A Near-Net Zero Retrofit Case Study: Walnut Court

ENVIROCENTRE, 2019

envirocentre

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This case study assesses the energy, emissions and cost impacts of a series of energy-related upgrades that were installed at one of the row units at 110 Walnut Court in Ottawa in 2019.

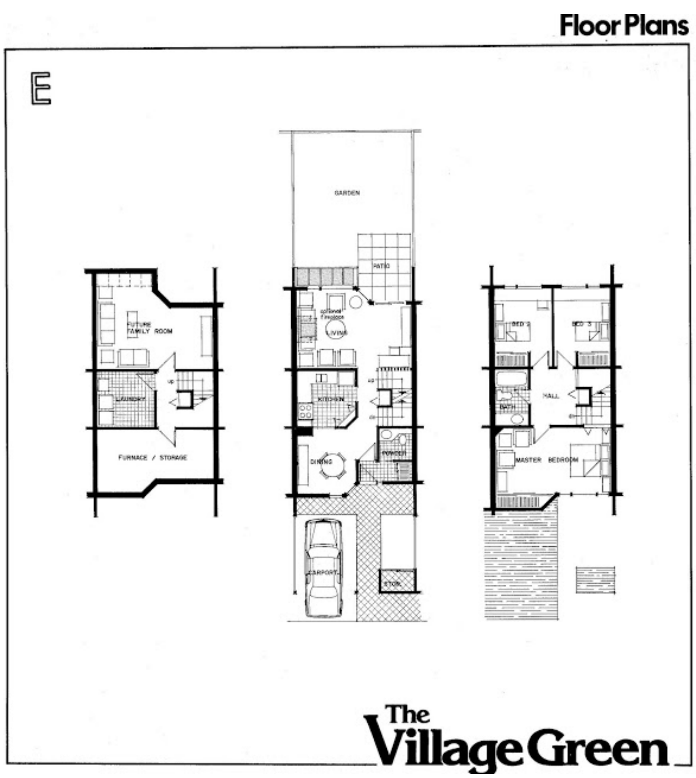
Property Description

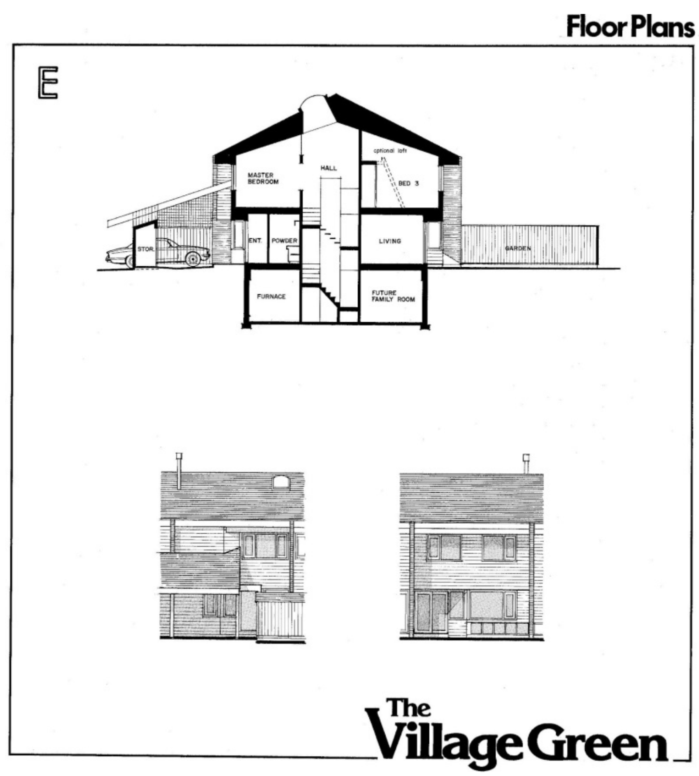
These townhouses were built by A.J. Perez in 1981 as part of The Village Green, which was itself part of Phase 1 of the LeBreton Flats redevelopment. The land in this area is owned by CMHC but was leased for 75 years for the purposes of redevelopment.

These houses were built to standards of insulation that were higher than code at the time, including R32 ceilings,R20 walls and R10 foundation insulation.

At the time of the retrofit, the mid-efficiency gas furnace and standard water heater had already been replaced once, and were16 years old. An HRV had been installed in 2012, and some airsealing upgrades performed, bringing leakage from 6 to 4.41 ACH@50 Pascals. The bathroom exhaust fans and range hood had also been upgraded.

