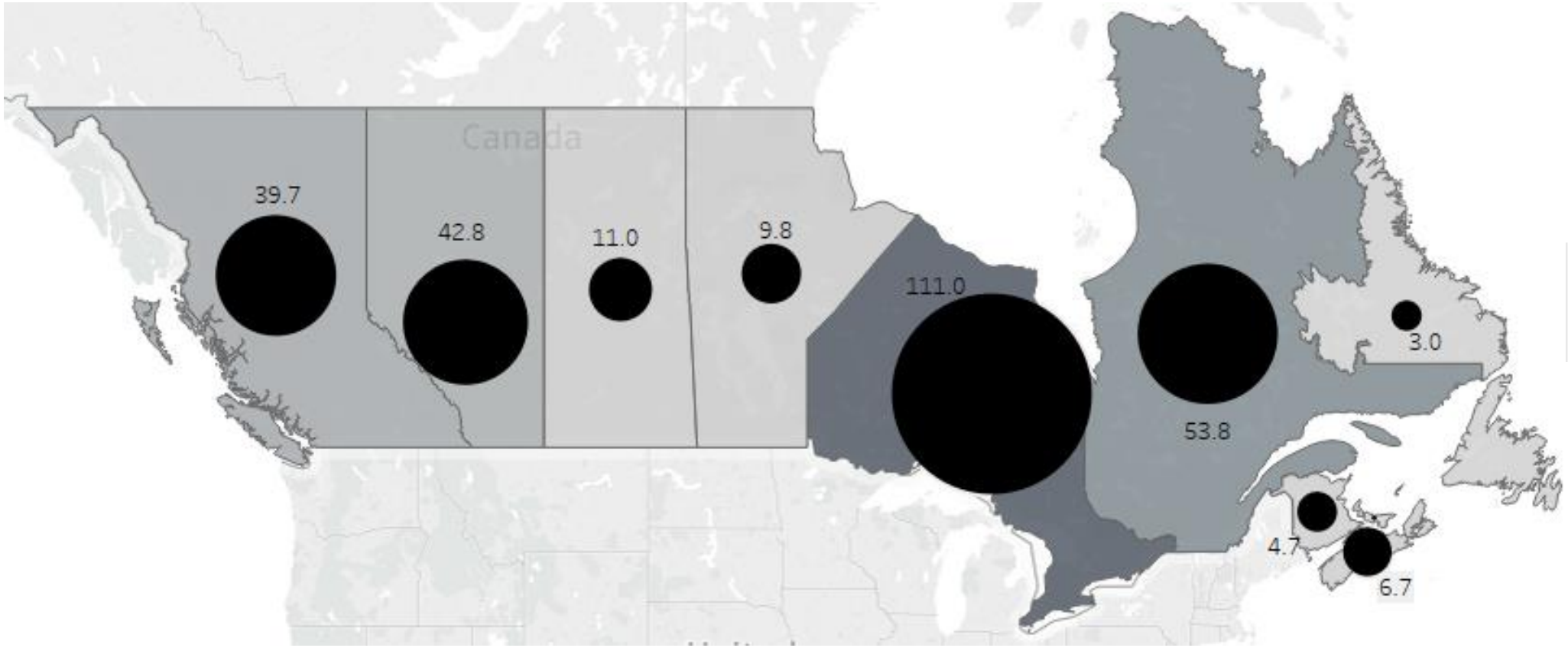
Evaluation of a Solar-Assisted Heat Pump Water Heater for Canadian Climates

By: Calene Treichel | Supervisor: Prof. Cynthia Cruickshank

Background – Residential Water Heating in Canada

- Water heating: 19.5% of residential energy consumption



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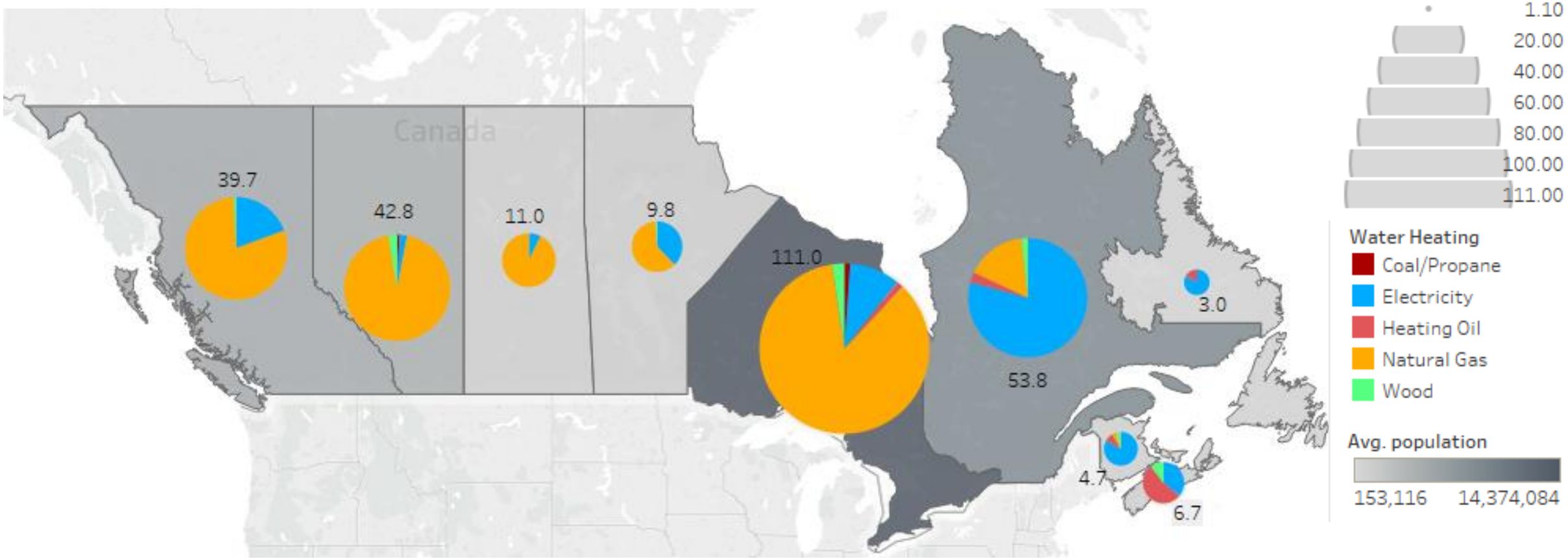
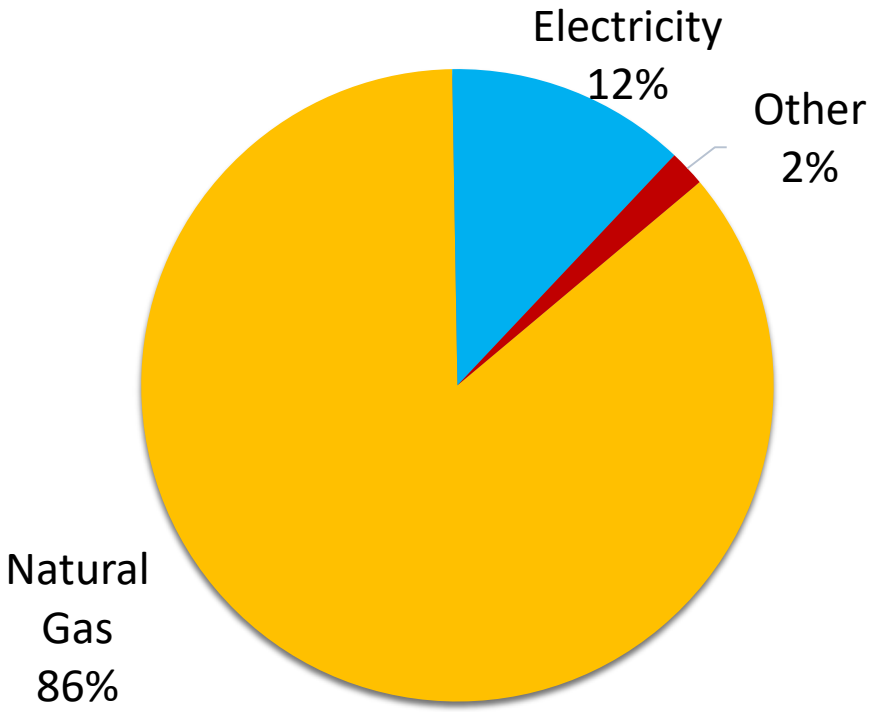
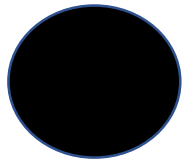


