Sustainable Technologies EVALUATION PROGRAM

Supported by Toronto and Region Conservation Authority

TECHNICAL BRIEF

Residential Heat Pump Case Study 2: Low-Cost Hybrid Heating in a Toronto 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 second 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 a Toronto installation.

SITE AND EQUIPMENT

The hybrid heating system was installed in October 2020 in a 2-storey 2,000 ft^2 single-family detached home located in The Beaches, Toronto. The home was constructed in 2002 and has four occupants. It uses a tankless on-demand gas water heater. The hybrid heating system replaced the original furnace (AFUE 92%) and A/C of the home. There have been no other recent energy efficiency upgrades. For the hybrid system, the homeowners selected a two-stage high-efficiency natural gas furnace (AFUE 96%) and a relatively low-efficiency single-stage air-source heat pump (ASHP). The equipment schedule is outlined in Table 1. The system was configured such that the heat pump provided all the heating above an outdoor temperature of -6 °C, and the furnace was used exclusively in more extreme cold. Switching between the furnace and ASHP was handled automatically by the thermostat and an outdoor temperature relay.

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.

"I wanted to significantly reduce our household fossil fuel consumption. My goal was to do this at little to no extra cost in the long term, and demonstrate to others how feasible this is to do today without sacrificing comfort or budget." -Homeowner

Table 1. Equipment schedule for this hybrid system.

	Equipment
Furnace	**GMVC960603BN** Goodman furnace; Two-stage; 60 kBTU; 96% Efficiency; 3 Ton ECM variable speed blower motor
ASHP	**ASZ130301** Amana single-stage heat pump; 8.2 HSPF (Note: This is a low heating efficiency for an ASHP); 13 SEER; 2.5 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 $1,000 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 2018/2019 were adjusted for weather and used as a baseline for comparison against the utility consumption from Winter 2020/2021. Data from 2019/2020 was not used because it included a number of changes to reduce carbon that were not sustainable for the homeowner (like electric space heaters and extremely low thermostat setpoints). Two additional factors were considered in the analysis:

- There was a decrease in electric vehicle (EV) usage post-retrofit due to the pandemic. The baseline utility consumption was adjusted based on available data and discussion with the homeowner regarding their EV usage.
- There was a significant effort from the homeowners to reduce hot water usage post-retrofit (reduced baths, navy showers, etc.). The gas savings attributed to the hot water usage was estimated from discussion with the homeowner and analysis of pre- and post-retrofit summer gas bills.

"Our heat pump is relatively low efficiency (2.5Ton 13 SEER), and it is feasible to run it only at -6 °C or above. I had considered purchasing a larger and more efficient heat pump (3Ton 16 SEER) which could operate at lower temperatures and further reduce gas usage, but the price jumped by approximately $3,000. We determined that using a lower-cost heat pump allowed us to reduce space heating gas usage by 74% at an affordable cost, thus giving us the best bang for the buck." -Homeowner

Table 2. Utility bill analysis results.

Parameter	Value
Actual post-retrofit gas consumption (Nov 2020 to June 2021)	457 m^3
Baseline gas consumption	1,517 m^3
Total gas reduction	1,060 m^3 (70%)
Gas reduction from hybrid heating system	830 m^3
Gas reduction from reduced hot water usage	230 m^3
Actual post-retrofit electricity consumption (Nov 2020 to June 2021)	9,029 kWh
Baseline electricity consumption*	5,956 kWh
Electricity increase from hybrid heating system	3,073 kWh
Gas reduction for *space heating* from hybrid system	**74 %**
Net utility cost increase for *space heating* from hybrid system**	**$41**
Net carbon savings for *space heating* due to hybrid system	**1.5 tonnes**

* Large correction was made for greater EV usage pre-retrofit.
**This is the *total* utility increase for Nov 2020 to June 2021 assuming *current* rates.

