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Electricity Savings through Heat Pump Heat Recovery in Buildings

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Introduction

Ontario Hydro expects that about 25% of its generating plants will have retired by the year 2014. Rather than simply building new generating plants Ontario Hydro wants to diversify its approach by reducing growth in demand as well as increasing supply. Heat recovery is one of several demand-side options with potential for displacing electrical energy in buildings.

Where space heating, cooling and service water heating in existing buildings is provided by electricity, savings both in electrical energy and demand are possible through heat pump heat recovery.

Heat Recovery in Ontario

A recent study [1] identified and described the most promising heat recovery applications, the status of the technology, and each application's maximum technical potential for electrical energy and demand savings in Ontario. The heat recovery technologies examined included desuperheater heat exchangers, heat pump water heaters, grey water heat recovery heat pumps, air-to-air heat exchangers, run-around heat exchangers, exhaust-air heat pumps, heat recovery chillers, dehumidification heat pumps and heat recovery ventilator heat pumps. The technical potential for electrical energy and demand savings of certain heat pump heat recovery technologies is the focus of this article.

Many of these heat recovery technologies have been applied, while others have not been developed commercially for largely economic reasons. While conventional end-user economics may be unattractive, from a utility demand-side management perspective, some heat pump heat recovery applications show sufficient promise to reduce electrical demand for space heating and service water heating to warrant incentives.

Heat Pump Heat Recovery Technologies

The three heat pump-based heat recovery technologies which showed the most promise are:

- the exhaust-air heat pump;
- the heat pump water heater (HPWH);
- the heat recovery ventilator heat pump.

Applications for these technologies in residential and commercial/institutional buildings were examined in detail.

Exhaust-air Heat Pumps

Exhaust-air heat pumps, (Figure 1), use warm ventilation exhaust air leaving the building as a heat source to pre-heat service water. They are well-suited to buildings with relatively constant occupancy, and high, continuous, domestic hot water loads such as high-rise residential buildings, hospitals and nursing homes.

Payback periods from 4 to 6 years and annual COPs between 3.5 and 5.0 have been reported.

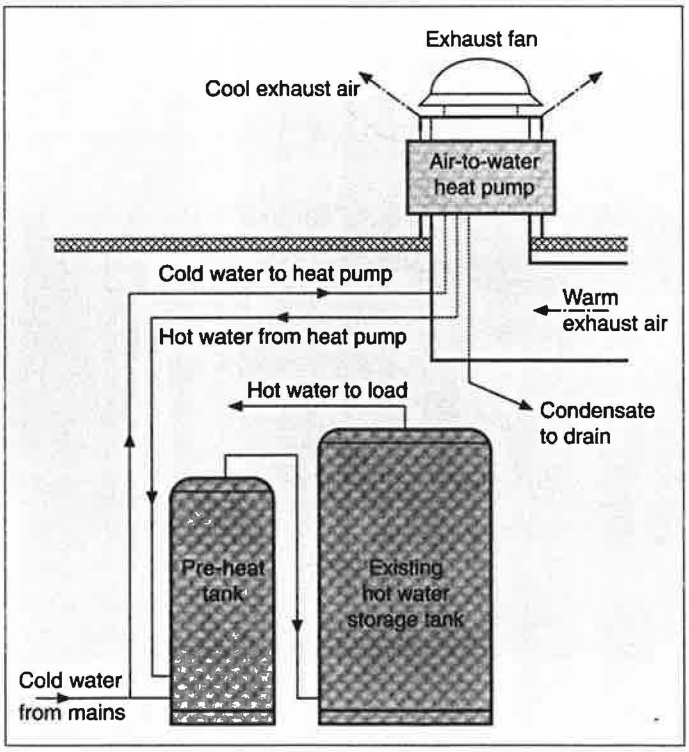


Figure 1: Exhaust-Air Heat Pump System.

Heat Pump Water Heaters

HPWHs recover heat from their ambient air surroundings to heat domestic water. The heat source generally varies between 7°C and 49°C. Two configurations are available in the North American market: an integral unit with a storage tank, and an add-on unit for retrofit applications to existing hot water tanks. In single-family applications, electrical energy savings of 1500 kWh per year compared with electrical resistance heaters with annual COPs up to 2.0, have been reported. Electrical demand can be reduced by anywhere from 1.5 kW to 3.0 kW. In summer, the same unit can cool and dehumidify the surroundings.

