Sustainable Technologies EVALUATION PROGRAM

Supported by Toronto and Region Conservation Authority

TECHNICAL BRIEF

Residential Heat Pump Case Study 3: Hybrid Heating in a Toronto Century Home

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 partners 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 promotes effective technological solutions for climate change mitigation.

INTRODUCTION

This is the third case study in a series evaluating heat pump installations in single-family homes in Ontario, focusing on the Greater Toronto and Hamilton Area. The City of Toronto targets a 65% reduction in carbon emissions by 2030. Most of the emissions (57%) are from homes and buildings, primarily a result of natural gas used for space heating. Home energy retrofits on a massive scale are therefore needed. Hybrid heating systems are a promising cost-effective low-carbon heating solution. This case study evaluates upfront costs, carbon reductions, and utility bill impacts of an installation in a Toronto home.

SITE AND EQUIPMENT

The hybrid heating system replaced an aging furnace-A/C system and was commissioned in October 2020 in a 1920s-era 3-bedroom 2-storey detached home in Toronto's East End. The home has two occupants and is less than 1,500 ft^2. Prior improvements to the energy efficiency of the home include foam insulation that had been added between the studs on the interior of both floors and windows upgraded to double-glazed. At the time of the heat pump retrofit, attic insulation was upgraded from 11″ (~R-38) to 18″ (~R-60) of blown-in cellulose over the majority of the attic. Also coinciding with the hybrid system was the addition of a heat recovery ventilator (HRV) to improve air quality, and a tankless water heater (AFUE 98%) that replaced a storage water heater. Table 1 shows the hybrid system equipment. The switchover temperature is -5 ºC. The ASHP is used for heating when outdoor temperatures are above this value. The furnace automatically turns on and provides all of the heating in colder conditions.

Hybrid heating systems (also called dual fuel systems) look the same as conventional furnace and A/C systems. The difference is that, in a hybrid system, the A/C unit is "upgraded" to an air-source heat pump (ASHP). The ASHP provides both cooling and heating. It is driven by electricity and it is much more efficient than a furnace. It can be used for heating in milder outdoor conditions when it is generally more cost-effective than a furnace. The furnace is then used in very cold conditions. In jurisdictions with a low-carbon electricity grid, like Ontario, this can result in lower utility bills and significantly lower carbon emissions.

Table 1. Equipment schedule for hybrid heating system.

	Equipment
Furnace	**GMVC960603BN** Goodman Furnace; Two-stage; 60 kBTU; 96% Efficiency; 3 Ton ECM variable speed blower motor
ASHP	**GSZ160241** Goodman single-stage heat pump; Up to 16 SEER and 9.0 HSPF (Note: This is a medium-level heating efficiency for an ASHP); 2 Ton

UPFRONT COSTS

A hybrid system including a single- or two-stage ASHP *and* a high-efficiency furnace should cost $8,000 to $12,000 installed (plus tax; not including rebates). At the low end of this spectrum are systems for small-to-medium homes that use a single-stage ASHP. At the higher end are systems for larger homes that include a high-efficiency two-stage ASHP.

Based on review of the installation invoice, the upfront cost for the hybrid system in this case study was at the low end of this spectrum, and was **approximately $2,000 more than a conventional furnace-A/C system**. Also note that, in many cases, it is possible to achieve lower upfront costs by replacing only the A/C unit with an ASHP that is then used with the *already-existing* furnace.

ANALYSIS

The pre-retrofit gas and electricity bill consumption data from Winter 2019/2020 was adjusted for weather and used as a baseline for comparison against the data from Winter 2020/2021. Due to the installation date and the natural gas periods for billing, the analysis results in Table 2 do not include September to November. Utility consumption changed as a result of all measures (HRV, water heater, attic insulation, and hybrid system). The following was considered to estimate the impacts of each measure:

- The gas savings resulting from the water heater upgrade was estimated using the change in efficiency against the gas consumption for DHW (known from summer bills).
- The HRV increased utility consumption and a small adjustment was applied to the baseline.
- A heat loss calculation estimated the gas savings resulting from the additional attic insulation.

Current (November 2021) utility rates were assumed. The full analysis is available online.[1] The hybrid system reduced the natural gas for space heating by an estimated 65% and cost slightly more to operate than the previous system ($64 at current rates). The actual cost increase was $41 when the savings from the tankless water heater and attic insulation were included. Note that, at current rates, the hybrid system could approach cost parity with conventional (or produce a small savings) if the switchover occurred at a warmer temperature.

> "We are very happy to have the heat pump, it is wonderful that it is keeping us toasty and we know it is not emitting GHGs. For me, the peace of mind is well worth it." -Homeowner

Table 2. Utility bill analysis results.

Parameter	Value
Actual post-retrofit gas consumption (Dec 2020 to May 2021)	534 m^3
Baseline gas consumption*	1,454 m^3
Total gas reduction	920 m^3 (63 %)
Gas reduction from hybrid heating system	862 m^3
Gas reduction from water heater upgrade	39 m^3
Gas reduction from attic insulation upgrade	18 m^3
Actual post-retrofit electricity consumption (Dec 2020 to May 2021)	4,760 kWh
Baseline electricity consumption*	1,556 kWh
Electricity increase from hybrid heating system	3,204 kWh
Gas reduction for *space heating* due to hybrid system	**65 %**
Net utility cost increase for *space heating* from hybrid system**	**$64**
Net carbon savings for *space heating* due to hybrid system	**1.6 tonnes**

* There was a small adjustment made for the HRV.
**This is the *total* utility increase for Dec 2020 to May 2021 assuming *current* rates.

