ARTICLE 5

MAKING HYBRID HEATING THE SMART CHOICE*

Submitted by | **ENBRIDGE**

Summary: The majority of space heating load in the province of Ontario is supplied by natural gas. Based on electric grid carbon emission factors (2018), fuel switching a portion of Ontario's heating system to electricity provides an opportunity to lower the province's greenhouse gas (GHG) emissions. An approach that leverages the value of both natural gas and electricity is to retrofit residential central air conditioning systems with air source heat pumps (ASHPs) to create hybrid heating system. Hybrid heating systems can then meet home heating requirements either using the ASHP or the existing gas-fired appliance.

One of the barriers of a hybrid heating system was the lack of sophisticated controls which optimize the operation of the overall system. By utilizing a recently developed cloud-based Smart Fuel Switching Control (SFSC), pilot home results show that it is possible to reduce GHG emissions and total utility costs for residential customers in Ontario.

Introduction

The majority of space heating load in the province of Ontario is supplied by natural gas. Based on electric grid carbon emission factors (as of 2018), fuel switching a portion of Ontario's heating system to electricity provides an opportunity to lower the province's greenhouse gas (GHG) emissions. An approach that leverages the value of both natural gas and electricity is to retrofit residential central air conditioning systems with air source heat pumps (ASHPs) to create hybrid heating systems. A hybrid heating system can then meet home heating requirements either using the ASHP or the existing gas-fired appliance (furnace or mini-boiler with air handler).

***AN EXCERPT FROM ASHRAE PAPER**

The original paper was presented at ASHRAE winter conference in 2020. The authors of the paper are: Farzin M. Rad, Senior Advisor at Enbridge Gas Inc., Toronto, Ontario. **Tom Grochmal**, Manager, Program Design, Technology & QA/QC for Enbridge Gas Inc., Chatham, Ontario, and **Nima Alibabaei** is CEO and Co-founder at BKR Energy, Toronto, Ontario.

There are several benefits to this concept:

- For homeowners, the hybrid approach retains the traditional benefits of heating with natural gas, including reliability, the cost advantage during times of peak electricity pricing, and the assurance of thermal comfort on peak winter days.
- For homeowners, the hybrid approach takes advantage of the efficiency of ASHPs to potentially lower total utility costs and GHG emissions during times of off-peak power pricing.
- For utilities, the hybrid approach avoids significantly increasing the peak load (and consequently the costly expansion) of electrical infrastructure, which would otherwise result from the electrification of residential heating of any significant scale.

Hybrid heating systems are available in market but not widely deployed, due to several barriers. An important barrier to obtaining the stated benefits of hybrid heating for homes is the lack of sophisticated controls that can optimize the operation of the overall system. Traditional smart thermostats available in the market lack the necessary sophistication to achieve this; generally, they operate hybrid systems on a static basis, i.e., fuel switching at a fixed outdoor temperature without consideration of utility pricing signals and the effect of weather on equipment performance such as capacity and Coefficient of Performance (COP).

A recently developed cloud-based controller, termed a Smart Fuel Switching Control (SFSC), addresses this barrier to optimizing hybrid heating systems. This controller calculates the optimal switchover point between gas and electric utilizing temporal information of equipment efficiencies, energy pricing, and a short-term weather forecast. Figure 1 depicts the system configuration. This hybrid heating system could also be configured with an ASHP and hydronic boiler/water heater with an air handling unit. The SFSC is demonstrated to confirm operational savings through case studies presented in this paper.

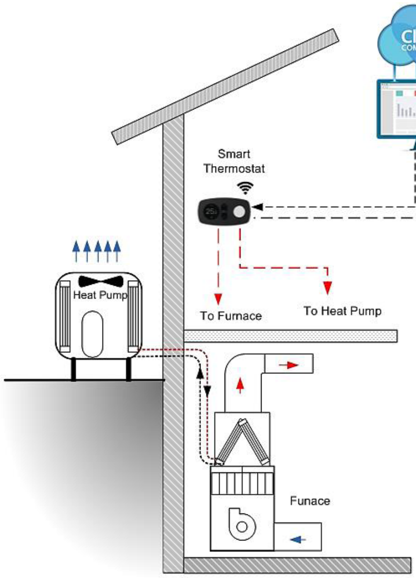

Figure 1 *System schematic – ASHP and furnace with a smart WiFi thermostat connected to a cloud-based Smart Fuel Switching Control (SFSC)*

Pilot Project description

The purpose of this project was to evaluate the annual energy savings, cost savings and GHG emission reductions of the hybrid system heating using the SFSC in a house compared to the same house using only a natural-gas furnace for space heating.

Four participants' homes were selected in different locations in Ontario with different climate conditions. The homes are all single detached houses with the age of 10 to 12 years with various sizes and thermal characteristics. Table 1 shows the location and thermal loads of each home's equipment.

