different outdoor temperatures and TOU brackets. This is described in Table 2.

FINDINGS

When controlled to produce the lowest possible carbon emissions, the dual-fuel heat pump system can reduce carbon by up to 41% annually when using a 2-ton heat pump, and up to 64% when using a 3-ton heat pump, while producing utility savings up to 13%. Results from the "Lowest Carbon Emissions" control scenario (i.e. when the heat pump is used whenever it has enough capacity) are shown in Table 4 and Table 5. Table 4 provides results assuming a 2-ton heat pump and Table 5 shows results assuming a 3-ton heat pump. Figures 4 and 5 visualize when the 2- and 3-ton heat pump would be operated using "Lowest Carbon Emissions" control.

When controlled to produce the lowest possible utility costs, the dual-fuel heat pump can provide between 9 and 18% cost savings while also producing carbon savings between 26 and 51%. Table 6 shows results for a 2-ton heat pump, and Table 7 for a 3-ton. Figures 6 and 7 visualize results for the 2-ton heat pump, assuming either a 10% or a 30% COP derate. Figures 8 and 9 visualize results for a 3-ton heat pump. It is clear from the visualizations that the function of smart control is largely to operate the heat pump during off- and mid-peak TOU whenever it has sufficient capacity. It should also be noted that this analysis did not consider the additional cost of a smart controller, which would include a one-time upfront cost and potentially an annual subscription fee as well.

Table 4. Cost and carbon results for a **2-ton** dual-fuel heat pump system operated according to **"Lowest Carbon Emissions"** control logic.

	Base Case Furnace and A/C	Dual-Fuel Heat Pump (10% COP Derate)	Dual-Fuel Heat Pump (20% COP Derate)	Dual-Fuel Heat Pump (30% COP Derate)
Utility Costs ($)	1,233	1,071	1,127	1,198
Utility Savings ($)	-	162	106	35
Utility Savings (%)	-	13	9	3
Carbon Emissions (tonnes)	4.94	2.92	2.97	3.04
Carbon Savings (tonnes)	-	2.02	1.97	1.91
Carbon Savings (%)	-	41	40	39

Table 5. Cost and carbon results for a **3-ton** dual-fuel heat pump system operated according to **"Lowest Carbon Emissions"** control logic.

	Base Case Furnace and A/C	Dual-Fuel Heat Pump (10% COP Derate)	Dual-Fuel Heat Pump (20% COP Derate)	Dual-Fuel Heat Pump (30% COP Derate)
Utility Costs ($)	1,233	1,076	1,178	1,310
Utility Savings ($)	-	157	55	-77
Utility Savings (%)	-	13	4	-6
Carbon Emissions (tonne)	4.94	1.77	1.87	1.99
Carbon Savings (ton)	-	3.17	3.07	2.95
Carbon Savings (%)	-	64	62	60

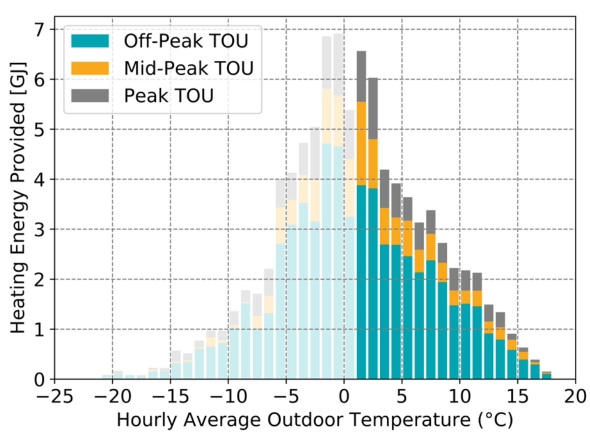

Figure 4. The dark colours indicate when a **2-ton** heat pump would be used in order to produce the **lowest carbon emissions**, while the shaded bars indicate when the furnace would be used.