Background – Common Water Heating Options

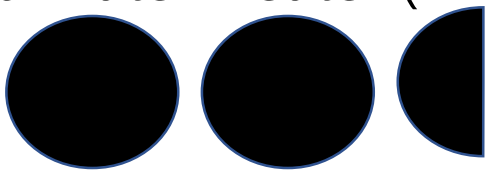


- Energy Factor: energy output per unit energy input
  - Natural gas: 0.67

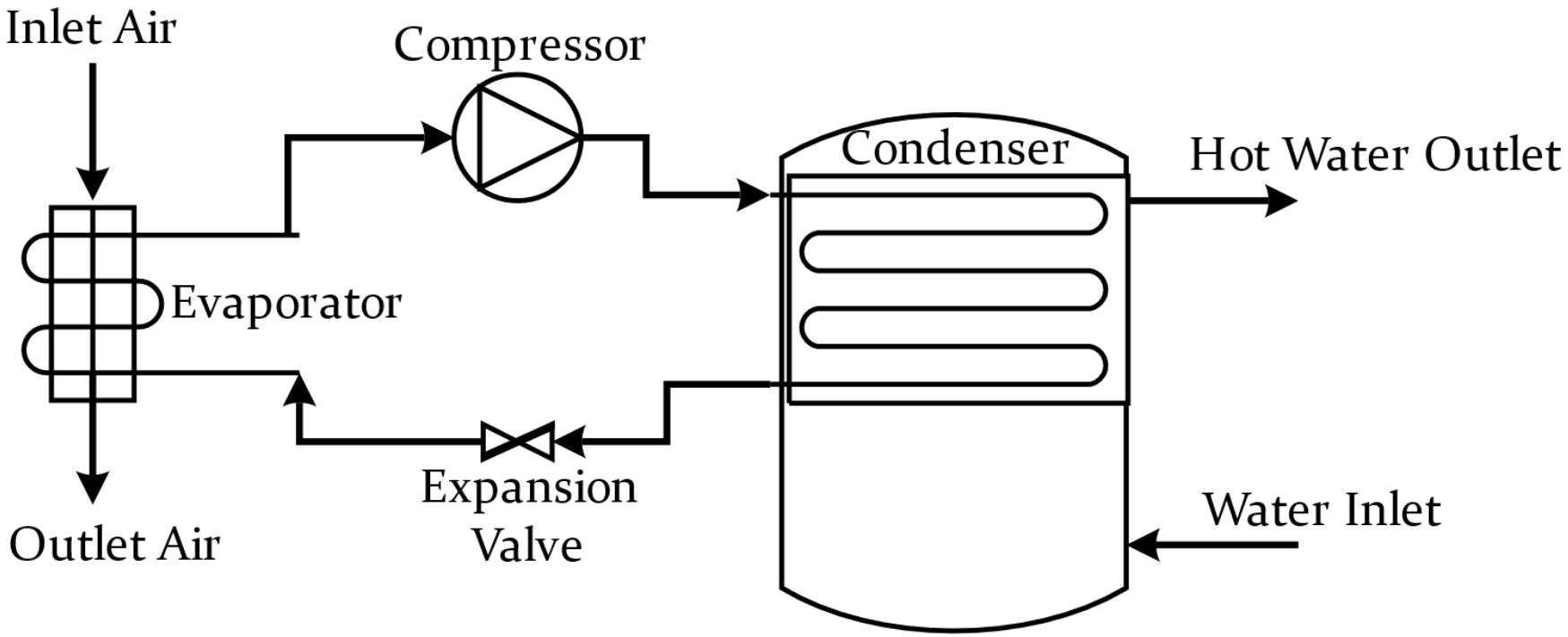
  - Electric: 1



  - Heat Pump Water Heater (HPWH): 2-3



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

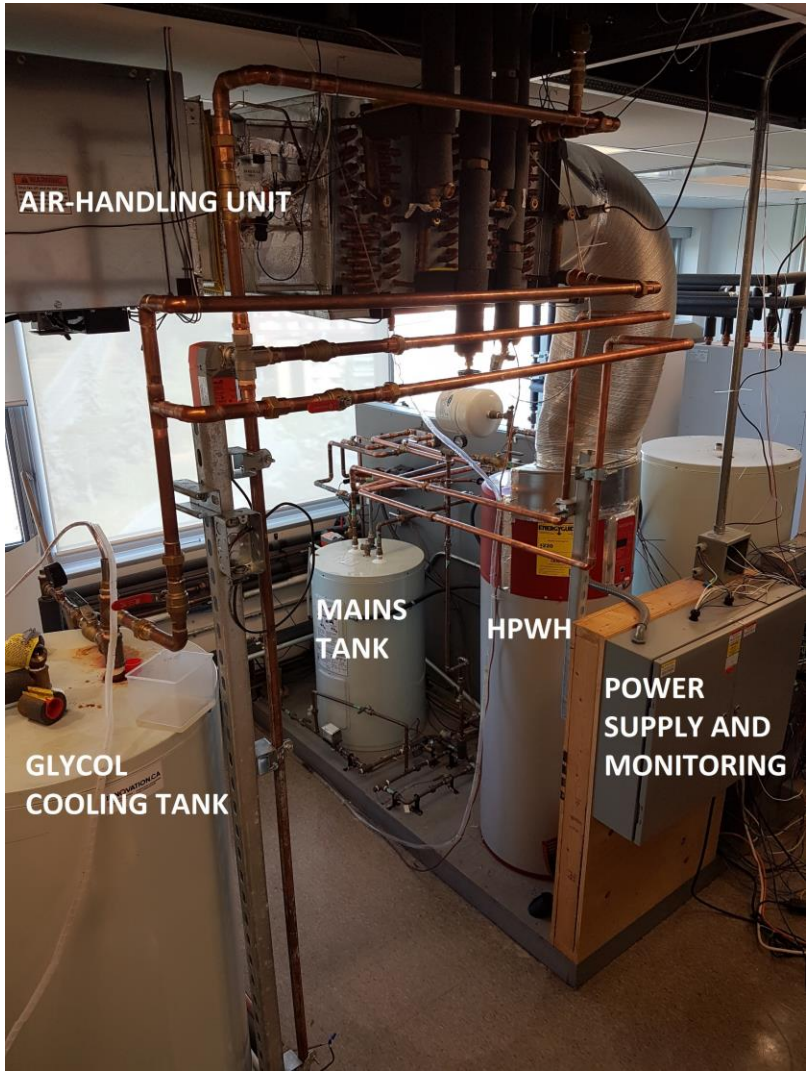
Experimental:
- Performance map tests
- Hot water draw tests

