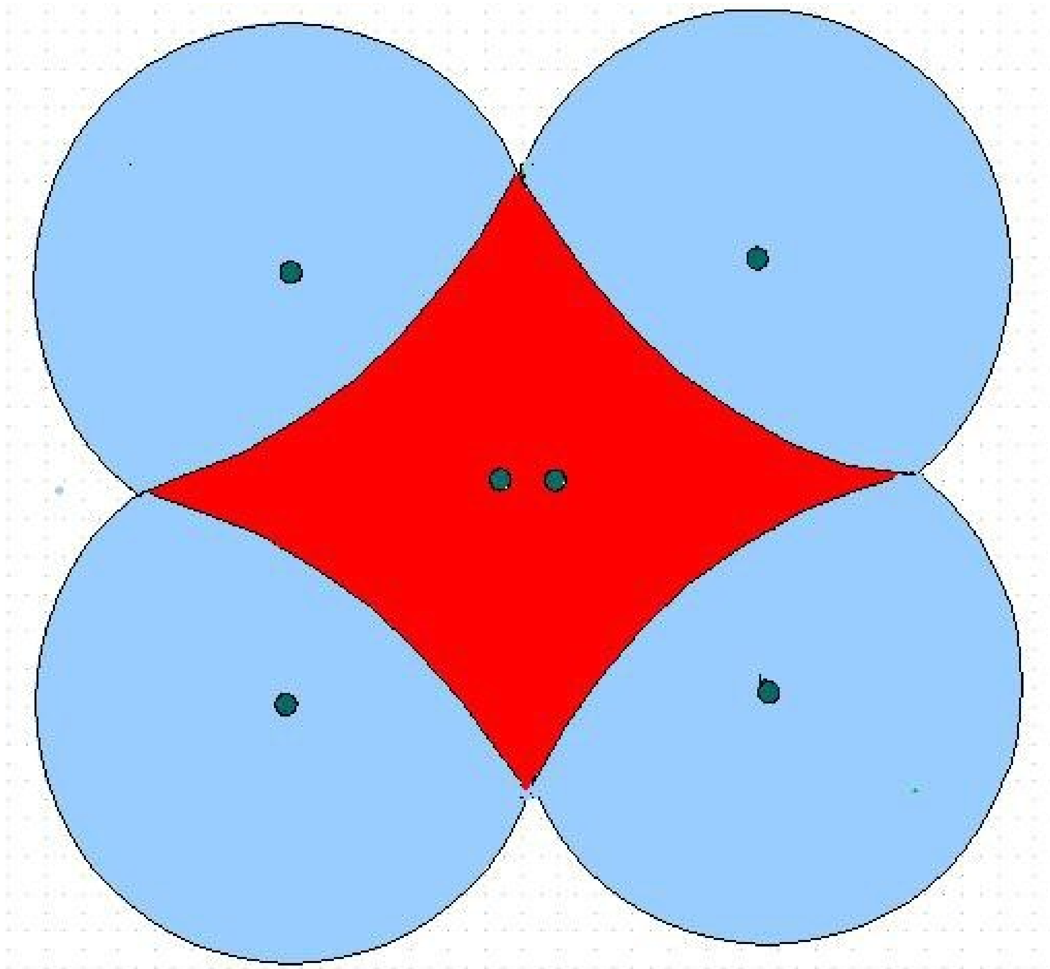
Heat injector box

Heat is extracted from the air and injected into the ground via the central boreholes

Tubes from the six boreholes lead to the house



Map of heat around the six boreholes

RED – above the ambient ground temperatures

BLUE – below the ambient ground temperature

The injector box is not visible from the street

The heat pump provides both underfloor and forced air heating

TEST RESULTS

- **Heat extraction rate – 20 kW**
- **Borehole depth – 20 metres**
- **Borehole extraction power – 192 watts/metre**
- ***COP – 4.3***
- **Flow rate – 1 litre/second**
- **Injection rate – 14.9 kW/borehole at 22.5 degrees C**
- ***Average ground temperature increase – 4.3 degrees C***
- ***Supply: 17,000 kWh from the air***
  5,000 kWh from the ground
  5,000 kWh from electric drive power
  27,000 kWh total

