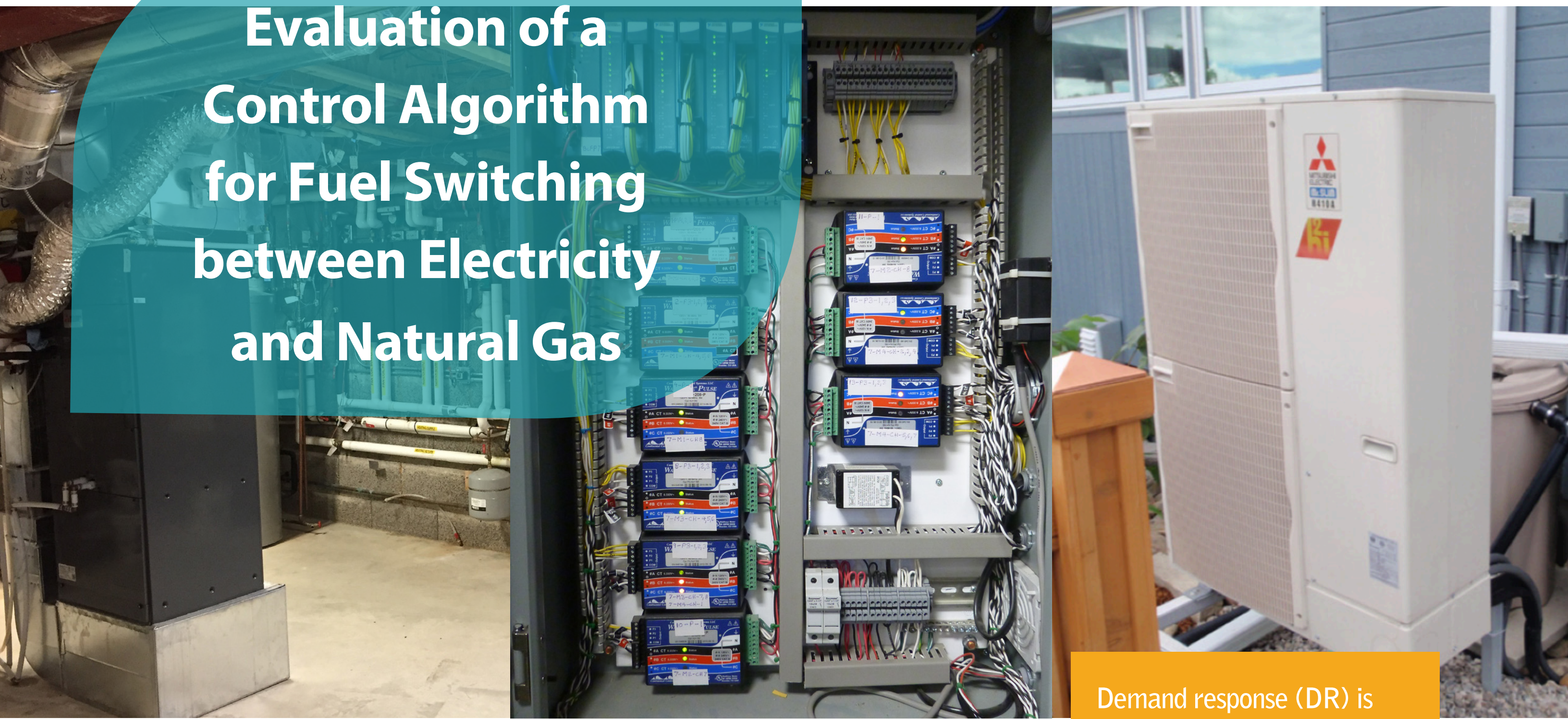
TECHNICAL BRIEF

Sustainable Technologies
EVALUATION PROGRAM

Smart Grid

Evaluation of a Control Algorithm for Fuel Switching between Electricity and Natural Gas



INTRODUCTION

With the potential to reduce building energy consumption and energy costs, smart heating and cooling control strategies are gaining increasing interest. One control strategy is fuel switching. This involves switching from electricity to another fuel based on equipment efficiencies, or demand response signalling from the grid. Fuel switching has the potential to reduce operational costs for a homeowner, as well as reduce peak electrical heating loads on the grid - a growing concern with increasing levels of electrification. Fuel switching can be performed between electricity and a variety of secondary fuels including natural gas and renewable energy such as solar thermal and biofuels.

This short technical brief summarizes fuel switching research that was conducted at the Archetype Sustainable House (ASH) in Vaughan, ON. Within the research, a fuel switching control algorithm controlled two different heating systems to optimize operational costs. The aim of the study was to demonstrate an actual fuel switching algorithm and estimate potential cost savings. Both experimental and simulation work was conducted, analyzing fuel switching at the ASH. Two space heating systems were used: a natural gas-fired mini-boiler and an air source heat pump (ASHP). The ASHP (pictured on the right side of the cover image) is a cold-climate, variable capacity unit, with a 10.5 kW (3 ton) nominal heating capacity. The mini-boiler has a capacity of 18.9 kW, with a gas utilization efficiency (GUE) of 95%.

The efficiency of an ASHP decreases as outdoor temperatures decrease, while the efficiency of a gas boiler is fixed. Therefore, depending on the heating systems and local fuel prices, there may be a breakeven temperature where the ASHP would operate more cost-effectively at any higher temperatures.

