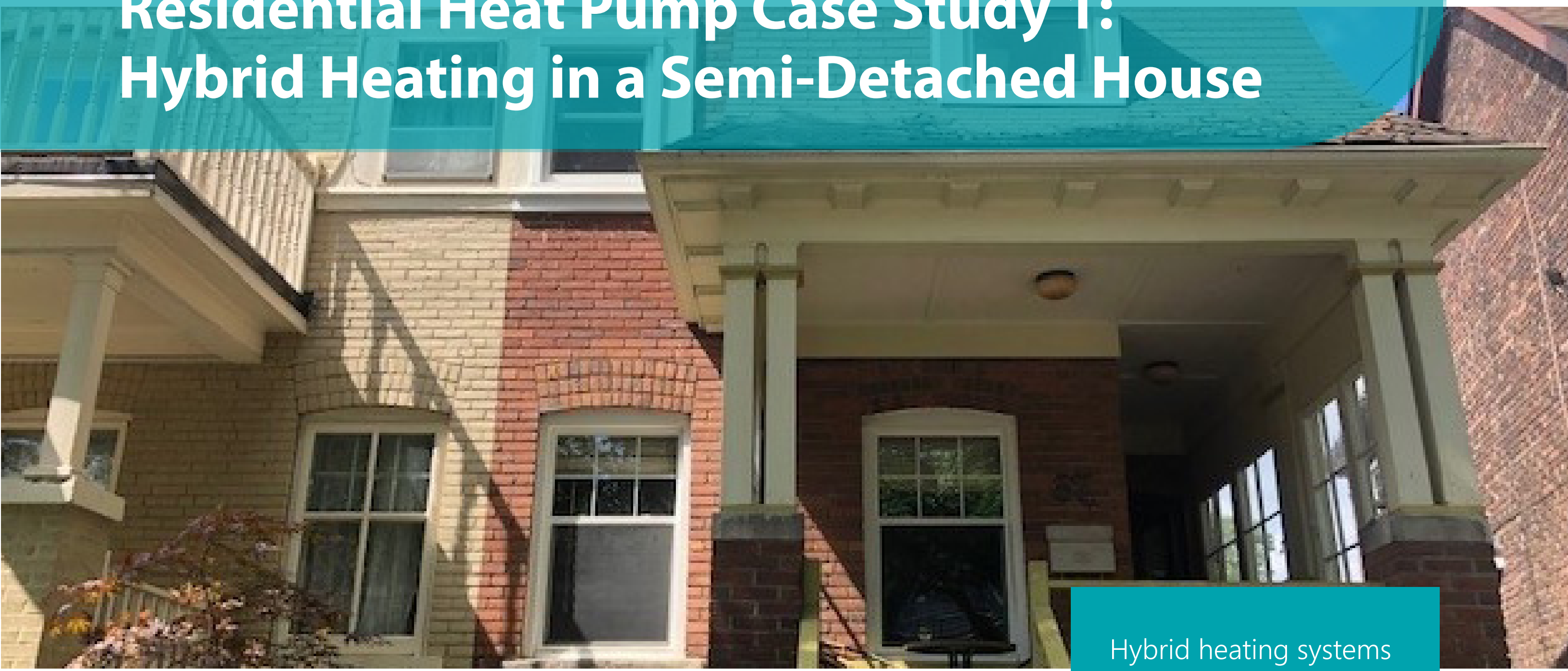
Sustainable Technologies
EVALUATION PROGRAM
Supported by Toronto and Region Conservation Authority

TECHNICAL BRIEF

Residential Heat Pump Case Study 1: Hybrid Heating in a Semi-Detached House



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 first case study[1] 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 system was installed in late-2020 and commissioned in early January 2021 in a 2,100 ft^2 pre-1935 3-bedroom 2-storey semi-detached home in Toronto's East End. The hybrid system replaced the homeowner's A/C, which was at end-of-life, as well as a 12-year-old mid-efficiency furnace. The homeowner chose a high-efficiency two-stage air-source heat pump (ASHP) and a variable capacity gas furnace (AFUE 97%) for the hybrid system (Table 1). The system is controlled by a smart thermostat. It does not switch between furnace and ASHP at a preset outdoor temperature (as is often the case) but instead chooses the ASHP until it is no longer able to meet the thermostat setpoint within 30 minutes of turning on. Concurrently with the hybrid system retrofit, the homeowner also had the home professionally air-sealed and insulation was added to the rear basement wall, which had been identified within an energy audit as a source of heat loss.