Prior to the upgrades described in this study, the present homeowners had occupied the house for 9 years, during which time several upgrades were performed, including removal of the fireplace, installation of an HRV, attic airsealing, and upgrading the back basement clerestory.





Opportunity

This house design offers several energy savings advantages. Because it is a middle unit attached on both sides, there is less than 40 feet of exposed wall area. The back wall faces SSW, and has several large windows that are mostly shaded in summer. The design heat loss before upgrades was only 30,500 btu/hr, and cooling load 13,000 btu/hr.

In spite of the existing low efficiency heating equipment, energy use was therefore quite low to start with. The house rated 75 on the old EnerGuide Scale, and 95 GJ under the new system. Actual energy use from billing data averaged only about 60 GJ per year.

This looked like a good candidate for a net zero energy retrofit. However, the presence of a large tree on the south eliminated the prospect of adding solar panels, at least for the time being, so **net-zero ready** was a more realistic target.

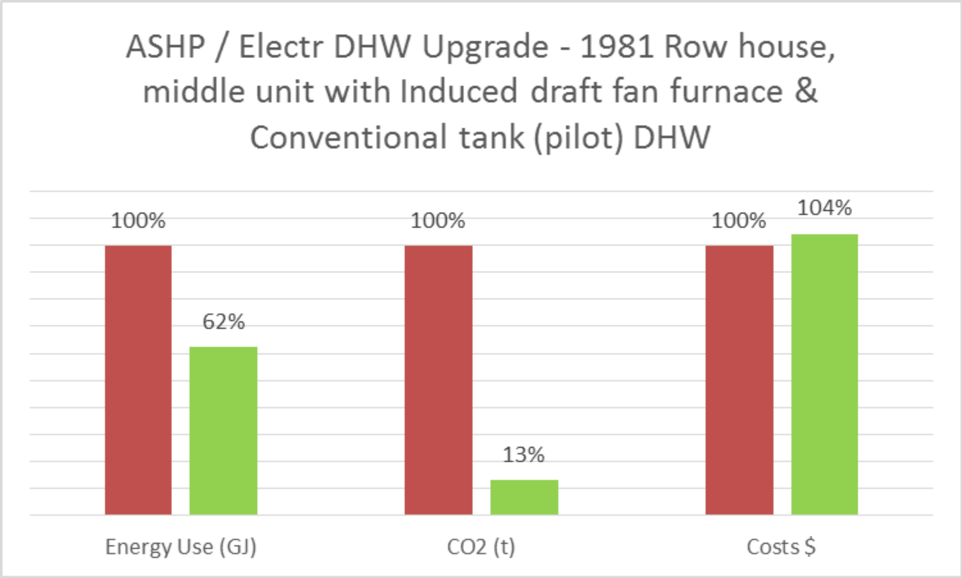
A secondary objective was to achieve a deep reduction in GHG emissions that is possible in Ontario, where the emission factor for electricity in 2018 was **85% lower** than that for natural gas. In this province, ASHP technology allows for an economical transformation of both heating and cooling systems, that can have huge impacts on both energy use and emissions.

Converting water heating to electricity has similar benefits, and also allows the homeowner to close the gas account entirely, eliminating almost $300 in annual fixed costs.

Process

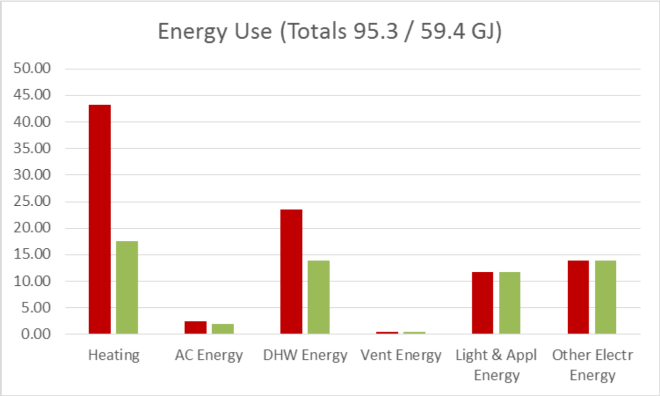
Energy modeling was performed with HOT2000 to see what upgrades would be necessary to greatly lower carbon emissions in a cost-effective manner. The results of modelling were further processed to evaluate the impacts on energy use, emissions and operating costs for each option.