For commercial/institutional buildings, larger HPWHs can be applied in boiler or compressor rooms to recover heat from surroundings to pre-heat service water. COPs of 2.6 have been reported with 50 to 60% of the service hot water loads met by the heat pumps. Heat recovery from restaurant or cafeteria kitchen ambients has also been accomplished with HPWHs. In these applications, surroundings are often over 25°C and there are large requirements for hot water. A payback period of 3.5 years, energy savings of 40% and a demand reduction of 7.6 kW were reported in one study. More comfortable working conditions should also improve kitchen staff productivity.

Heat Recovery Ventilator Heat Pumps

These are used in single-family buildings where exhaust temperatures are between 20°C and 23°C, and ventilation air flow rates are between 50 and 100 litres per second. These units source from the exhaust stream to provide space and/or domestic water heating. Annual COPs between 1.5 and 2.0 and annual electricity savings between 1500 and 3000 kWh have been reported.

Technology	End-use	Building type	Estimated electricity reduction in end-use
Domestic HPWH	Water heating	Single-family	
Heat recovery ventilator heat pump	Space and water heating	Single-family	
Exhaust-air heat pump	Water heating	Comm./Instit.	
Kitchen HPWH	Water heating	Restaurants	
Boiler room HPWH	Water heating	Comm./Instit.	

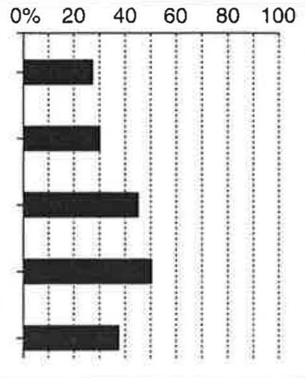


Table 1: Heat Pump Heat Recovery Applications.

Potential Electricity Savings

The primary objective of the study was to estimate the electrical load reduction potential through heat recovery. The information for this estimate was drawn largely from heat recovery technical literature and other published reports.

Estimating the electrical demand and energy saving potential for the identified applications involved a number of steps:

- the buildings to which the technologies were applicable were identified;
- the number of such buildings in Ontario were determined;
- potential end-uses for the recovered energy were identified;
- the amount of electricity associated with each end-use was established for each building type.

Consideration was also given to the type of distribution system, whether central or distributed, for both space and water heating systems. An estimate of the percentage or fraction of electrical energy saved with each heat recovery heat pump application was determined from published literature.

The total number of single-family dwellings in Ontario in 1988 was 2.6 million while the total floor area in commercial/institutional buildings was 165 million square metres. Each individual heat recovery technology was applicable to only a fraction of the total single-family or commercial/institutional building population.

Results

For each of the heat recovery technologies, the building types and potential end-uses are summarized in Table 1, together with an estimate of their percentage reduction in electrical end-use.

The electrical energy saved for each heat pump heat recovery technology covered in this article, depends on the number of buildings or households meeting the special requirements, and the amount of electricity currently used for the particular end-use. The estimated residential electrical energy savings through heat recovery for Ontario are shown in Figure 2 for single-family and commercial/institutional buildings.

Estimates of electricity demand reduction assume that the end-use hours of operation are unchanged after heat recovery implementation. By dividing the electrical energy savings by the end-use hours of operation, the average demand reduction can be determined. The results for Ontario for single-family and commercial/institutional building heat pump heat recovery technologies covered in this article are summarized in Figure 3.