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've been sweating about climate change for a while now. So, naturally, I felt prompted to put my money where my mouth was when it came to greening my own abode.I decided to set myself the task of making the DEEPEST possible cuts in my carbon emissions for the LEAST amount of money." -Homeowner

Table 1. Equipment schedule for hybrid heating system.

	Equipment
Furnace	**GMVM970603BN** Goodman furnace; Modulating gas valve; 60 kBTU; 97% AFUE; 3 Ton ECM variable-speed blower
ASHP	**GSZC160241** Goodman two-stage heat pump; Up to 17 SEER and 9.5 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 near the middle of this spectrum, and was **approximately $3,000 more than conventional furnace-A/C**. Also note that, in many cases, it is possible to achieve lower upfront costs by using a single-stage ASHP or by replacing only the A/C unit with an ASHP that is then used with the *already-existing* furnace.

ANALYSIS

To calculate utility bill impacts post-installation, utility bill consumption data for January to May 2021 were analyzed and compared against data during the same period from 2020. Current utility rates were assumed. Modeling estimated results for a full heating season also incorporating September to December. The full analysis is available online.[2]

All measures (hybrid system, basement insulation, and air-sealing) contributed to the savings. However, the impact of the insulation was estimated to be small in proportion to other measures since it only covered one of the basement walls. Reductions in total air changes per hour from air-sealing could be significant depending on the pre-retrofit air leakage (which was not known). However, conservative estimates of heat pump performance suggest that gas and cost savings can be explained primarily by the hybrid system. Baseline electricity consumption was also adjusted for a secondary fridge that was unplugged.

" I had vaguely heard of something called an Air Source Heat Pump – which functioned as an air conditioner in the summer and a heating source in the colder months (when it basically became a reverse air conditioner). I knew that ASHPs were 3x more efficient than gas or conventional electric heating because they didn't generate heat or cold just moved it from one place to another. I decided to investigate further." -Homeowner

Table 2. Utility bill analysis results.

Parameter	Value
Whole-home post-retrofit gas consumption (Sep 2020 to May 2021)	1,050 m^3
Whole-home baseline gas consumption	1,772 m^3
Total gas reduction	722 m^3 (41%)
Whole-home post-retrofit elec. consumption (Sep 2020 to May 2021)	5,946 kWh
Baseline electricity consumption*	3,951 kWh
Electricity increase from hybrid heating system	1,994 kWh
Gas reduction for *space heating*	**51 %**
Net utility cost savings for *space heating***	**$46**
Net carbon savings for *space heating*	**1.4 tonnes**

* There was a large adjustment made for the secondary fridge.
**This is the *total* utility savings for Sept 2020 to June 2021 assuming *current* rates.

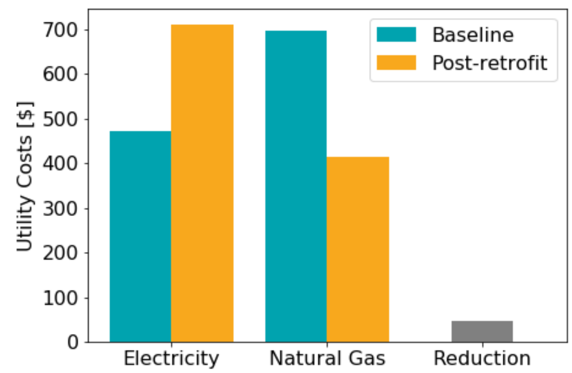


Figure 1. Utility cost impacts at *current* rates including all measures.

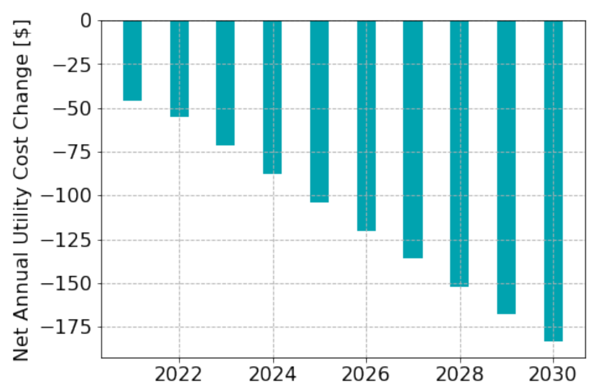


Figure 2. Estimated annual net utility cost changes considering carbon pricing. Electricity rates were assumed to increase at 2%/year from current values. Negative values are savings. Note the savings are from both the ASHP and the increase in efficiency from the previous mid-efficiency furnace. By 2030, approximately $100 of the savings per year should be from the hybrid system alone.