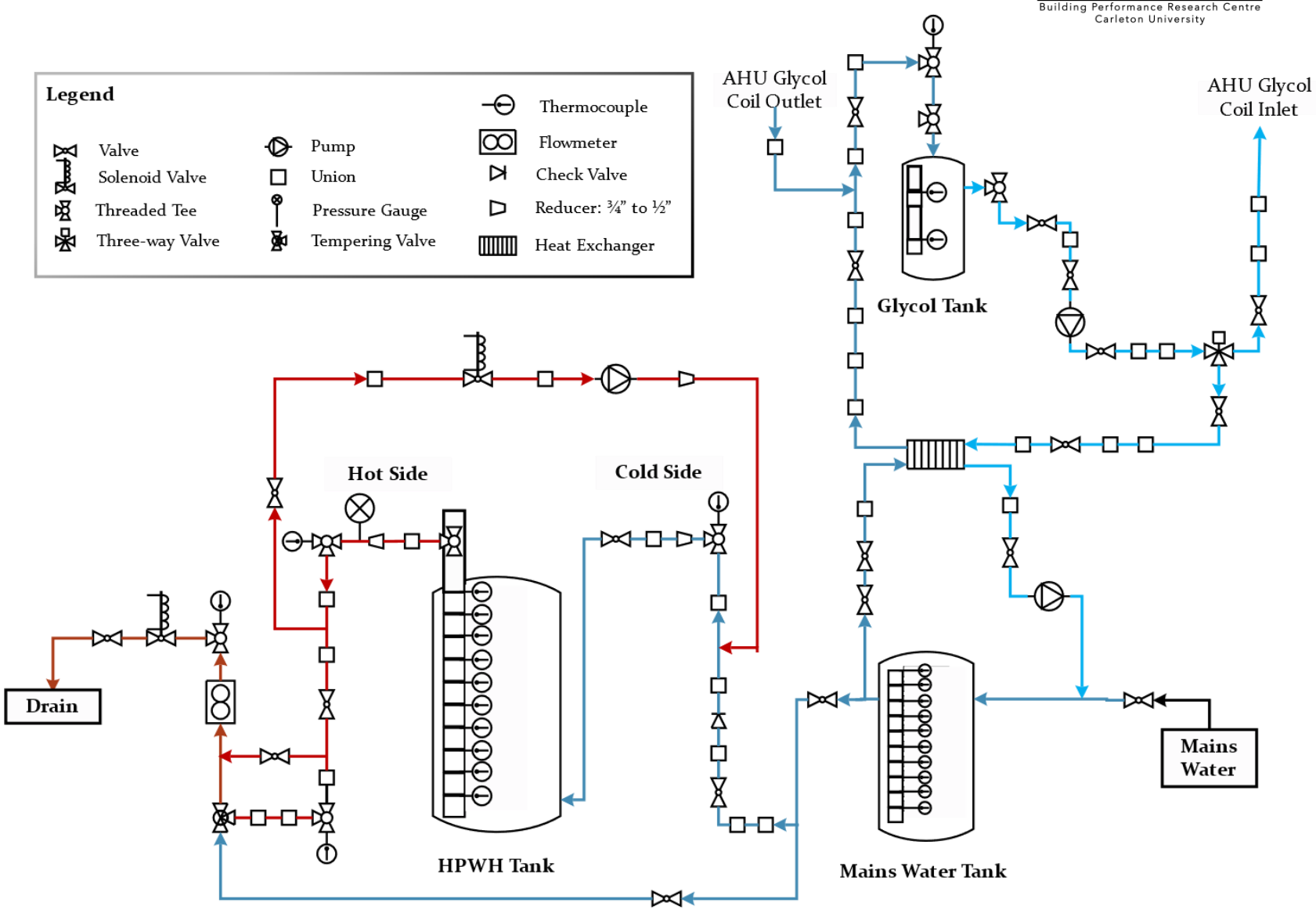
HPWH Model Development:
- TRNSYS model
- Experimental validation