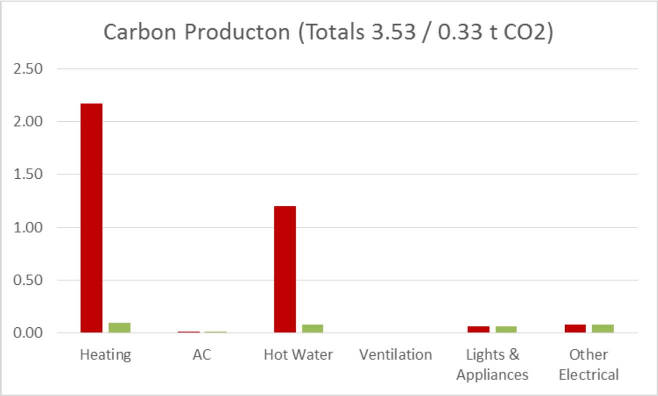
Upgrades in three areas were modeled, suggesting a **38% drop** in energy use and an **87% drop** in GHGs, with virtually no change in operating costs (Chart has been updated to reflect actual equipment installed and 2020 utility rates).



- Heating /cooling system: Gas furnace and AC replaced with ASHP
- Water heater: Standard gas with pilot light replaced with electric tank with drain water heat recovery system
- Air leakage: ACH50 reduced by 10%, from 4.41 to 3.97

The individual contribution of upgrades to energy and emissions were as follows, along with the projected reduction in each area;





Based on these encouraging modeling projections, the decision was made to proceed with upgrades, and quotes were obtained from three different contractors. The quotes varied widely in cost, for equipment that was quite similar in performance and efficiency. The final decisions were made on the bases of cost, perceived value, and contractor availability.

Installed equipment was as follows:

1. **Air source heat pump (ASHP)**, 2 stage with 2 ton capacity, 7.39 HSPF (Region V), 15 SEER
2. **Air handler** with ECM blower motor and 10 kW backup heat
3. **Electric hot water tank**, 184 litres, 62 W standby loss rating
4. **Drainwater heat recovery** unit, 42.8% rated efficiency, delivering preheated cold water to both water heater and shower

The water heater upgrades were installed first, in early summer (June 2019), when the gas account was also closed. However the existing air handler continued to be used for occasional air conditioning. The ASHP and air handler were installed at the beginning of the heating season.

Heat pump, air hander and water heater with drainwater heat recovery unit

After the heating system upgrades, the chimney flue was removed and the chase airsealed at the attic floor. The basement header was airsealed and insulation upgraded to R24. The range hood vent was also upgraded at this time.

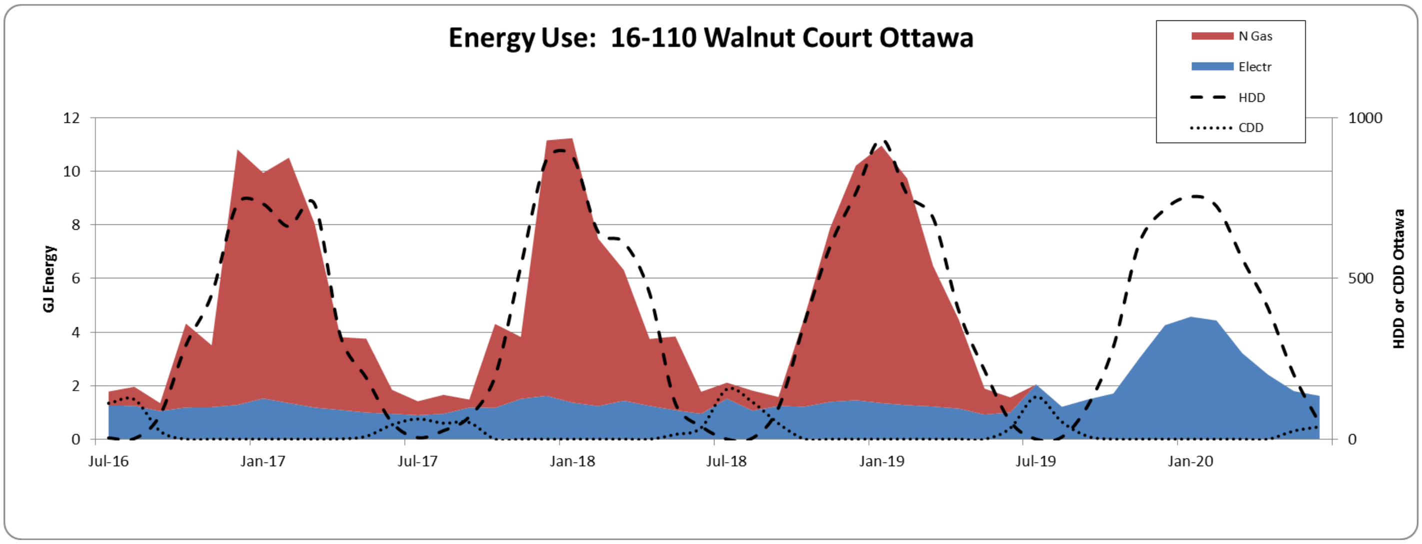
Utility bills were monitored over this period to determine the actual usage of electricity and water.