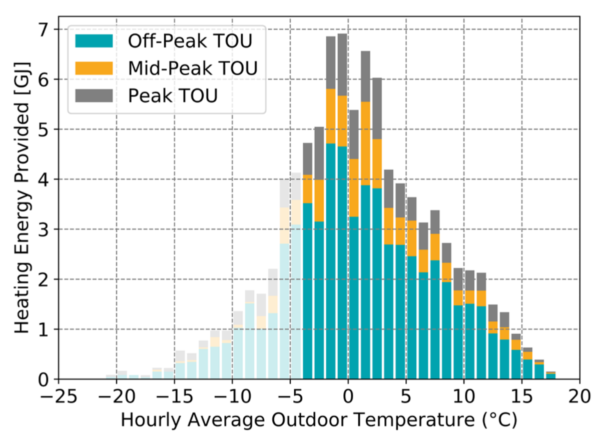

Figure 5. The dark colours indicate when a **3-ton** heat pump would be used in order to produce the **lowest carbon emissions**, while the shaded bars indicate when the furnace would be used.

Table 6. Cost and carbon results for a **2-ton** dual-fuel heat pump system operated according to **"Lowest Utility Costs"** control logic.

	Base Case Furnace and A/C	Dual-Fuel Heat Pump (10% COP Derate)	Dual-Fuel Heat Pump (20% COP Derate)	Dual-Fuel Heat Pump (30% COP Derate)
Utility Costs ($)	1,233	1,047	1,084	1,127
Utility Savings ($)	-	186	149	106
Utility Savings (%)	-	15	12	9
Carbon Emissions (tonnes)	4.94	3.25	3.40	3.63
Carbon Savings (tonnes)	-	1.69	1.54	1.31
Carbon Savings (%)	-	34	31	26

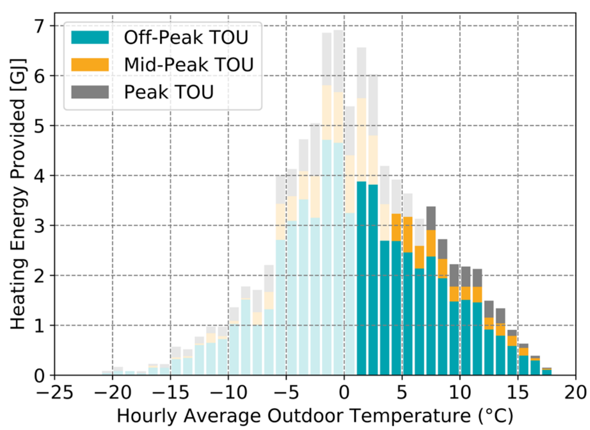

Figure 6. The dark bars show when the **2-ton** heat pump is operated in order to produce the **lowest utility costs**, assuming a **10% COP derate**. The shaded bars indicate when the furnace would operate.

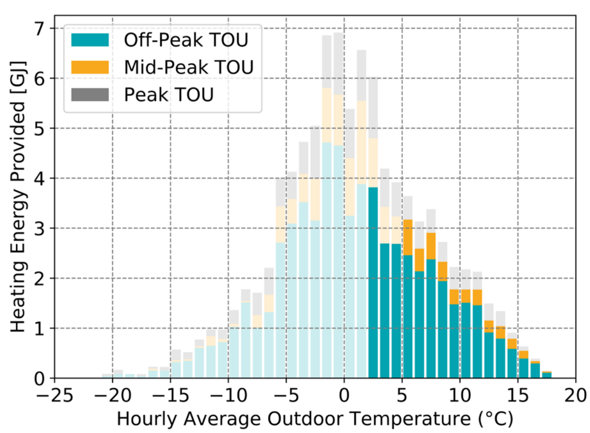

Figure 7. The dark bars show when the **2-ton** heat pump is operated in order to produce the **lowest utility costs**, assuming a **30% COP derate**. It is clear that the heat pump would operate much less frequently in this scenario.

Table 7. Cost and carbon results for a **3-ton** dual-fuel heat pump system operated according to **"Lowest Utility Costs"** control logic.