Table 1. Participant Homes and Their Existing Equipment

Location	Size (Sq.ft/Sq.m)	Cooling Load (MBH/kW)	Heating Load (MBH/kW)
Vaughan, Ontario	4600/427	32.6/9.5	76.5/22.4
Mississauga, Ontario	3800/353	49.5/14.5	76.7/22.5
Chatham, Ontario	2800/260	37.2/11	63.8/18.7
Thunder Bay, Ontario	2700/251	35.6/10.4	79.8/23.4

The HVAC system of these houses was upgraded using a variety of brands of energy-efficient equipment. Furthermore, different types of proprietary (modulating) and staging HVAC equipment was selected to cover the different preferences of the customers. The existing thermostats in the homes were replaced by custom communicating smart thermostats. Table 2 shows the specification of HVAC equipment and the control system of each house:

Table 2. Upgraded HVAC Equipment

Location	ASHP	Furnace	Smart Thermostat
Vaughan, Ontario	4 ton, HSPF 9, 16 SEER, 2-Stage	100MBH, Modulating, 98%	2way, communicating
Mississauga, Ontario	4 ton, HSPF 9.7, 19 SEER, Modulating	90MBH, Modulating, 96%	2way, communicating
Chatham, Ontario	3 ton, HSPF 9.5, 17 SEER, 2-Stage	70MBH, Modulating, 96%	2way, communicating
Thunder Bay, Ontario	3 ton, HSPF 9.5, 16 SEER, Inverter	90MBH, Modulating, 96%	2way, communicating

For each participant's home, different wireless metering sensors were installed to monitor the performance of the upgraded HVAC systems over the winter of 2018/2019.

System monitoring results

The project data-reading and logging (in heating season) was from Oct. 1, 2018 to May 31, 2019. The five months of October and November 2018 along with March, April, and May 2019 are collectively referred to as the shoulder season. The months of December 2018, January, and February 2019 are collectively referred to as the peak season.

In Ontario, the delivered electricity prices vary based on the location. On average, the time-of-use electricity prices per kWh estimated at Can$0.086 in off-peak, Can$0.115 in mid-peak, and Can$0.153 in peak hours (Power Stream, 2018). The natural-gas price is Can$0.31/m3 (Can$0.86/therm) and Can$0.253/m3 (Can$0.70/therm) depending on the location (Enbridge Gas and Union Gas, 2018). For the GHG emission calculations, the hourly grid emission in Ontario is considered (Power Advisory, 2018).

Figures 2, 3, and 4 depict the average monthly HVAC system energy consumption, cost, and GHG emission savings for the shoulder and peak winter seasons for each pilot home.

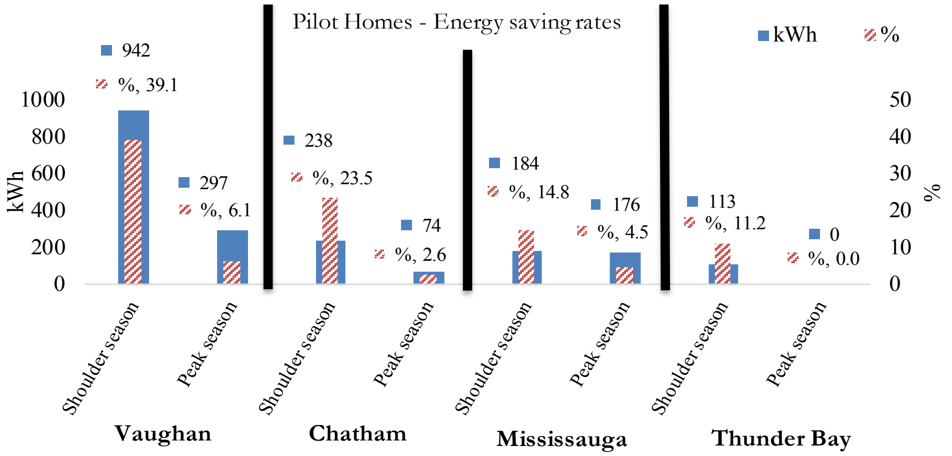

Figure 2 *Average monthly consumption savings for the shoulder and peak winter seasons*

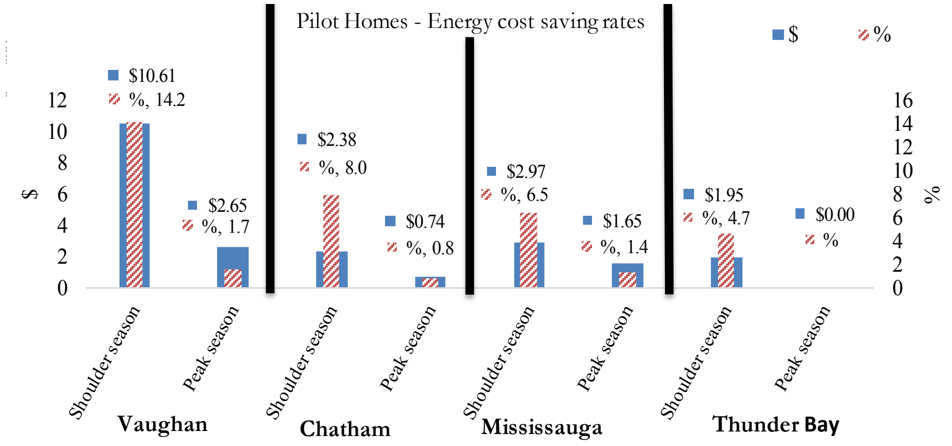

Figure 3 *Average monthly heating cost savings for the shoulder and peak winter seasons*