There were also two significant appliance upgrades during this period

- An older model fridge rated at 650 kWh/year broke down and was replaced in mid-August by a new model rated at 397 kWh/y
- The unused dishwasher was replaced in late March 2020 by a new model rated at 234 kWh/year, which is now used regularly instead of hand washing

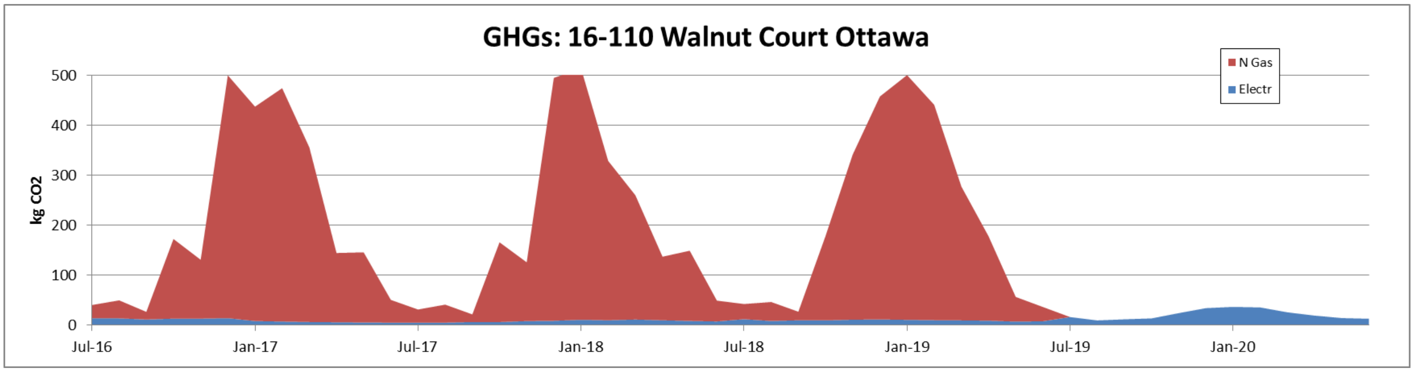
Results

For performance analysis, four years of billing and weather data were compared to actual weather data (Heating- and Cooling-Degree Days), with results as follows:



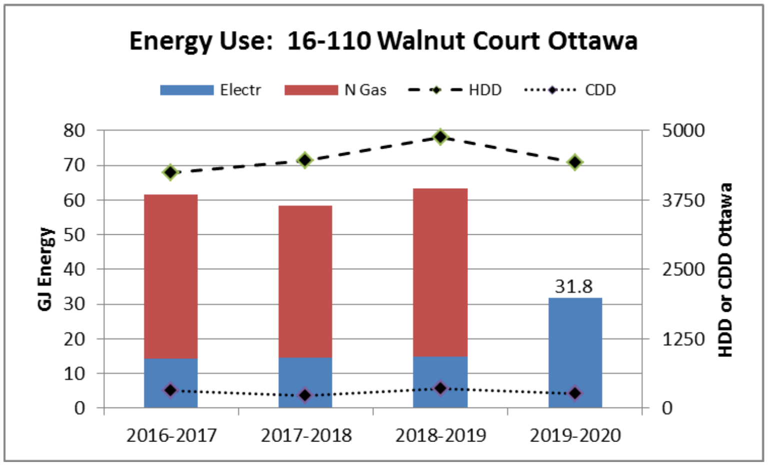
Energy use analysis showed a yearly drop of 48% after upgrades, compared to the average of the previous three years, despite typical Ottawa weather conditions over that year.