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

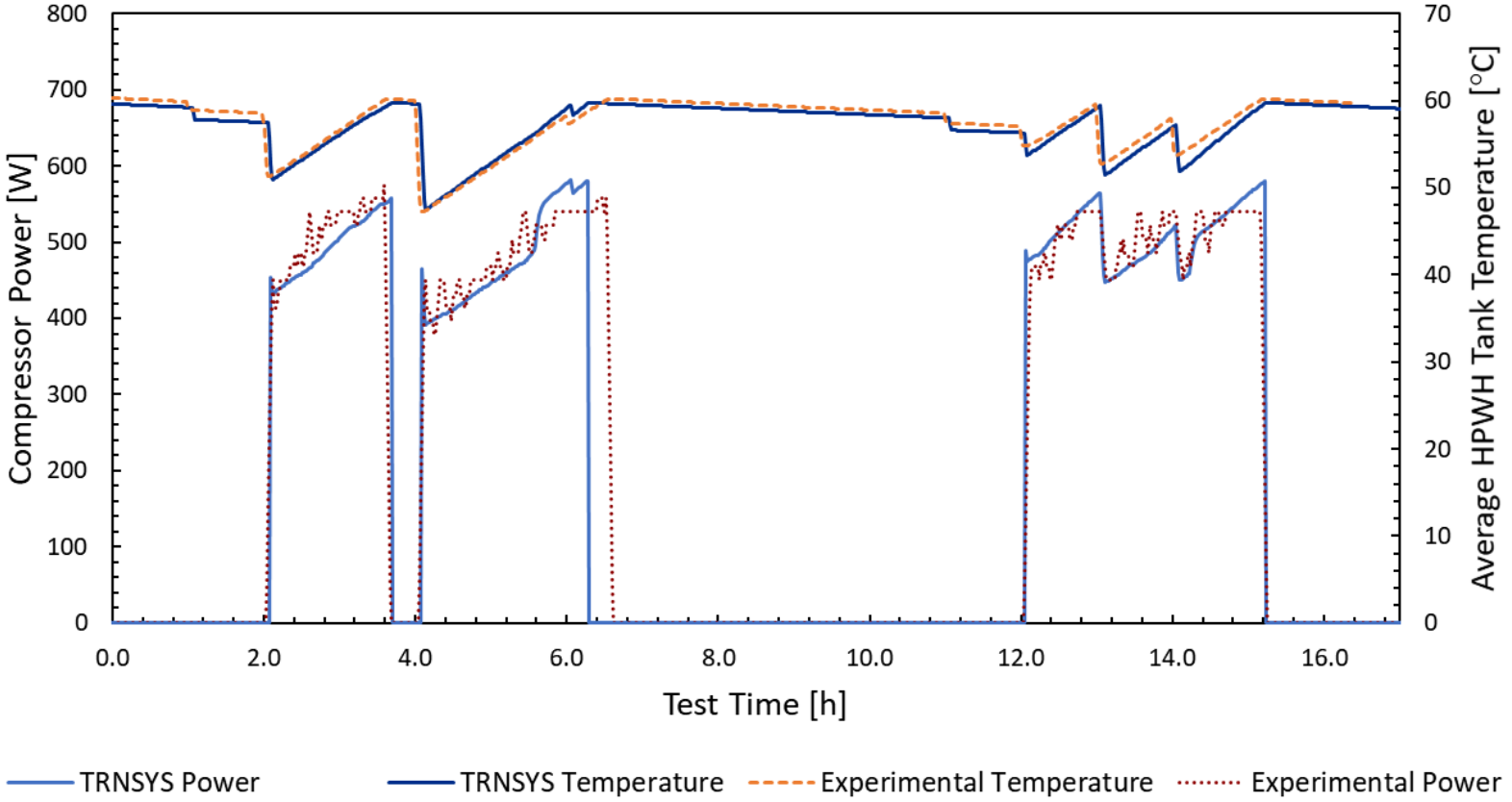
Experimental Test Setup





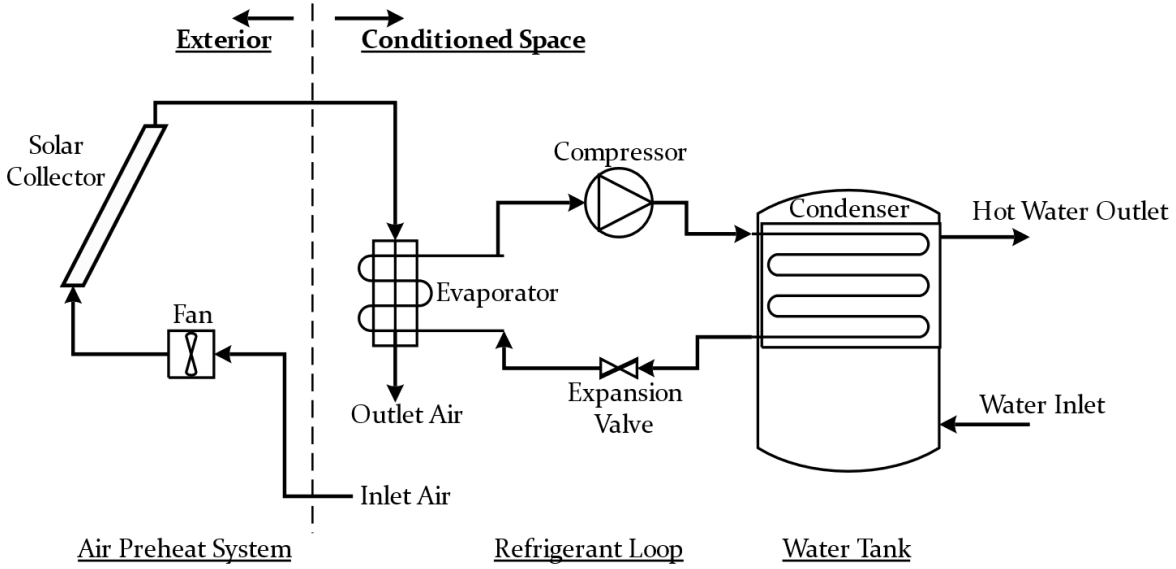
Experimental Validation for TRNSYS Model

- Mean Average Error:
  - Power = 28 W
  - Temperature = 0.6 °C
- Average percent difference
  - Power = 6.2%