Demand response (DR) is when electricity consumers reduce their consumption based on a signal from their electric utility. These signals may be sent to participating consumers when a utility experiences peak electrical loads. DR is gaining increasing interest and is already playing a role in Ontario. A pilot DR program known as PeakSaver controlled participants' thermostats in order to ensure grid reliability during peak demand hours on hot days. In addition to its DR capabilities, fuel switching has the potential to help electricity consumers reduce their utility bills.

FINDINGS

The breakeven outdoor temperature to switch from electricity to natural gas was determined as a function of marginal fuel prices. Below the breakeven point, it is more cost-effective to heat with the natural gas mini-boiler than the ASHP. As electricity and natural gas prices vary over time, Figure 1 shows the breakeven point at different marginal fuel prices. The marginal price includes *all* fees that are charged per unit energy consumed (regulatory, delivery, transmission, etc.), neglecting any fixed monthly costs. This means that the marginal rate is not the price advertised on the time-of-use (TOU) charts.

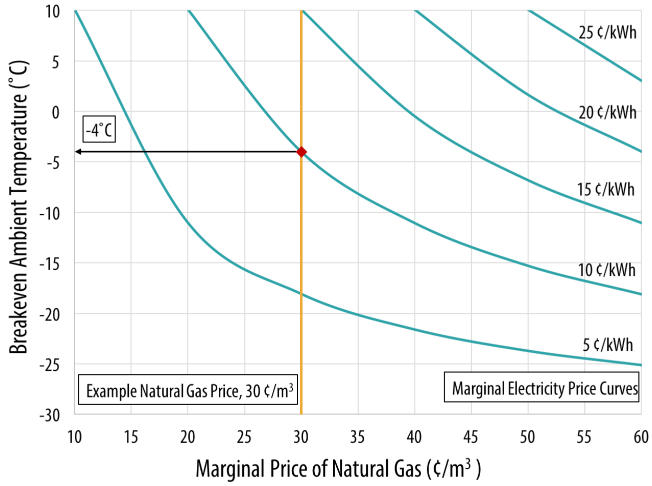


Figure 1. Breakeven ambient fuel switching temperature chart with an example using approximate current off-peak marginal electricity (10¢/kWh) and natural gas prices (30 ¢/m3). The breakeven temperature can be determined by following a line upwards from a given natural gas price until it meets an electricity price curve. The y-value where the two curves meet is the breakeven temperature. Above this temperature, the ASHP is more cost-effective. The curves shown are specific to the two heating systems used in this work.

Fuel switching was successfully implemented at the Archetype Sustainable House. Custom software was developed using LabVIEW that switched space heating from electricity to natural gas when the outdoor temperature dropped below a given breakeven point based on the TOU fuel prices. The appliances were switched on or off using software-controlled relays. While this demonstration was highly customized, simple off-the-shelf solutions are available today (e.g. hybrid heat pumps), and more adaptive, Internet of Things-enabled technologies are expected on the horizon.

Simulations show that fuel switching produces greater savings at colder outdoor temperatures. As outdoor temperature decreases so does the efficiency of the ASHP, and therefore the cost per unit of delivered heat rises. Figure 2 displays simulated daily energy cost savings when performing fuel switching using the two heating appliances at the ASH. Simulations of the ASH estimate the potential for 23.8% cost savings in the heating season, using a marginal natural gas price of 41.6 ¢/m3 and marginal electricity prices of 11.7, 15.4, and 18.0 ¢/kWh for off-, mid- and on-peak time-of-use rates, respectively.

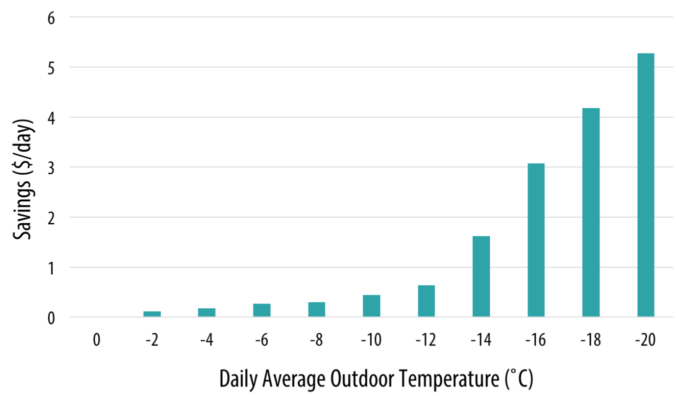


Figure 2. Simulated daily energy savings achieved by fuel switching, compared to an all-electric ASHP baseline.

DISCUSSION & CONCLUSION

Fuel switching has benefits both for cost-optimization and for demand response. The secondary fuel option can also provide homeowners with greater flexibility if the price of one of the fuels were to rise drastically. However, it does introduce additional equipment (and associated costs), and more complicated control. Cost-optimization may also increase carbon emissions. This research looked at a natural gas mini-boiler and an ASHP. Other sources of low-carbon energy, like biofuels or solar water heating, could be considered as well. Combined heat and power (CHP) units can also be used to achieve greater efficiency gain in a fuel switching context.

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