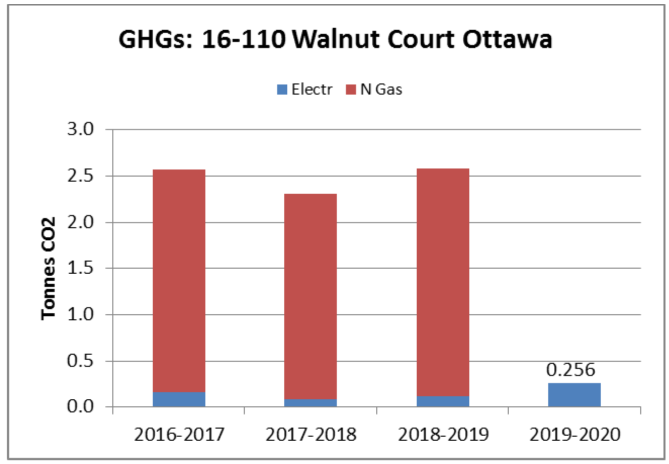
A comparison of GHG emissions over the same period shows an even more dramatic 90% annual reduction:



Note that in previous years, natural gas constituted the major component (95%) of GHG emissions.

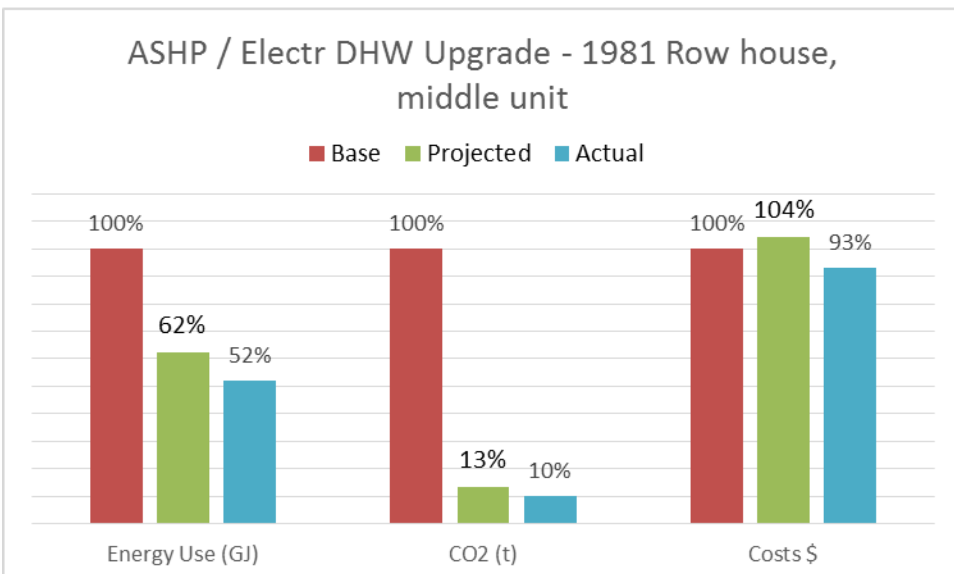
A comparison of annual summaries illustrates these points more clearly: energy use and GHG emissions have fallen spectacularly as a result of the installed upgrades.