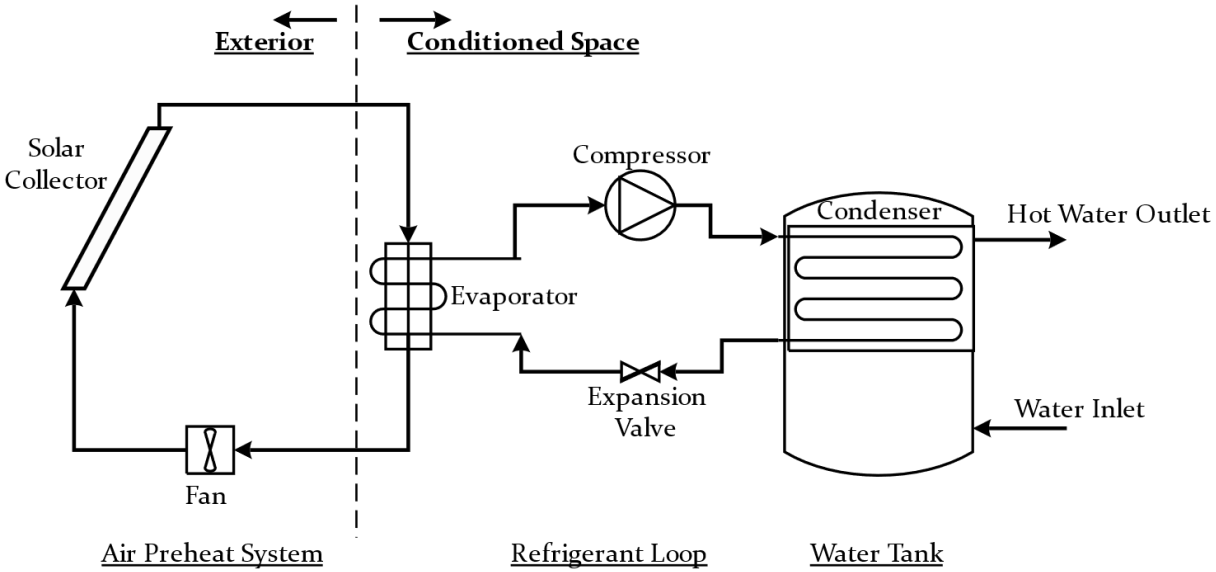


Solar Assisted Heat Pump Water Heater Configurations

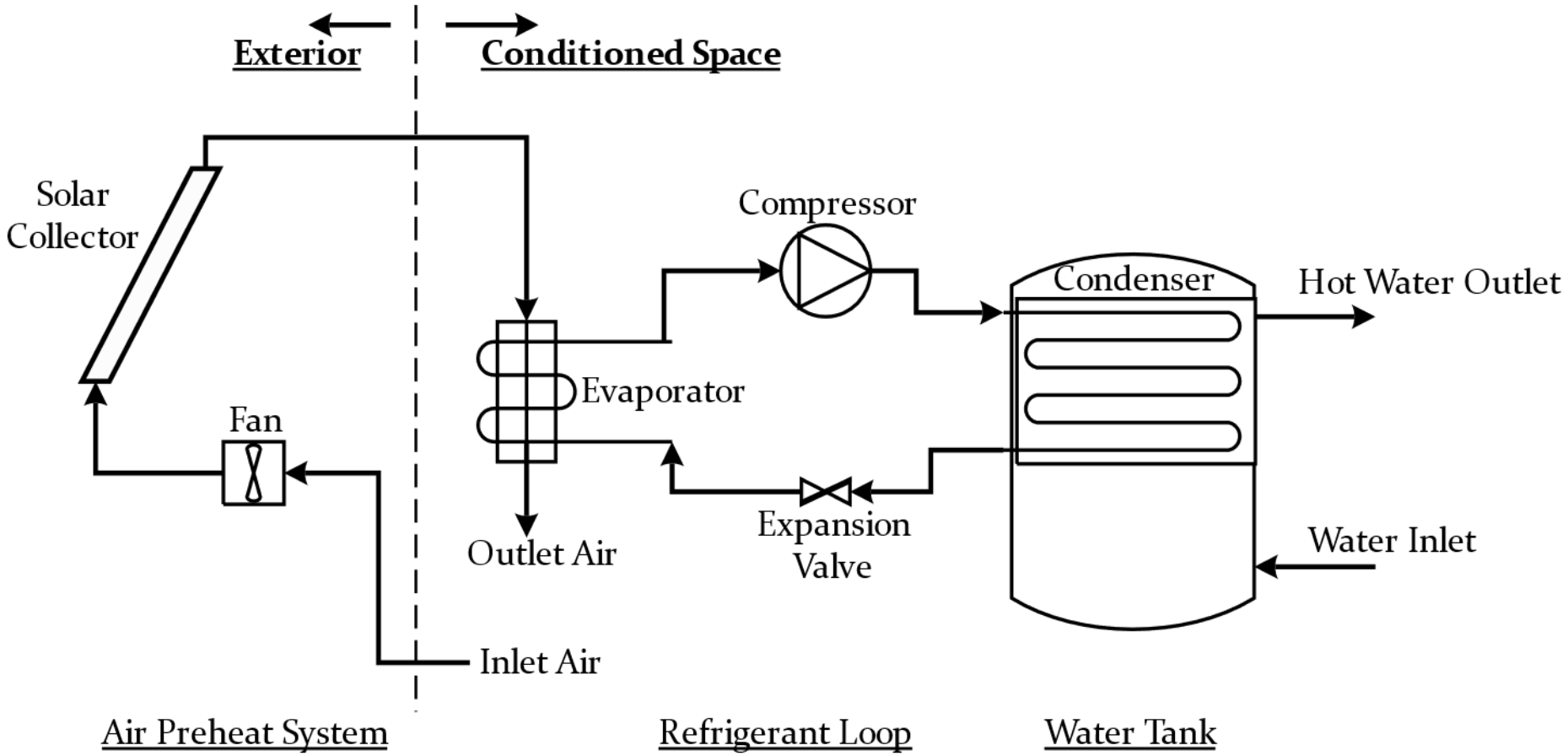
- Conditioned Space



- Closed Loop

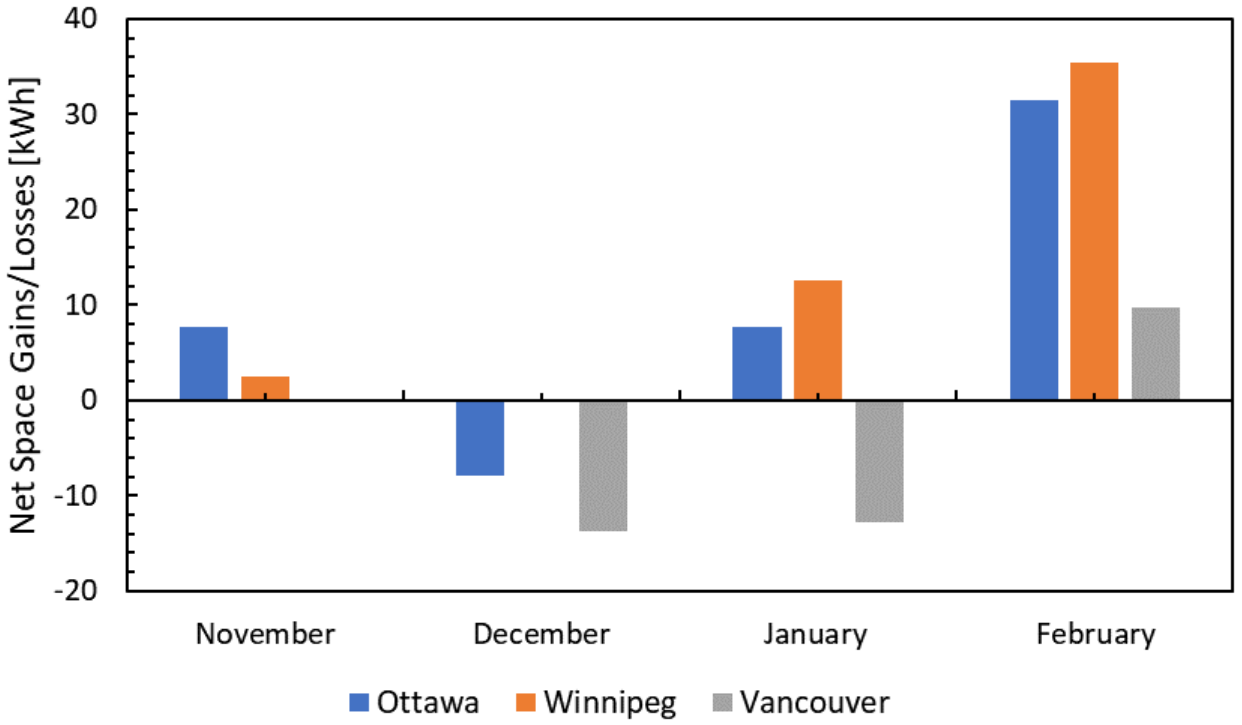


Conditioned Space Solar Assisted HPWH

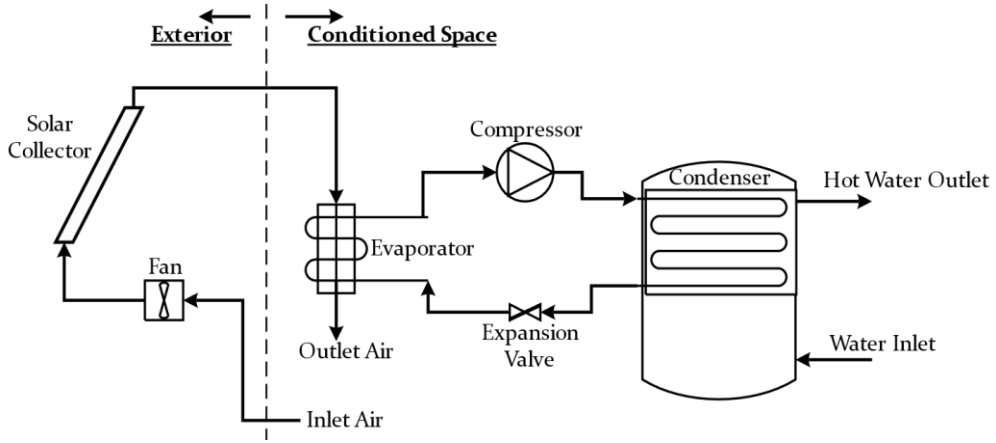


- Has impact on space heating and cooling like HPWH-only system