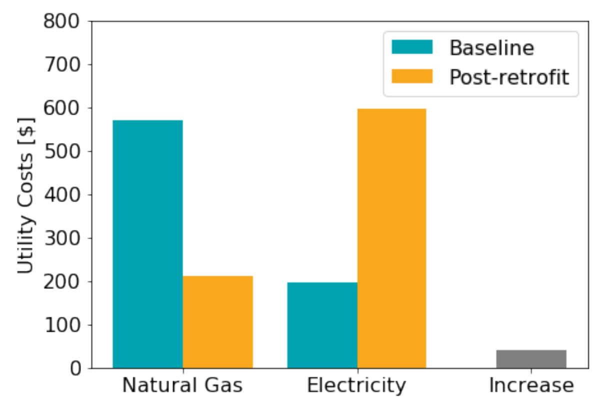

Figure 1. Utility cost impacts at *current* rates including all measures.

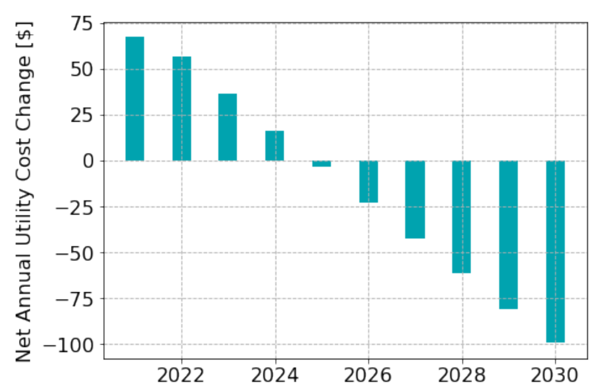

Figure 2. Estimated annual net utility cost changes from the hybrid system considering carbon pricing. Electricity rates were assumed to increase at 2%/year from current values. Positive values are a utility cost increase. Negative values are savings.

The federal carbon pricing schedule will significantly increase the cost of natural gas on an annual basis to 2030. Taking this into account, with the current switchover temperature, **the system is expected to produce a net annual utility cost savings starting in 2025 and totaling $138 cumulatively**

"The heat pump behaves differently from the gas furnace. It doesn't recover the temperature as quickly when the temperature is below the target. We used to setback the furnace significantly at night, but found that the heat pump could not get it back to daytime temperature in a reasonable time. We now only set it back 3 degrees. This is just a change that one gets used to." -Homeowner

to 2030 (Figure 2). Beyond 2030, it may be producing utility savings on the scale of $100 per year compared to the previous system. Deeper utility costs savings should be feasible (at the expense of lower carbon reductions) for hybrid systems which use smart control algorithms that switch between the ASHP and furnace based on whichever is more economical according to real-time factors like time-of-use.

HOMEOWNER EXPERIENCE

The homeowners are overall very happy with their hybrid system, and other upgrades they've made. The HRV, in particular, has transformed the air quality of the home. The hybrid system is quiet inside the home when the heat pump is running, and outside it sounds like an air-conditioner. The added noise outside has not been an issue for the homeowners. In April 2021, the system required a follow-up visit from the contractor to increase the switchover temperature of the heat pump up to -3 ºC. Aside from that, it has been operating without issue during both the summer and winter. While the homeowners are happy with their heat pump, in hindsight they would have preferred deeper consideration of a cold-climate ASHP. It would allow them to eliminate the furnace and reduce gas consumption for space heating by 100% but it would have had significantly greater upfront costs.

"The circulation in the house is actually very quiet, no noisier than it was before, even though the ductwork is a dog's breakfast that has grown from the original convection duct. In fact, when the fan is on low speed I have to check the vents to see if it is actually working. But the heat pump is mounted on the exterior wall as you can see. The noise is not a problem, just unfamiliar... [Sounds] like an air conditioner [outside]. I believe that different makes have different specs for noise, so you can choose a quieter one if that is important." -Homeowner

CONCLUSION

This case study evaluated the upfront costs, utility bill impacts, and carbon reductions associated with a hybrid heating system installed in a century-old detached Toronto home. The building has had different building envelope upgrades, to windows and to the insulation in the walls and attic. Similar homes are common across the City. These improvements were complementary to the hybrid heating system. They reduced the heating load of the older home to a point where a relatively small ASHP can handle the majority of the heating requirements and the furnace could run much less often.

The hybrid heating system cost on the scale of $2,000 more than conventional furnace-A/C to install, and it was able to reduce the gas consumption for space heating by an estimated 65%. The system nearly broke even on utility costs at current rates and is expected to start producing annual savings starting in 2025 due to the federal carbon pricing schedule. Overall, this case study builds on the growing body of knowledge and data on the performance of hybrid heating systems and further demonstrates that it is a viable solution for low-cost deep-carbon retrofits in Southern Ontario homes.

REFERENCES AND ENDNOTES

[1]Note that, while this analysis is based on actual pre- and post-retrofit utility bill data, it still required modeling and estimation which introduces a level of unavoidable scientific uncertainty into the results. To ensure calculation results were reasonable, the amount of gas savings attributed to the ASHP was checked against expectations from manufacturer COP data. The full data analysis for this document was completed in a Jupyter Notebook. It is freely available for review at a public online repository, located at: https://github.com/SustainableTechnologies/CaseStudy3

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