The natural gas used for *space heating* was reduced by an estimated 51% and there was a slight cost savings ($46 total, at current rates for the full heating season) compared to pre-retrofit. It is believed that the ASHP heat pump is breaking even on utility costs at current rates, and that the additional savings is due to the increase in efficiency of the new furnace compared to the previous furnace.

Savings will increase due to the carbon pricing schedule from the Federal Government. **A net annual utility cost savings**

"Ontario's electricity grid is very clean or at least, very low carbon (90% of our electric power comes from non-carbon-emitting sources) so electrifying our home heating makes a GIANT impact on our GHG emissions." -Homeowner

totaling $1,124 cumulatively by 2030 (Figure 2) is expected with current setpoints. 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

There were some initial challenges with the retrofit due to the constraints of the existing ductwork in this nearly century-old home. The homeowner credits her "fabulous HVAC contractor" for their additional troubleshooting visits which ultimately found that the issue was with insufficient cold air return ducting. This issue was then easily remedied.

The homeowner had expected deeper gas savings than was uncovered in the initial analysis of her utility bills. The likely culprit is the thermostat control which coordinates the switching between ASHP and furnace.

The capacity of an ASHP is reduced in colder temperatures and it takes longer to meet thermostat setpoints, especially when the setpoint changes due to a thermostat setback schedule. The research team believes the thermostat was reverting to the furnace prematurely because there was not enough time for the ASHP to fully meet the setpoint in colder conditions. For Winter 2021/2022 the homeowner has changed the thermostat settings and it is expected that deeper gas savings will be achieved as a result.

The homeowner is enthusiastic about haven chosen hybrid heating and is currently investigating other opportunities to reduce carbon, focusing on electric options for her hot water.

"It works great as an air conditioner. It costs more to heat my house in the dead of winter but less in the shoulder months – resulting in a slight overall savings in energy bills." -Homeowner

CONCLUSION

This case study demonstrated that deep carbon reductions are possible in an older home by using a hybrid heating system. The incremental upfront cost of the retrofit was low compared to other low-carbon retrofit options. There was also a small utility cost savings at current rates and, if the controls were not changed, that would increase to more than a thousand dollars cumulatively to 2030 due to carbon pricing while reducing space heating gas consumption by 51%. However, it is anticipated that thermostat setpoint changes should drive deeper gas reductions.

Overall, this case study has shown that hybrid heating systems with low-cost ASHPs are a viable approach to achieve deep carbon savings in single-family homes. The low cost can help bring heat pumps into the mainstream for cost-conscious homeowners and prevent like-for-like replacement of conventional systems.

REFERENCES AND ENDNOTES

[1] Note that this study has been updated from a previous version titled "Cost and Carbon Savings from a Dual-Fuel Heating System in a Toronto Home" and formerly published on the STEP website July 2021. This update was undertaken because STEP has since started a series of case studies, and there was a need to harmonize analysis assumptions and presentation. Key changes for this update are (i) increased cost savings due to increases in current gas rates and (ii) a discussion of the thermostat setpoint problem which was uncovered after original publication.

[2] 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. Data and analysis are freely available at a public online repository, located at: https://github.com/SustainableTechnologies/CaseStudy1

This communication has been prepared by the Sustainable Technologies Evaluation Program (STEP). STEP gratefully acknowledges the insights shared by homeowner Liisa Repo-Martell and installing contractor Imperial Energy for this analysis. The contents of this report do not necessarily represent the policies of supporting agencies. Mention of trade names and commercial products does not constitute an endorsement of those products.

Published Dec 2021. Visit us at sustainabletechnologies.ca for a web version of this document and to explore our other resources on low-carbon technology.

If you are interested in getting involved through any of our engagement opportunities, please contact us at:

STEP@trca.ca | twitter.com/STEPLivingCity

Toronto and Region Conservation

Primary support for the creation of this case study provided by:

TAF

TORONTO

Additional base support for STEP Energy projects provided by:

Region of Peel

York Region