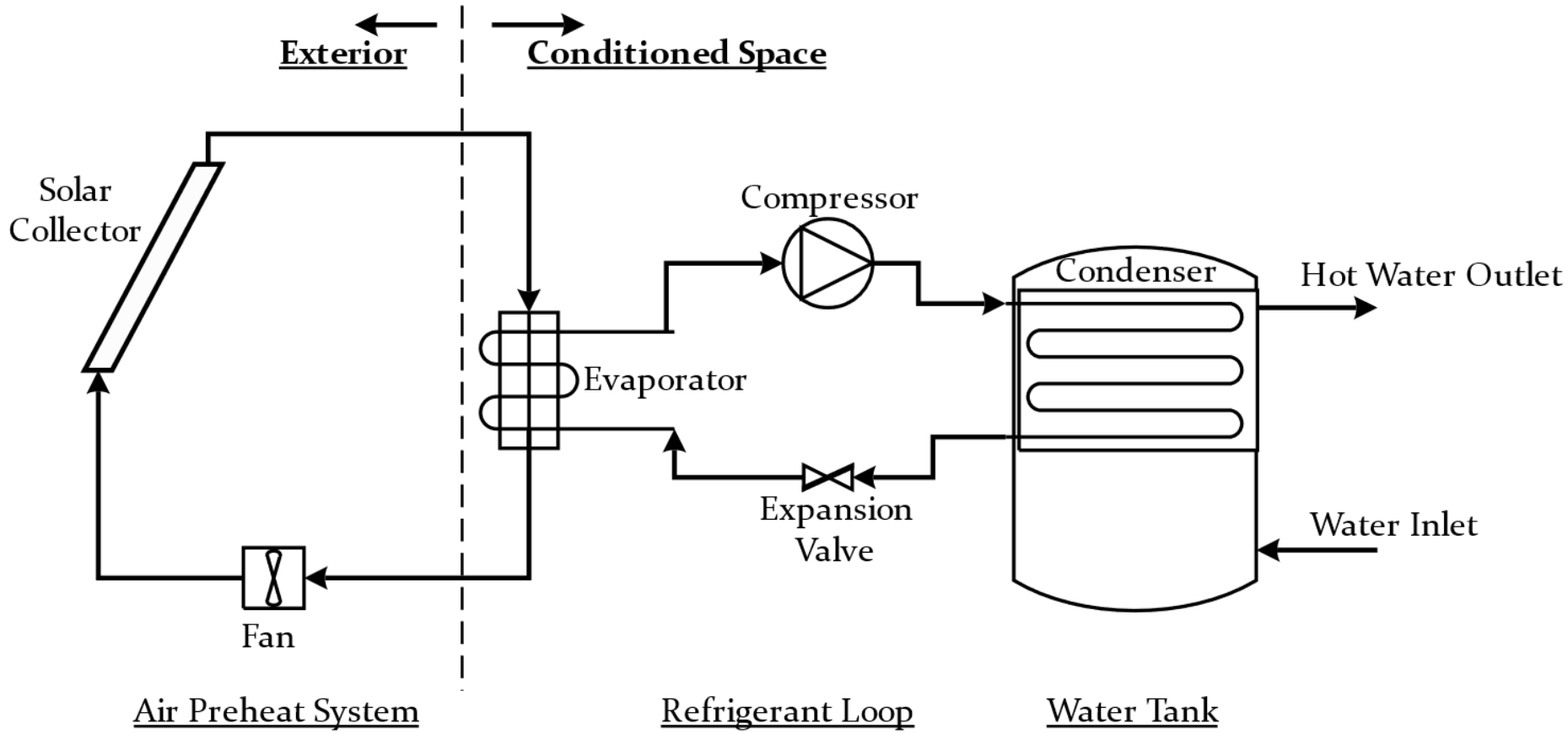
Conditioned Space Solar Assisted HPWH



- 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

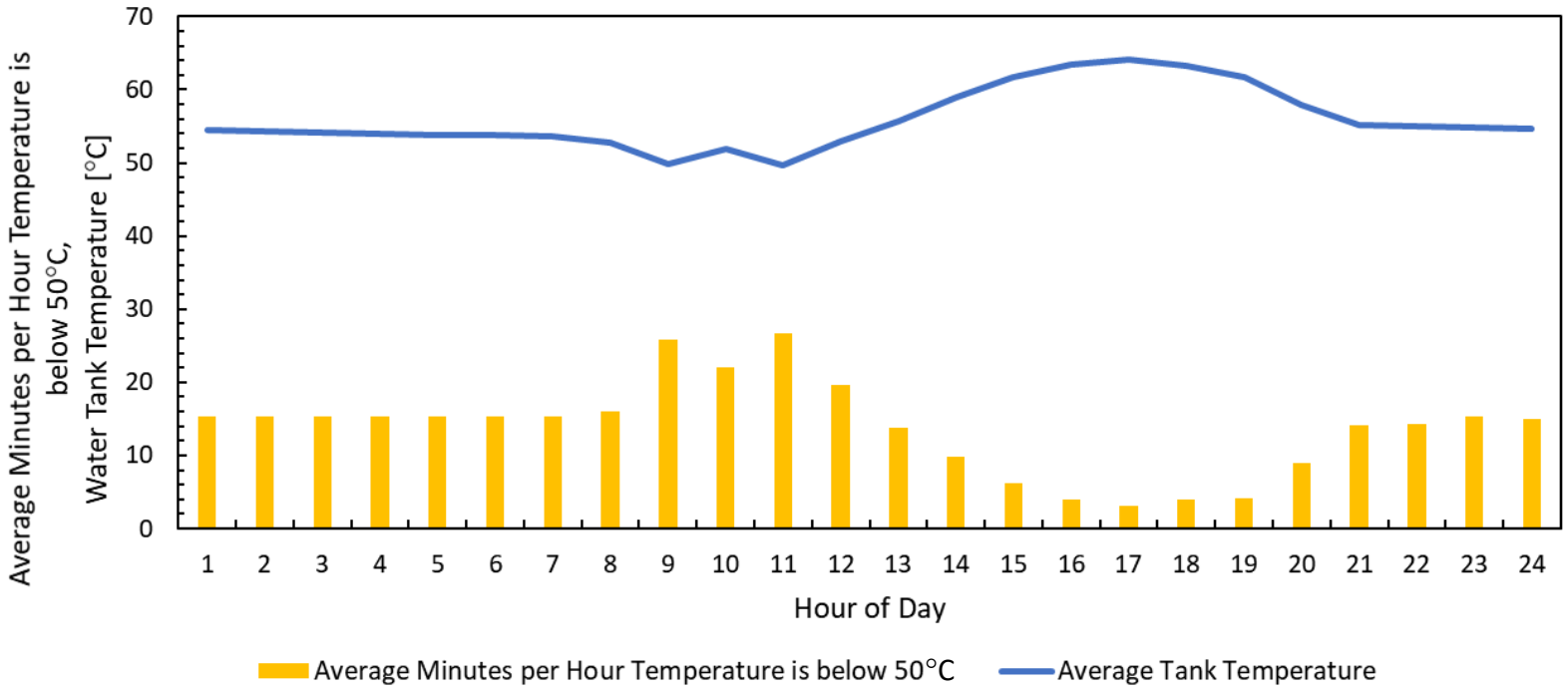


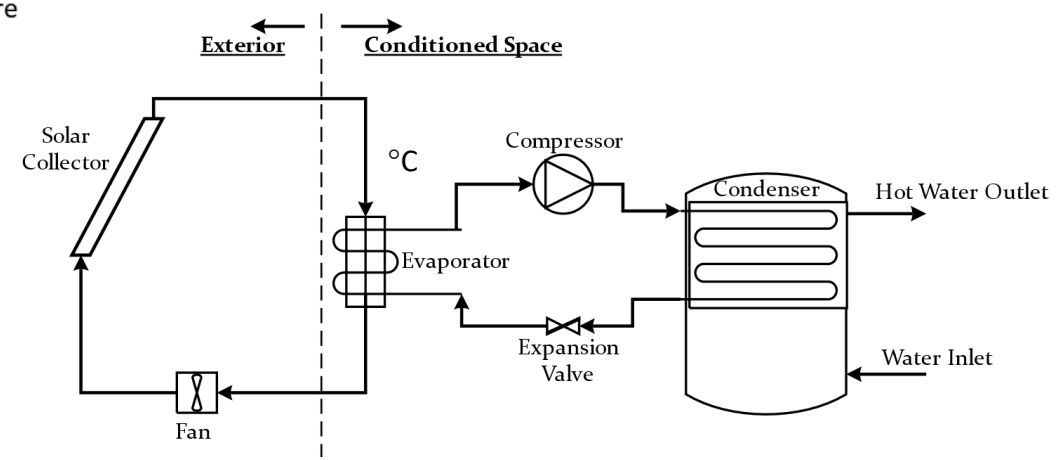
Closed Loop Solar Assisted HPWH



- HPWH only operates when inlet temperature (collector outlet) sufficiently high

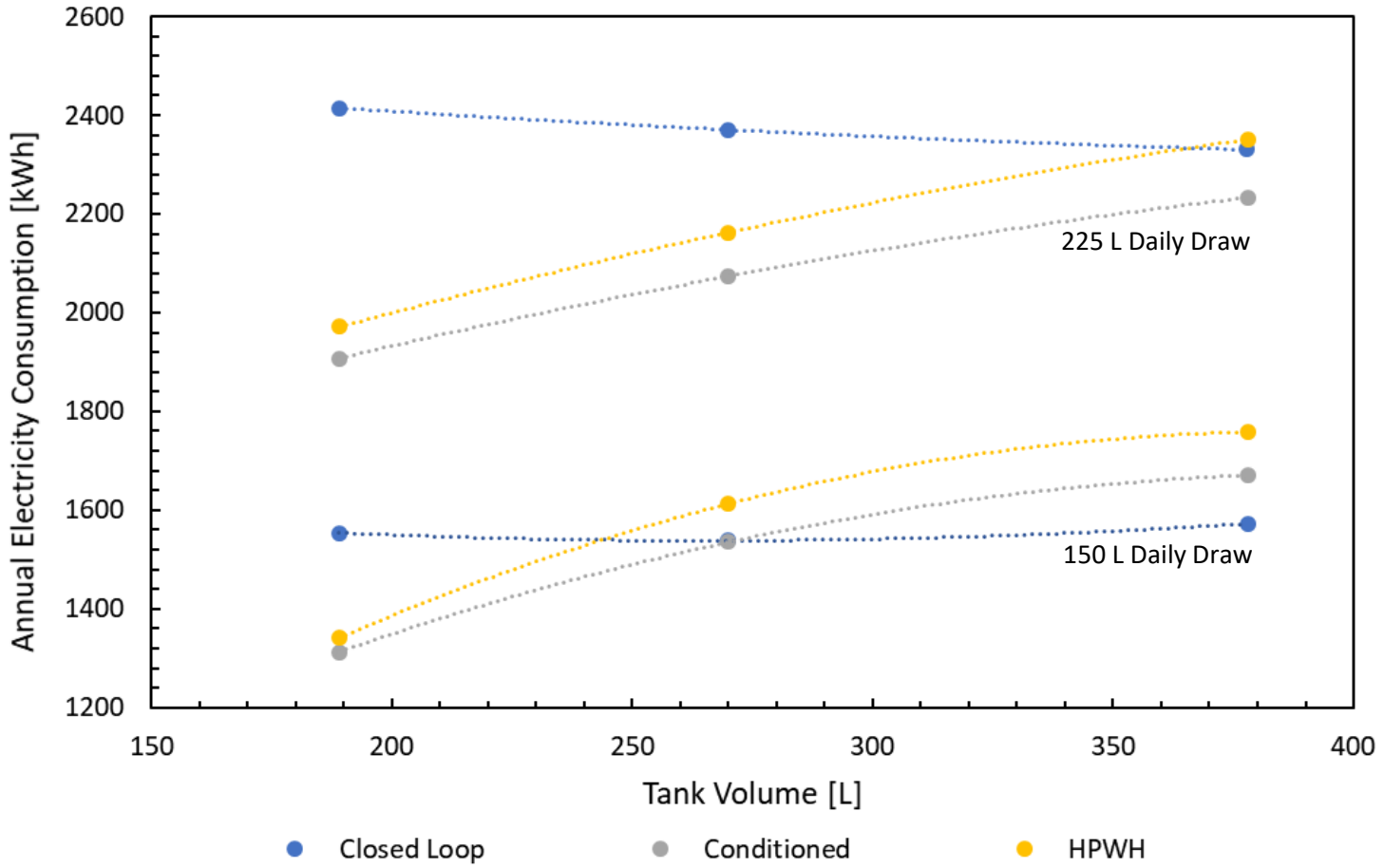