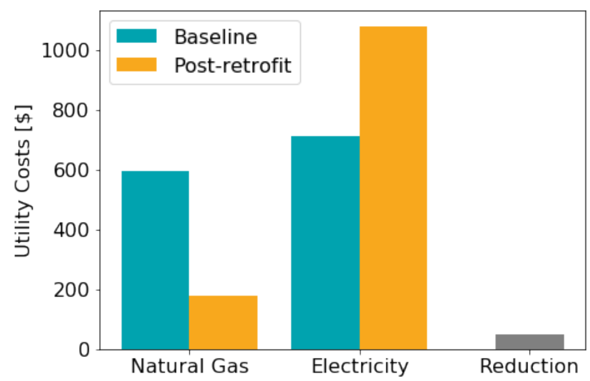

Figure 1. Utility cost impacts including hybrid system *and* hot water reductions.

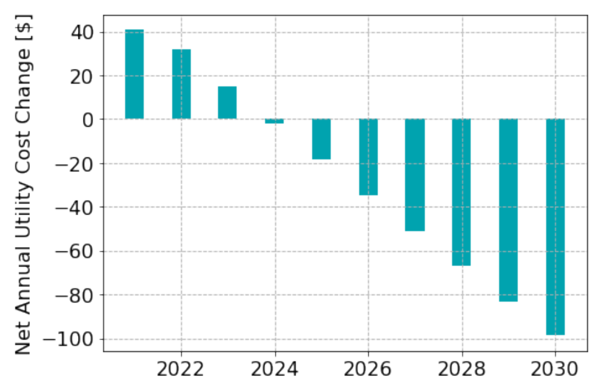

Figure 2. Estimated annual net utility cost changes from the hybrid system considering carbon pricing. Electricity rates were assumed to increase at 2%/year from current values. Positive values are a utility cost increase. Negative values are savings.

Current (November 2021) utility rates were assumed. The full analysis is available online.[1] Results are shown in Table 2 and Figure 1. The **natural gas used for space heating was reduced by an estimated 74%** and the system was estimated to cost slightly more to operate ($41) total over the post-retrofit period. For future low-efficiency ASHP deployment, this cost increase will vary with the efficiency of the previous furnace and with real-world factors, like cycling, that will differ across installations. Annual utility cost increases as high as $150 (at current rates) might be expected for similar retrofits using a low-efficiency ASHP. Utility cost increases can be mitigated through higher switchover temperatures and through medium-efficiency ASHPs (i.e. >9 HSPF). Note that, with the hot water reductions, there was an overall net savings of $49.

Federal carbon pricing will significantly increase the cost of natural gas annually to 2030. Taking this into account, compared to the previous HVAC system, **a net annual utility cost savings is expected starting in 2024 and totaling $267 cumulatively to 2030.** Deeper utility cost 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 very happy with their system and with their contractor. The comfort of their home has increased and the indoor temperature is better regulated. Having chosen a low-cost ASHP, it is noisier outside than other models. It is hardly noticeable in the winter but they would have paid more for an ASHP with low noise in the backyard for the summer. The homeowners have also reduced the overnight setback of their thermostat because the ASHP takes longer to recover indoor temperatures. Summer electricity bills were near pre-retrofit and there were no operational issues.

> "We looked for and found a contractor with significant experience in heat pump installations, and were happy with their work. Our house is actually more comfortable now than when we used the natural gas furnace exclusively. The heat pump cycles on and off less frequently, and maintains a steadier consistent temperature." -Homeowner

> "The outdoor unit does make some noise, same as an air conditioner, but it is at the back of our house so is not too noticeable." -Homeowner

CONCLUSION

There is a wide variety of ASHPs available to fit the specific needs of different homeowners. They range from premium variable-capacity cold-climate models that drive the deepest carbon savings, to simple low-efficiency single-stage models that can only be used as part of a hybrid system in a Canadian climate. Costs vary greatly across this spectrum.

This case study demonstrates that low-cost single-stage ASHPs are a viable solution for homeowners that want the greatest carbon emission reductions for the absolute lowest upfront costs. The hybrid system incremental cost over conventional furnace-A/C was approximately $1,000 and it reduced gas consumption for space heating by 74%.

It is also worth noting that the homeowner did not sacrifice comfort. Inside the home, the system was quiet and the indoor temperature was better regulated than with the previous furnace. The homeowner set out to accomplish their goal. They've demonstrated a home retrofit option that significantly reduces their household carbon emissions at little to no extra cost in the long term, and shown that it is feasible to do today without sacrificing comfort or budget.

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/CaseStudy2

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