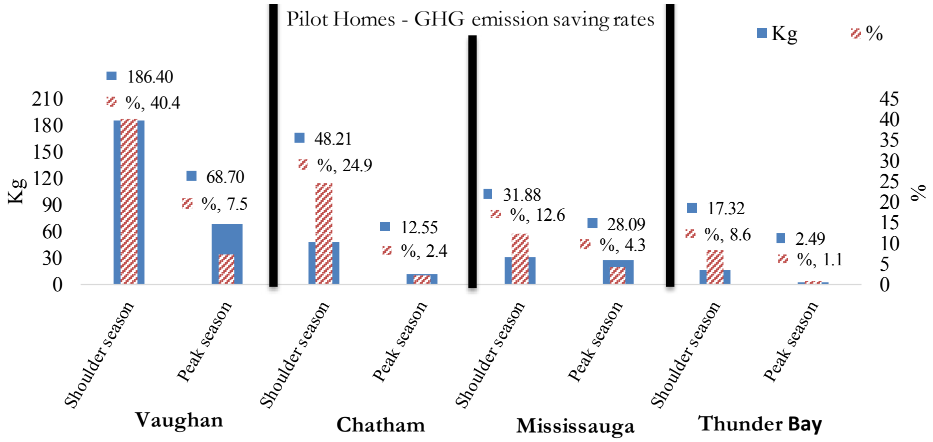

Figure 4 *Average monthly GHG emissions savings for the shoulder and peak winter seasons*

In the Vaughan home, compared to the baseline scenario (in which the entire home's thermal demand is provided by the furnace), the SFSC controller saved a monthly average of 39.91% and 6.11% in energy consumption in the shoulder and peak winter seasons, respectively. In terms of energy cost savings, for the same testing period, the SFSC controller saved on average 14.19% and 1.71% per month in the shoulder and peak winter seasons, respectively. In the same testing period, the monthly GHG emission reductions were 40.36% and 7.47% on average. The total energy cost and GHG emission saving in the heating season were $60.76 and 1.14 tons respectively.

In the Chatham home, in the shoulder season, this home saved a monthly average of 23.49%, 8.04%, and 24.85% in energy consumption, energy costs, and GHG emissions, respectively. In the peak winter season, this home saved a monthly average of 2.61%, 0.84%, and 3.6% in energy consumption, energy costs, and GHG emissions. The total energy cost and GHG emission saving in the heating season were $14.13 and 0.28 tons respectively.

In the Mississauga home, in the shoulder season, this home saved a monthly average of 14.77%, 6.48%, and 22.55% in energy consumption, energy costs, and GHG emissions, respectively. In the peak winter season, this home saved a monthly average 4.51%, 1.44%, and 6.48% in energy consumption, energy costs, and GHG emissions. The total energy cost and GHG emission saving in the heating season were $20.00 and 0.24 tons respectively.

In the Thunder Bay home, in the shoulder season, this home saved a monthly average of 11.17%, 4.73%, and 8.57% energy consumption, energy costs, and GHG emissions, respectively. In the peak winter season, the HVAC system only operated on the furnace. The total energy cost and GHG emission saving in the heating season were $9.75 and 0.09 tons respectively.

Conclusion

The pilot projects highlight the complexity and the variables affecting the energy savings, utility savings, and GHG reduction potential of a hybrid heating system. Factors that were recognized for the variation of saving results in different homes were the following:

- Heating load, as determined by both local climate and the indoor thermostatic set point temperatures.
- ASHP capacities, which all were selected based on the cooling load due to the constraints of retrofitting to existing homes (e.g. limitations with ductwork). The Vaughan home ASHP capacity was selected one ton larger than the house cooling load.
- The make and model of each houses' ASHP. Each ASHP had different COPs and capacity performance with respect to the outdoor temperature. Vaughan home had the best-performing unit compared to other homes.
- Local utility rates for natural gas and electricity. The combination of higher natural gas rates and lower electricity rates lead to increased savings.

Our test results show that a hybrid heating system with smart controls successfully reduces energy consumption, energy costs, and GHG emissions. We are in the early stages of the growth curve and excited about the opportunity to further support this low carbon energy solution.

Critical to the further development of Hybrid Heating Systems is to implement smart control technology into existing HVAC manufacturer platforms. A collaborative industry effort will accelerate the acceptance and awareness around hybrid heating with smart controls. Wider adoption of this control strategy, paired with a hybrid heating system, provides a path forward that will combine the effective use of existing gas and electric energy infrastructure, with the objective to reduce GHG emissions in alignment with our efforts to mitigate climate change.

ACKNOWLEDGMENTS

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NOMENCLATURE

ASHP	Air Source Heat Pump
COP	Coefficient of Performance
SFSC	Smart Fuel Switching Control
TOU	Time of Use

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