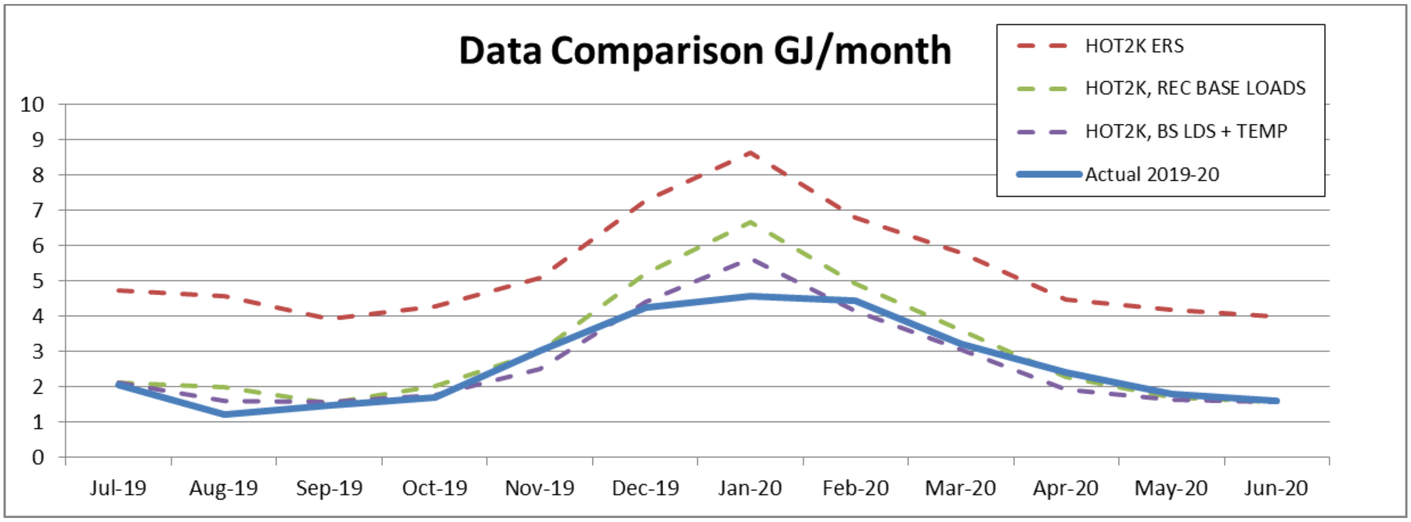
Energy Modeling

After upgrades were completed, the HOT2000 energy model was revised with upgraded header insulation, new blower door data showing that air leakage had improved to 4.13 ACH50, and details of the actual installed equipment. Still, actual results were somewhat better than the projected values in all three categories:



This is partly because of limitations in the ERS mode of HOT2000: the default **base loads** were twice as large as actual values, and thermostat settings were not taken into account. HOT2000 also bases its results on monthly weather conditions of a typical year, which were somewhat different from the actual weather.

To help determine actual base loads in the home, a monitoring device was installed at the electrical panel. The house was then remodeled in **General** mode with reconciled base loads and adjusted temperatures so that the annual energy use was the same. Here are the results:



This reconciled model can now be used to more accurately predict the effects of further upgrades.

Benefits

Howeowner benefits:

- Cost savings including lower utility bills lower maintenance costs (less equipment) and fewer bills to pay
- Safer household due to lower risk of fire, CO poisoning and explosion, 5% lower insurance costs
- Better comfort due to lower air leakage

Broader benefits:

- Less waste: 48% reduction in energy use for the same levels of comfort
- Cleaner Air: 90% GHG emission reduction; elimination of fossil fuel combustion; improvements in local air quality

Costs

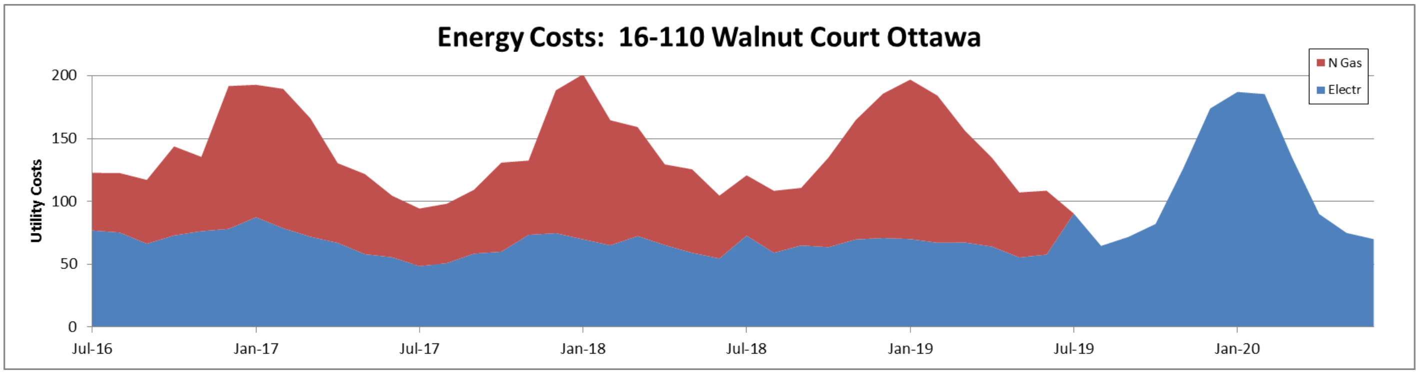
All HVAC equipment was due for replacement, and installation costs were roughly equal to replacement costs for improved new gas equipment. In other words, the **incremental cost**s of the installed upgrades was not significant.

The costs of that alternative strategy of installing gas equipment, along with currently applicable rebates, is shown in the table below.