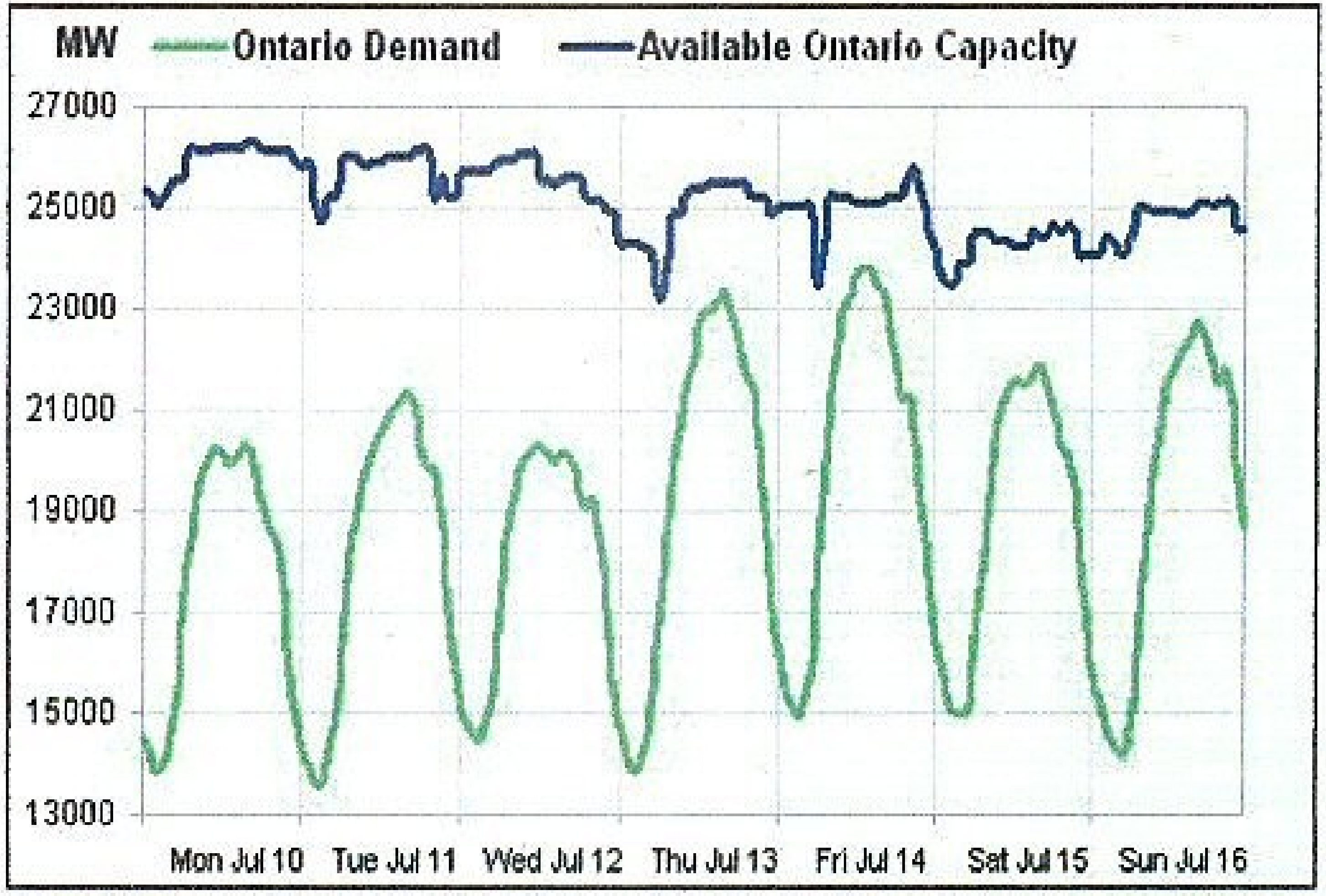
POTENTIAL

- **Applicable to detached homes, including at remote sites**
- **Condominiums can share the ground stores**
- **Applicable to dense housing because of high storage capacity**
- **Applicable to commercial, industrial, and institutional applications**
- **Could replace natural gas and heating oil for heating**
- **Could eliminate the summer power demand peak**
- **Can be used for DHW (domestic hot water)**

Note: The systems discussed in this paper are called Atmospheric Energy (AE) systems to distinguish them from air-source systems (without storage) that are commonly used in warmer climates.