	Base Case Furnace and A/C	Dual-Fuel Heat Pump (10% COP Derate)	Dual-Fuel Heat Pump (20% COP Derate)	Dual-Fuel Heat Pump (30% COP Derate)
Utility Costs ($)	1,233	1,009	1,073	1,118
Utility Savings ($)	-	224	160	115
Utility Savings (%)	-	18	13	9
Carbon Emissions (tonnes)	4.94	2.41	3.08	3.55
Carbon Savings (tonnes)	-	2.53	1.86	1.39
Carbon Savings (%)	-	51	38	28

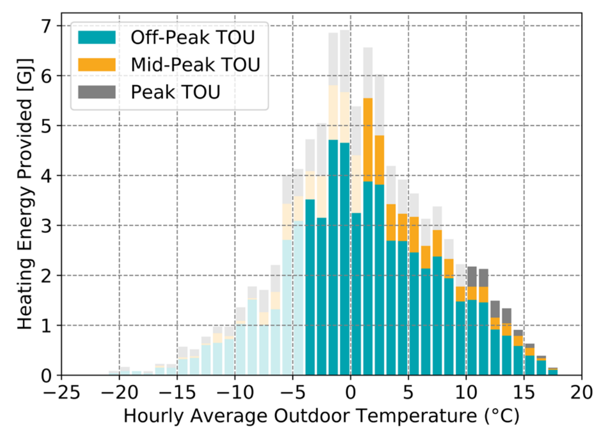

Figure 8. The dark bars show when the **3-ton** heat pump is operated in order to produce the **lowest utility costs**, assuming a **10% COP derate**. The shaded bars indicate when the furnace would operate.

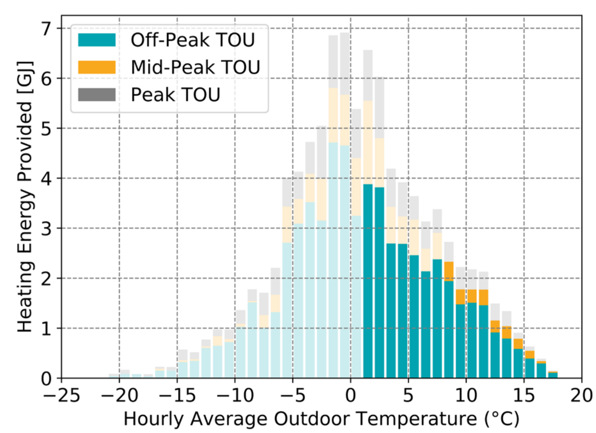

Figure 9. The dark bars show when the **3-ton** heat pump is operated in order to produce the **lowest utility costs**, assuming a **30% COP derate**. It is clear that the heat pump would operate much less frequently in this scenario.

Cost and carbon savings results in between that of "Lowest Carbon Emission" and "Lowest Utility Costs" control can be achieved using "Adjustable Smart Control." Using the 2-ton heat pump as an example, and assuming a 30% COP derate, "Lowest Utility Costs Control" can result in a cost savings of $106 while producing a carbon savings of 26% while "Adjustable Smart Control" can increase carbon savings to 32% while increasing cost by only $11. In this scenario, an additional factor (i.e. the "smart factor") was introduced into the control algorithm to allow the heat pump to continue operating until it was more expensive than the furnace by some preset value (see Table 2). This type of control acknowledges that low-cost carbon savings are possible when the heat pump and furnace are *near* each other in their cost of operation, even if the heat pump is slightly more costly to operate. For small increases in the utility costs, comparatively greater carbon savings are achievable. Table 8 shows results for a 2-ton heat pump using "Adjustable Smart Control" assuming a smart factor of 0%, 10%, 20%, or 30%, and a COP derate of 30%. Again, note that the cost of the smart controller has not been included in the analysis. This is because it is a new concept with relatively few options, and the cost today is likely not going to be reflective of the cost in the near future when there are more manufacturers.

Carbon and cost savings can also be balanced using the "Constant Switchover Temperature" control that is commonly used today. This is shown in Figure 10. It plots cost and carbon savings as a function of the constant switchover temperature, both for 2025 and for 2030. The 2030 natural gas rate was estimated using the current rate corrected for the updated carbon pricing schedule. The 2030 electricity rates assumed a 2% per year increase from current values. Note that there are no extra equipment costs or subscription fees involved with this approach.

