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Background – Residential Water Heating in Canada

- Water heating: 19.5% of residential energy consumption
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Background – Common Water Heating Options

- Energy Factor: energy output per unit energy input
  - Natural gas: 0.67
  - Electric: 1

![Pie chart showing energy sources: 86% Natural Gas, 12% Electricity, 2% Other.](image)
Background – Heat Pump Water Heaters

- Have electric backup elements
- Significant energy and GHG reductions with HPWHs
- Heat removed from space: impractical during cold-climate winter
Motivation

- HPWHs can significantly reduce GHG emissions and electricity consumption
- Solar-assisted HPWH option for cold climates
- Research shows improved HPWH performance with solar in warmer climates

Objectives

- Determine solar assisted HPWH winter performance using experimentally-validated model
- Assess feasibility of various configurations in Canadian locations
- Determine economic and technological feasibility
Methodology

Experimental:
- Performance map tests
- Hot water draw tests

HPWH Model Development:
- TRNSYS model
- Experimental validation

Expand Model to Include Solar:
- Expansion of TRNSYS model
- Different configurations

Analysis of Solar-HPWH Configurations:
- Performance in winter
- Comparison to HPWH-only system
- Canada-wide performance
- Year-round performance
Experimental Test Setup
Experimental Validation for TRNSYS Model

- Mean Average Error:
  - Power = 28 W
  - Temperature = 0.6 °C
- Average percent difference
  - Power = 6.2%
Solar Assisted Heat Pump Water Heater Configurations

- Conditioned Space

- Closed Loop
Conditioned Space Solar Assisted HPWH

- Has impact on space heating and cooling like HPWH-only system
Conditioned Space Solar Assisted HPWH

- Impact on heating load small relative to total heating load in winter
- Largest (negative) impact in Vancouver
  - Due to high cloud cover and low solar gains

[Bar chart showing net space gains/losses for different months in Ottawa, Winnipeg, and Vancouver.]
Closed Loop Solar Assisted HPWH

- HPWH only operates when inlet temperature (collector outlet) sufficiently high
Closed Loop Solar Assisted HPWH

- Cannot reliably meet demand without electric backup in winter months
Canadian Annual Electricity Consumption Trends

- At larger tank volumes, temperature variation decreases and Closed Loop electric backup operates less
Annual Electricity Consumption (Conditioned Space)
Annual Electricity Consumption (Conditioned Space)

- 10% variation in yearly electricity consumption
- Influenced by: mains water temperature, weather (relative humidity, clouds, solar gains)
Annual Cost Relative to HPWH Alone

- Highest savings in locations with high electricity prices
- Larger savings in warmer southern areas (higher COP)
Future Work

• Economic analysis of solar assisted HPWH configurations and HPWH-only
• Analysis of American cities for different configurations
• Using solar assisted HPWH for radiant floor heating
Thank You

Questions?

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References