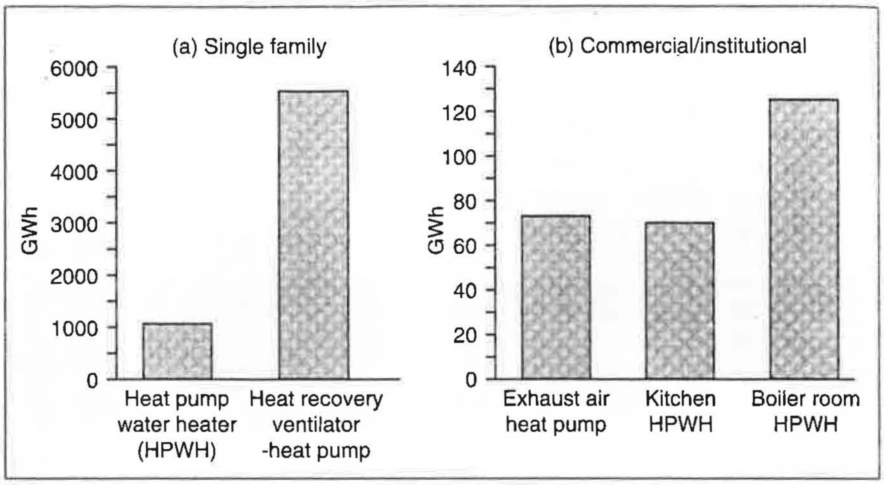


Figure 2: Electrical Energy Savings.

Conclusions

Looking at all single-family heat recovery applications examined, the total potential for annual electrical energy savings is estimated to be 7600 GWh. The potential winter electrical demand reduction is over 900 MW, while in summer the peak demand reduction is estimated to be about 700 MW.

In the commercial/institutional building sector in Ontario, where electricity use for all end-uses of interest (space and service water heating) is significantly less than in the residential sector, the total potential for annual electrical energy savings, through all heat recovery applications examined, is estimated to be about 440 GWh. The potential winter electrical demand reduction is estimated to be 110 MW. The potential impact on summer demand is an estimated reduction of 85 MW.

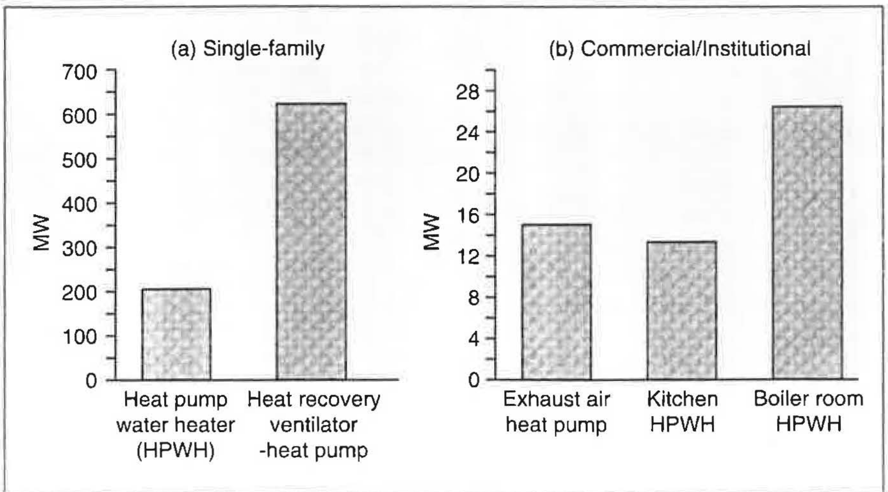
While the potential impact of all heat pump and non-heat pump-based heat recovery technologies examined in the study are included in the total potential energy and demand savings reported above, the heat pump heat recovery technologies described in this article offer significant potential for electricity savings by themselves, as shown in Figures 2 and 3.

The most promising residential heat pump heat recovery application is the replacement of electric water heaters by HPWHs, in all homes using gas or oil for space heating (estimated to be 680,000 homes in Ontario). This could achieve an electrical demand reduction of 200 MW.

In the commercial/institutional building sector in Ontario, while the total heat recovery potential is less, the applications are larger and concentrated on fewer sites, therefore they are easier to target with demand-side management programmes. Heat pump heat recovery from boiler or compressor room ambient air using HPWHs has an estimated total potential demand reduction of 27 MW. Exhaust-air heat pumps could reduce electrical demand for water heating in Ontario's commercial/institutional buildings by about 15 MW. HPWHs applied to restaurant kitchens have a technical potential to reduce electrical demand by another 14 MW.

One can therefore conclude that exhaust-air heat pumps and HPWHs are capable of achieving significant demand reductions, in both single-family and commercial/institutional buildings. In some applications, exhaust air heat pumps or HPWHs can contribute useful space cooling and improved working conditions as an additional benefit.

Figure 3: Electrical Demand Reduction.



1) Caneta Research Inc., "Opportunities for Electricity Savings Through Heat Recovery in Residential and Commercial Buildings", prepared for Ontario Hydro Research Division, November, 1991.

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