EFFICIENCY

- **Heat recovery can exceed injection (with ground heat contribution)**
- **High COP because of warmer ground temperature**
- **Maximum output at mid winter because of heat flow pattern**
- **High extraction efficiency because of vertical temperature gradient**
- **Thermal short circuiting is minimized**
- **Quad extraction tubes achieve high gain/metre**
- **Comparatively shallow boreholes**
- **Very little power is needed for injection**
- **Can utilize direct air-source heating during mid temperature periods**



Hourly Ontario demand vs. available generation capacity within the province. Internal supply is supplemented by import capacity of up to 4,000 MW.

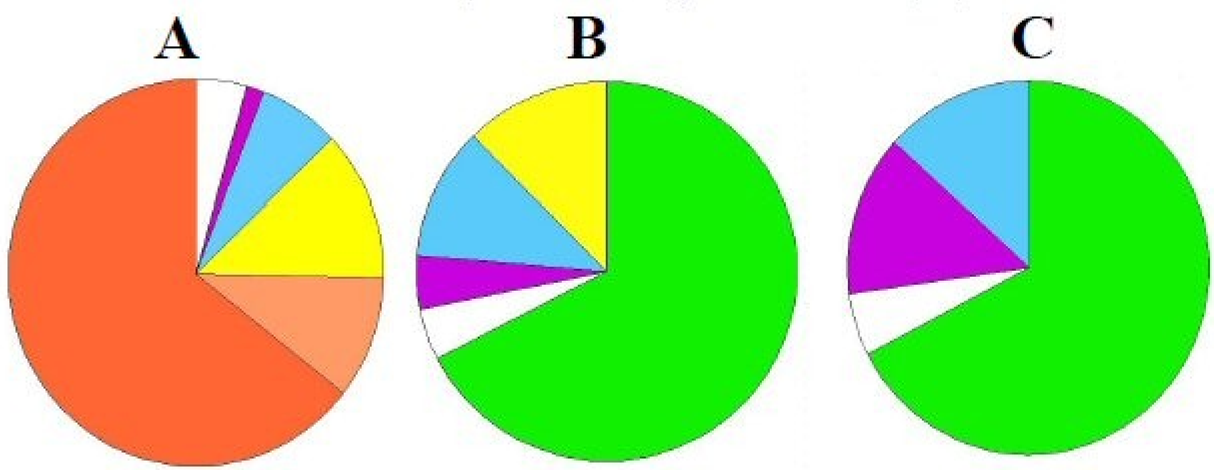
In Ontario there are very large winter, summer and daily demand fluctuations

MATCHING ENERGY SUPPLY AND DEMAND

- **Simply summing energy supplies does not work**
- **Storage is the key to matching supply with demand**
- **The primary energy demand in winter is for heat**
- **The main demand in summer is for AC (currently using electricity)**
- **Short term storage of heat can minimize power fluctuations**
- **Most renewable energy sources do not provide storage**
- **AE needs electricity so such sources are mutually dependent**
- **Only a small portion of electric power generation uses fossil fuels**
- **AE could eliminate that fossil fuel component**

POTENTIAL IMPACT OF AE PLUS WIND IN ONTARIO

Summary The present pattern of energy use in buildings is shown for the present case (**A**), for the case where nuclear power continues to be used (**B**) and for the case where both fossil fuels and nuclear power are phased out (**C**).



RED – fossil fuels for heating (orange – for power)
GREEN – AE systems
YELLOW – nuclear
BLUE – hydro
PURPLE – wind (white is "Other")

CONCLUSIONS

- **Our largest energy source is being ignored**
- **It is also the most readily accessible energy source**
- **The storage can handle dense urban environments**
- **AE systems could supply up to 2000 petajoules of energy**
- **AE systems make other renewable energy sources more practical**
- **They could diminish CO_2 production by 101 megatonnes**
- **The limiting factor is government policy**