Installed Upgrades	Cost	Alternative Gas Upgrades	Cost
ASHP with Electric Backup	$ 6,667	Condensing furnace, 96 AFUE	$ 4,500
Electric water heater	$ 1,463	Condensing tank, 0.80 EF	$ 3,000
Drainwater heat recovery	$ 508	Air conditioner, 16 SEER	$ 2,000
Airsealing / Insulation	$ 300	Airsealing / Insulation	$ 200
Rebate	$ -	Rebate	$ (700)
TOTAL	**$ 8,939**		**$ 9,000**

Although costs after rebates are roughly similar for these two strategies, the installed upgrades resulted in much greater reductions in energy use and emissions, with roughly equivalent operating costs. In fact, on a cost basis the installed upgrades are roughly **4 times better** at reducing energy use and **5 times better** at reducing GHG emissions than the gas alternative above (see **Appendix A**).

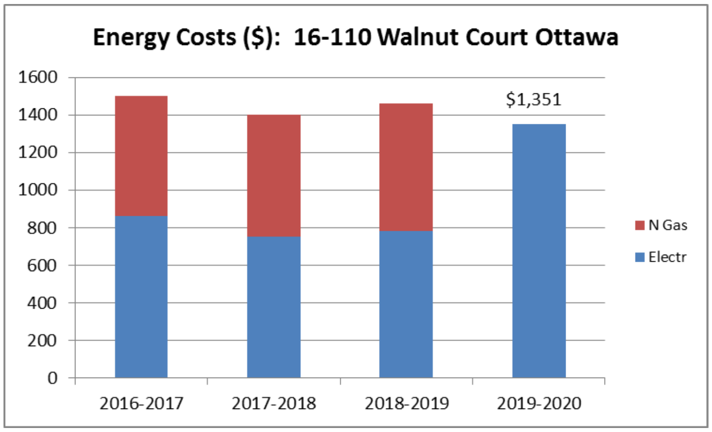
The following annual summary shows how energy costs have fallen.

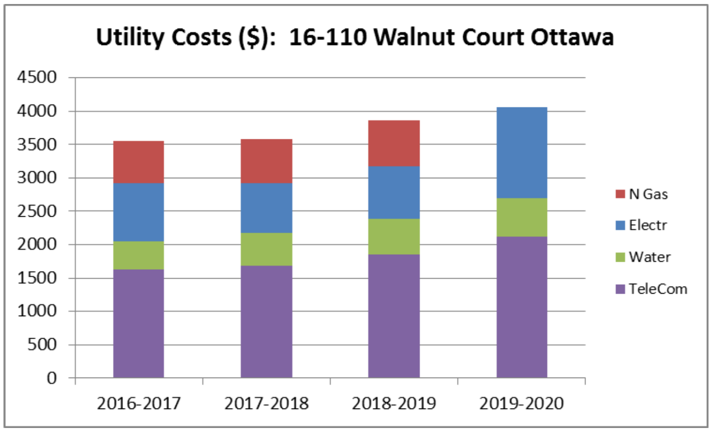


Annual energy costs have gone down by 7% compared to an average of the previous three years. **Fixed costs** play an important role in this reduction, because closing the gas account has eliminated roughly $280 in annual fixed costs, representing over 15% of total utility costs.

Note that the highest monthly electricity bill for the winter of 2018/19 was lower than the highest monthly total energy bills of any previous year. This is partly due to weather, but is also because the combined savings from heat pump efficiency and elimination of fixed gas fees outweigh the low cost of gas as a form of energy.

It's also worthwhile comparing the costs of other utilities; in this home, energy use represents only one third of utility costs while telecommunications represents more than half, so reducing energy use should not be the primary target for reducing household costs. Note that for telecommunications, a reduction in operating costs is not expected to be the sole justification for upgrades!





Lessons Learned

These upgrades illustrate cost effective strategies to dramatically reduce energy consumption and GHG emissions, without increasing operating costs. Reductions from these kinds of upgrades do not directly benefit the homeowner, but have potentially huge national and global benefits as strategies for making the best use of energy infrastructure, and helping to meet GHG reduction targets. As such, these strategies are an excellent candidate for government support to encourage further activity of this kind. The level of support, including rebates, could be at least equal to that given for gas-fired efficiency improvements, which are far less cost effective and result in smaller net energy use reductions and much smaller reductions in GHG emissions.

ASHP pricing varies widely for similar equipment in this jurisdiction. This is possibly because low demand and expertise encourage heating contractors to treat each potential client as a special case compared to the run-of-the –mill gas furnace replacements. As demand increases, we should expect to see lower and more stable pricing.

Software projections are helpful in comparing percentage benefits, but the present large size of default base loads in HOT2000 (25.6 GJ) make it difficult to get reliable absolute estimates. This is especially true in a home like this, where the total energy use is less than 32 GJ and actual base loads are less than half those of HOT2000. It is possible to adjust the energy model by entering actual onsite information, but only in General mode with reduced functionality.