Table 8. Cost and carbon results for a **2-ton** dual-fuel heat pump system operated according to "**Adjustable Smart Control**" logic.

	Base Case Furnace and A/C	Dual-Fuel Heat Pump (0% Smart Factor)	Dual-Fuel Heat Pump (10% Smart Factor)	Dual-Fuel Heat Pump (20% Smart Factor)	Dual-Fuel Heat Pump (30% Smart Factor)
Utility Costs ($)	1,233	1,127	1,129	1,132	1,138
Utility Savings ($)	-	106	104	101	95
Utility Savings (%)	-	9	8	8	8
Carbon Emissions (kg CO2e)	4.94	3.63	3.48	3.42	3.34
Carbon Savings (kg CO2e)	-	1.31	1.46	1.52	1.60
Carbon Savings (%)	-	26	30	31	32

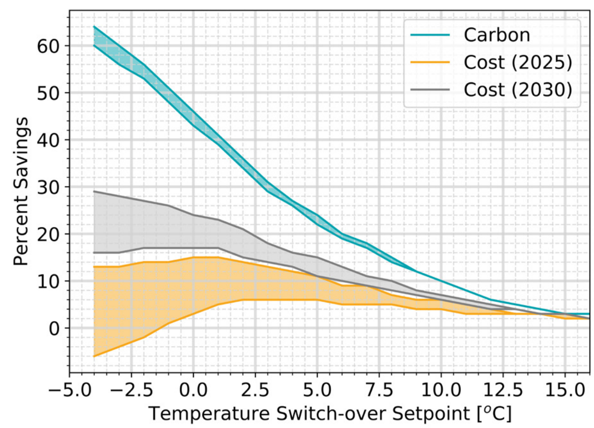

Figure 10. Calculated cost and carbon savings are shown for different constant switchover temperatures. This is the temperature at which the heat pump switches from furnace to heat pump and vice versa, and is different than smart control. The width of the curves is representative of the uncertainty of real-world heat pump efficiency. Results are shown for both 2025 and 2030. Even with a simple control strategy, significant cost and carbon savings can be achieved.

By 2030, approximately halfway through the system lifetime, the dual-fuel approach is estimated to reduce utility costs by greater than $200 per year with "Lowest Utility Costs" control, and greater than $150 per year with "Lowest Carbon Emissions" control. Figure 11 shows annual utility savings from 2021 to 2030. It is a conservative estimate and assumes a COP derate of 30%. "Lowest Carbon Emissions" control will consistently reduce carbon emissions by 39% in this scenario, while the carbon savings from "Lowest Utility Costs" control will increase from 17% in 2021 to 31% in 2030. The total cost savings from 2021 to 2030 with "Lowest Utility Costs" control was calculated at $1,226, while that for "Lowest Carbon Emissions" was $481.

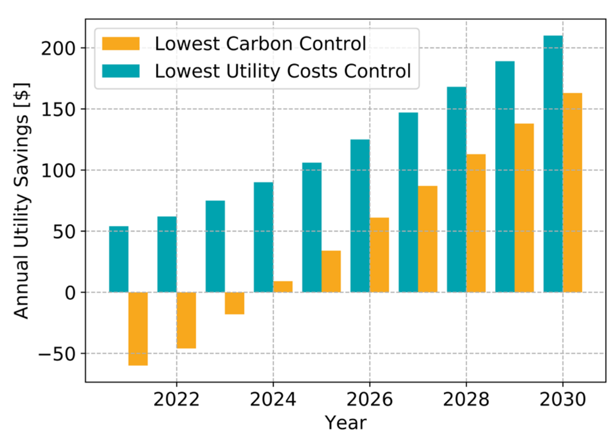

Figure 11. The annual savings from the dual-fuel system will increase as carbon pricing increases the cost of natural gas. This figure considers two different control approaches and assumes that the heat pump COP is going to be 30% lower than is reported by the manufacturer due to real-world factors, making it a conservative estimate of cost savings.