Closed Loop Solar Assisted HPWH





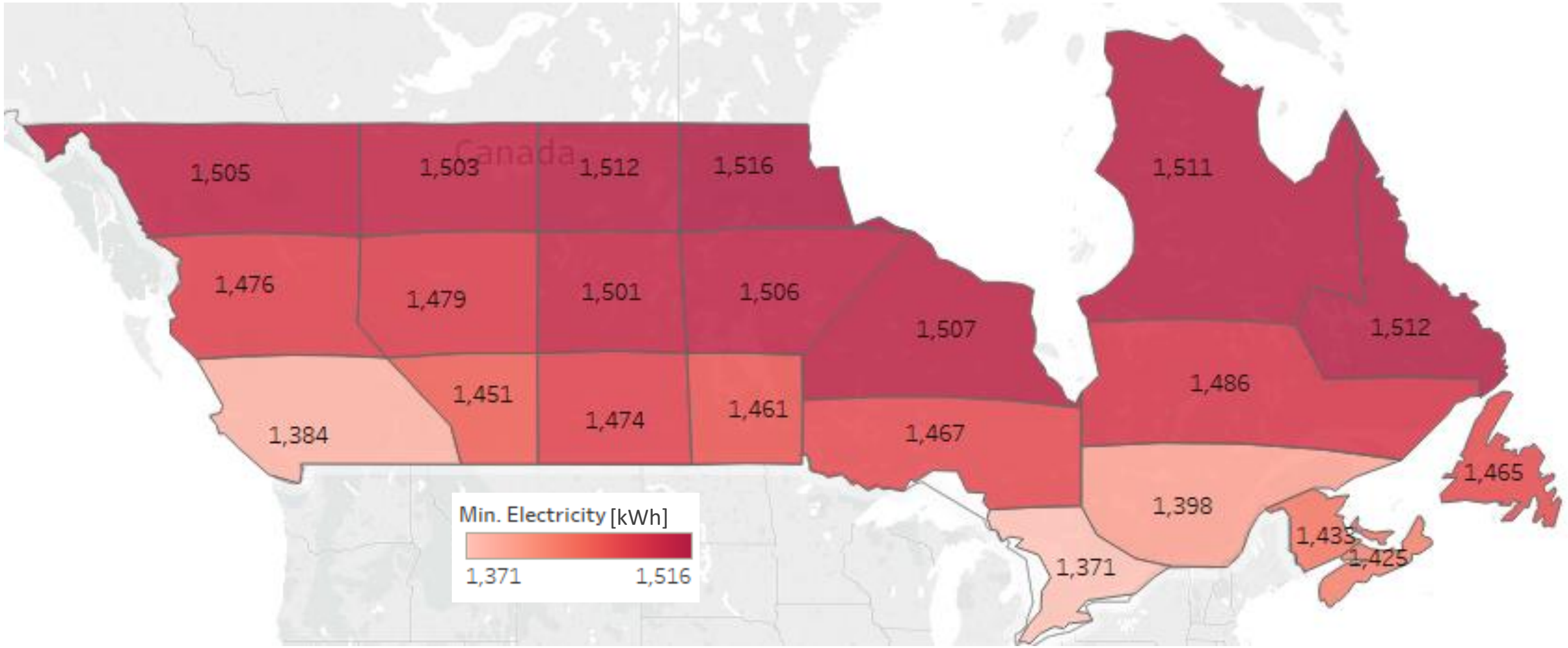
- Cannot reliably meet demand without electric backup in winter months

Canadian Annual Electricity Consumption Trends



- At larger tank volumes, temperature variation decreases and Closed Loop electric backup operates less

Annual Electricity Consumption (Conditioned Space)