The upgrades outlined in this report are not sufficient to achieve net-zero energy, but are close; a few further upgrades could reduce energy use to the point where a compact solar array would offset yearly consumption. The following list to achieve net zero energy shows other upgrades, potential impacts on energy use, and costs.

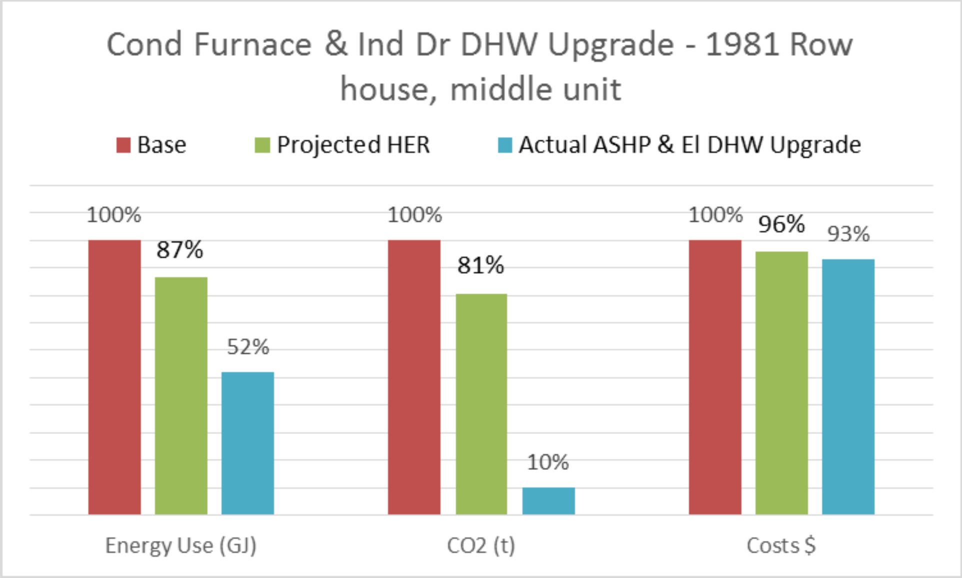
- 1.5 GJ: Install 7 fibreglass triple pane windows - $7,000
- 4.5 GJ: Reduce air leakage to 1.5 ACH50 - $1,000
- 0.6 GJ: Upgrade to heat pump clothes dryer - $1,000
- 0.6 GJ: Upgrade front foundation to R20 – $1,000
- 26.6 GJ generation: Install 380 sq.ft. of solar PV on the SE sloping roof - $20,000 (would also require removing two large trees)

It is important to note that none these upgrades, including the second-tier upgrades listed above, require serious disruption to the life of the resident. The first tier retrofit, outlined in this case study, achieved a 90% GHG emissions reduction and a 48% net energy use reduction for a total project cost hovering around $10K, an amount well within the upgrade budget of an average homeowner, even without incentives. The cost for the second-tier measures, to reach net-zero energy, total around $30K, for an additional 10% energy reduction, suggesting that the cost to reduction ratio of a near-net-zero (or net-zero ready) retrofit dwarf the gains of a full net-zero retrofit both in terms of costs and efficiency, and that this model may be the preferred approach to attain deep energy and GHG reductions in the immediate future.

Appendix A

Alternative Scenario: Staying with Gas. For comparison, the energy model was also used to generate the results of an alternative upgrade scenario with the following improved upgrades of similar cost after applicable rebates:

- Furnace upgraded to condensing gas furnace, 96 AFUE with ECM motor
- Air conditioner upgraded to 16 SEER model
- DHW upgraded to condensing tank, 0.8 UEF
- No drainwater heat recovery installed



Note that the benefits of the actual installed upgrades outweigh the benefits of this alternative gas scenario in all three categories.

However, the homeowner could have received a rebate under the Enbridge **Home Efficiency Rebate** (HER) program in Ontario, whereas there would currently be no rebate at all for the superior performance of the all-electric upgrades outlined in this report, because these improvements are not currently eligible under this or any other existing program in this jurisdiction.

Given that each strategy has a total cost of roughly $9000. cost-effectiveness can be compared:

Cost Effectiveness of Upgrade Strategies		
	Installed Upgrades	Gas Alternative
Energy (per GJ)	$ 303	$ 1,117
Emissions (per kg CO2)	$ 4	$ 19

This shows that the installed upgrades are almost 4 times better in reducing energy use, and almost 5 times better for reducing GHG emissions.

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