DISCUSSION

Dual-fuel heat pump systems provide a cost-effective near-term route for significant carbon emission reductions in single-family homes currently heated by natural gas. The incremental cost of a dual-fuel system compared to a conventional furnace-A/C system is on the same scale as previous heat pump rebates, as well as currently available incentives for energy upgrades that are less impactful on carbon.

For example, building energy modeling has shown that adding continuous insulation (R-20) to a basement, or insulation (R-60) to an attic space, of 1970's era home will reduce carbon emissions by 2.7% and 1.4%, respectively.[5] The Enbridge Home Efficiency Rebate (as of May 2021) provides $1,000 for a basement insulation upgrade and $650 for an attic insulation upgrade near these insulation values, and an additional $500 for insulating a full basement. This is $2,150 in rebates for measures that will likely reduce carbon emissions by 4.1%. Using conservative estimates of heat pump performance, this analysis showed that a 2-ton dual fuel system in a nearly average home using simple constant temperature switch-over control can reduce carbon emissions by 39%, and it would require a $3,000 rebate to achieve comparable upfront costs with conventional equipment. This scenario was also estimated to save nearly $500 in total on the utility bills from 2021 to 2030 due to the rising cost of natural gas from carbon pricing. Greater relative carbon savings are possible, even approaching the 3-ton result, if the building load is lower than the was assumed in Figure 2.

A rebate program is therefore recommended. However, since this technology leaves a natural gas heating option in place, there is potential for a homeowner to purchase a system and receive a rebate but then choose to not operate the heat pump for heating, thinking that the benefit is primarily from an upgraded furnace and more efficient air-conditioning. Measures need to be taken to ensure that this does not happen. One measure is education for homeowners and contractors. Education should be based on real-world results demonstrating savings. It follows that performance monitoring of pilot installations is recommended. Initial pilots have been conducted and results are promising.[6] Additional pilots should confirm or refine the results of this analysis and provide useful examples for contractors and homeowners.

Smart control approaches can drive deeper utility savings at the expense of lower carbon emission savings. However, smart control options are not yet widely available and could involve additional upfront and subscription costs. Larger heat pumps can provide greater benefits, with a 3-ton unit pushing carbon savings to greater than 60%. However, a larger heat pump will not always be feasible. Ductwork, electrical, and equipment upgrades may be required.

CONCLUSION

Heat pumps are the most efficient technology for home heating, and can also produce substantial carbon emission reductions. Central cold-climate air-source heat pumps and geothermal systems remain the "greenest" home heating and cooling systems, and the uptake of these options will likely rise in the future as society transitions to low-carbon. However, in the near term, dual-fuel heat pump systems offer a more financially advantageous retrofit option for many homeowners with a furnace-A/C system at the end of its useful life, while also achieving substantial carbon reductions. Pilots in Ontario are also exploring air-source heat pump replacements of A/C only, leaving the existing furnace in place. It is recommended that utilities and government implement a rebate for this technology and support further efforts to analyze its effectiveness and promote its deployment. However, any government or utility program must also acknowledge potential pitfalls and include measures that help to ensure effective operation.

References

[1]The Atmospheric Fund. Carbon Emissions Inventory for the GTA. 2019 Edition.
[2]Statistics Canada. Households and the Environment: Energy Use (2011).
[3]Natural Resources Canada. Energy Efficiency Trends in Canada 1990 to 2013.
[4]The Atmospheric Fund. A Clearer View on Ontario's Emissions. 2019 Edition.
[5]City of Vaugham LIC Study - Business Case Report. 2020. Appendix A.
[6]Sager et. al. Performance Assessment of Hybrid (Gas Furnace + Heat Pump) Systems with Smart Switching Controls. ASHRAE Transactions. Volume 126. 2020.

The full data analysis for this document was completed in a Jupyter Notebook using the Python programming language. It is freely available at a public online repository, located at: https://github.com/SustainableTechnologies/Dual_Fuel_April_2021

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