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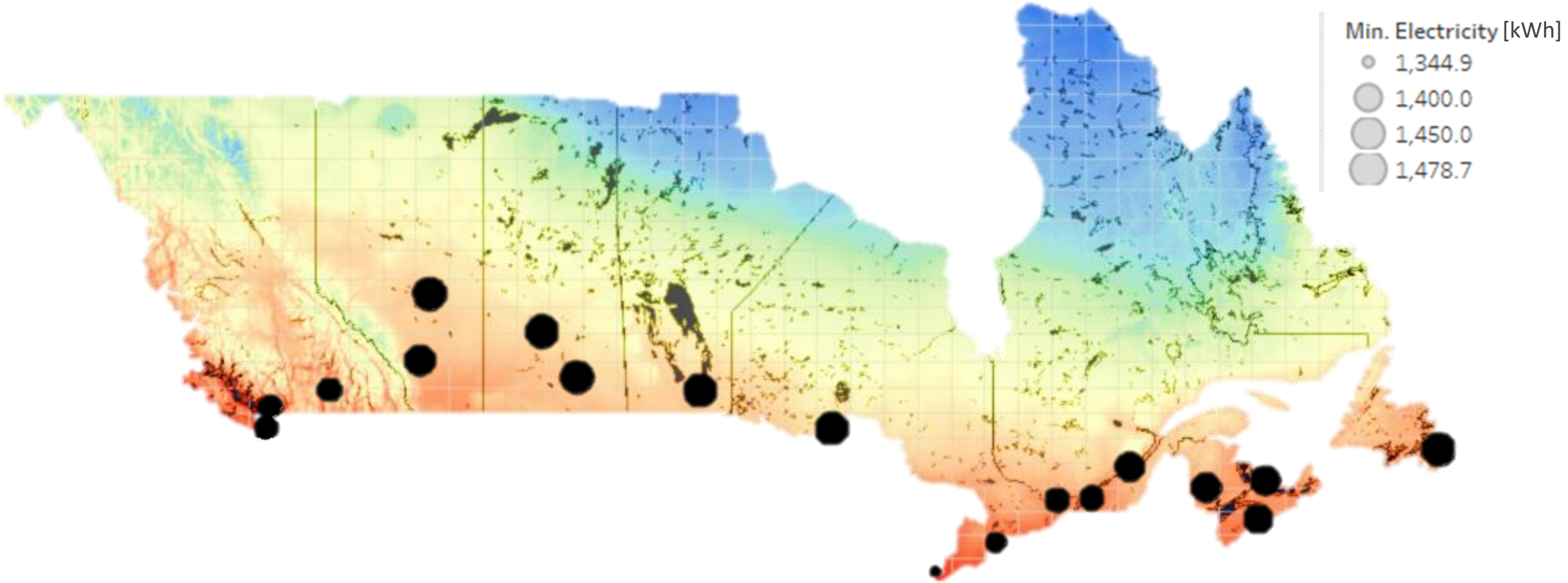
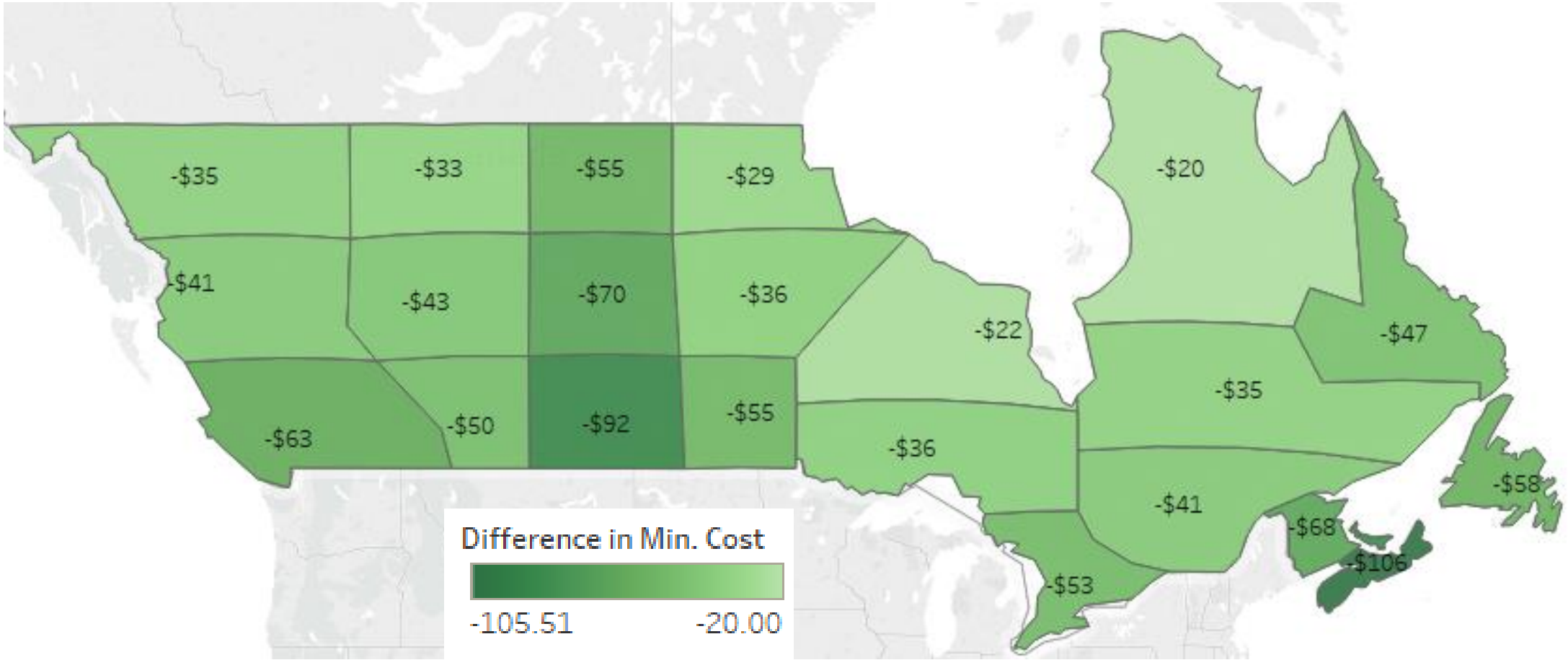


- 10% variation in yearly electricity consumption
- Influenced by: mains water temperature, weather (relative humidity, clouds, solar gains)

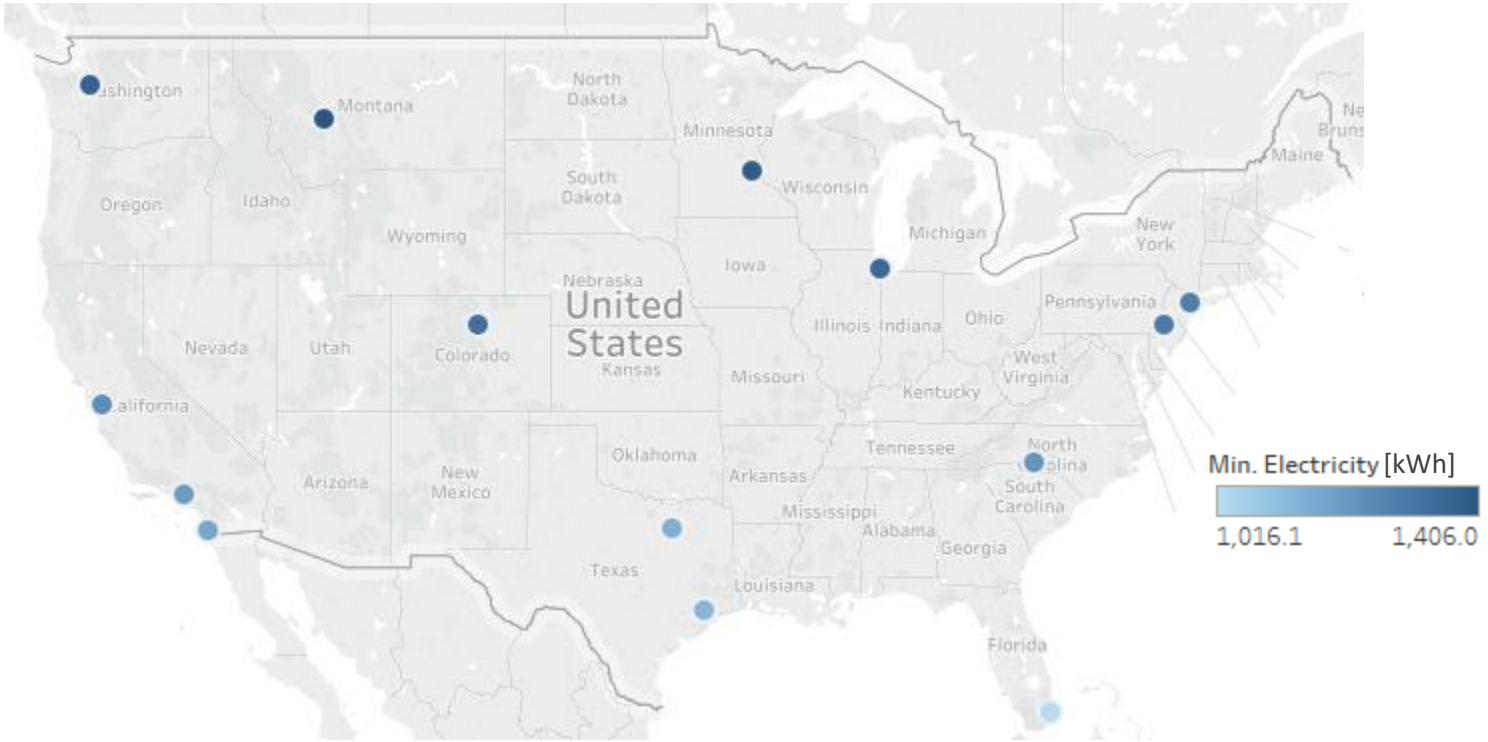
Annual Cost Relative to HPWH Alone



- 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

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[2] Prairie Climate Centre, “Climate Atlas of Canada,” 25 May 2019. [Online]. Available: https://climateatlas.ca/map/canada/annual_meantemp_2060_85#z=4&lat=53.9&lng=-101.16&prov=12