OAK RIDGE National Laboratory

Optimization of Water Heater Control Strategy to Maximize UEF and FHR

Hot Water Forum – March, 2019

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U.S. DEPARTMENT OF ENERGY

Water heater rating

First Hour Rating (FHR)

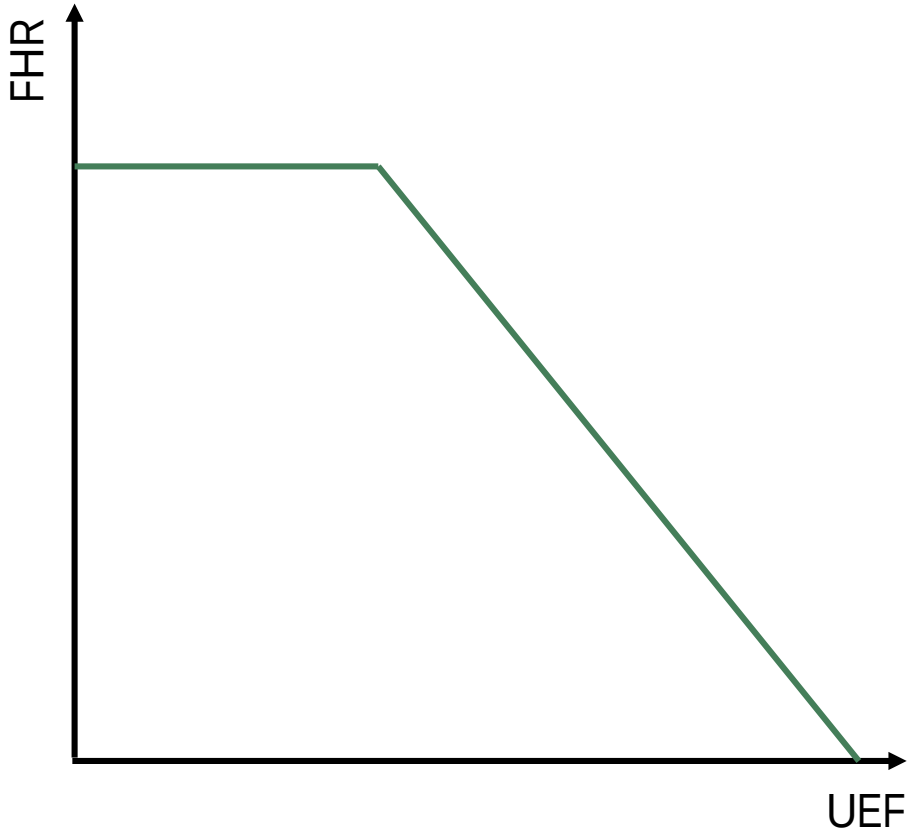
- FHR is the amount of hot water, within prescribed supply temperature range, the water heater can provide in one hour.
  - Strongly dependent on heat capacity. Dependent on control scheme but to lesser degree.
  - Auxiliary heating in heat pump water heaters plays important role.
  - *Think 0-60 mph rating of cars; bigger engine will invariably help you*

Unified Energy Factor (UEF)

- UEF is an overall energy efficiency metric.
  - Ratio of energy input to useful energy output (hot water within prescribed suppl temperature range) over 24 hours subject to certain imposed water draw pattern.
  - Strongly dependent on control scheme. Dependent on heating capacity but to lesser degree.
  - *Think of mpg of cars; smaller engine will help BUT how you drive is the principal factor*

FHR vs UEF

- There is a trade off between FHR and UEF
  - In general terms, increasing one, decreases the other.
  - Increasing heating capacity over some threshold will NOT increase FHR.
  - Decreasing heating capacity below some threshold will result in zero UEF (supply water temperature is below requirement and test is invalidated.)



Representation of general trend

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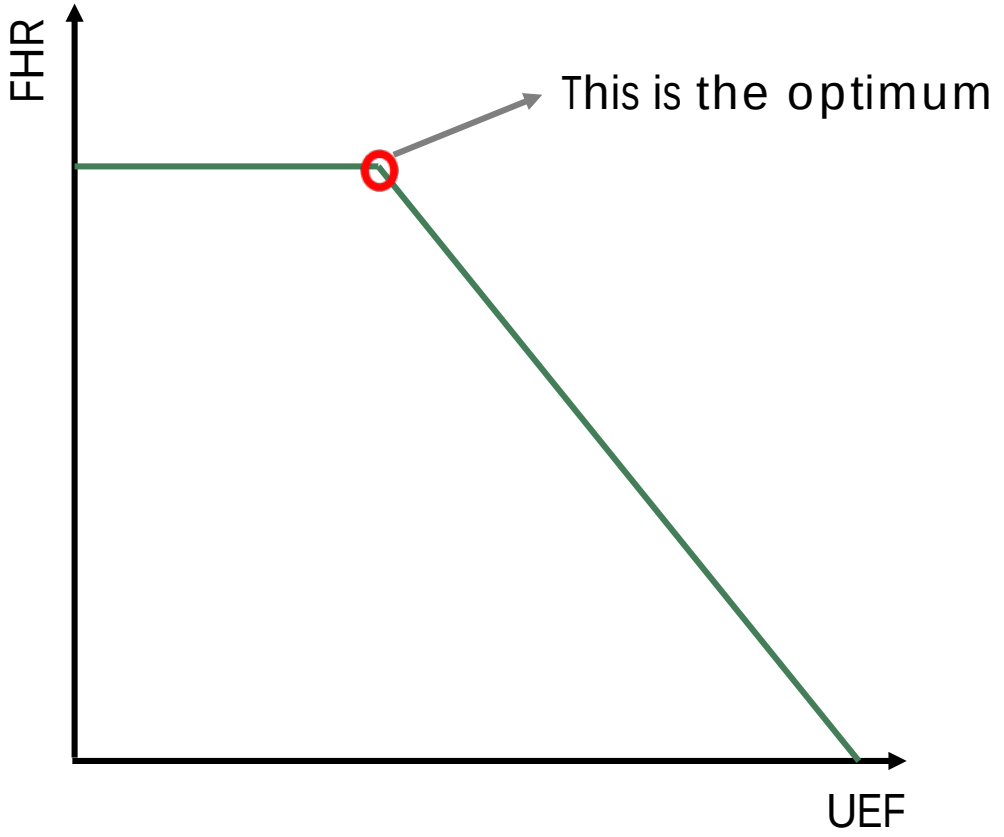
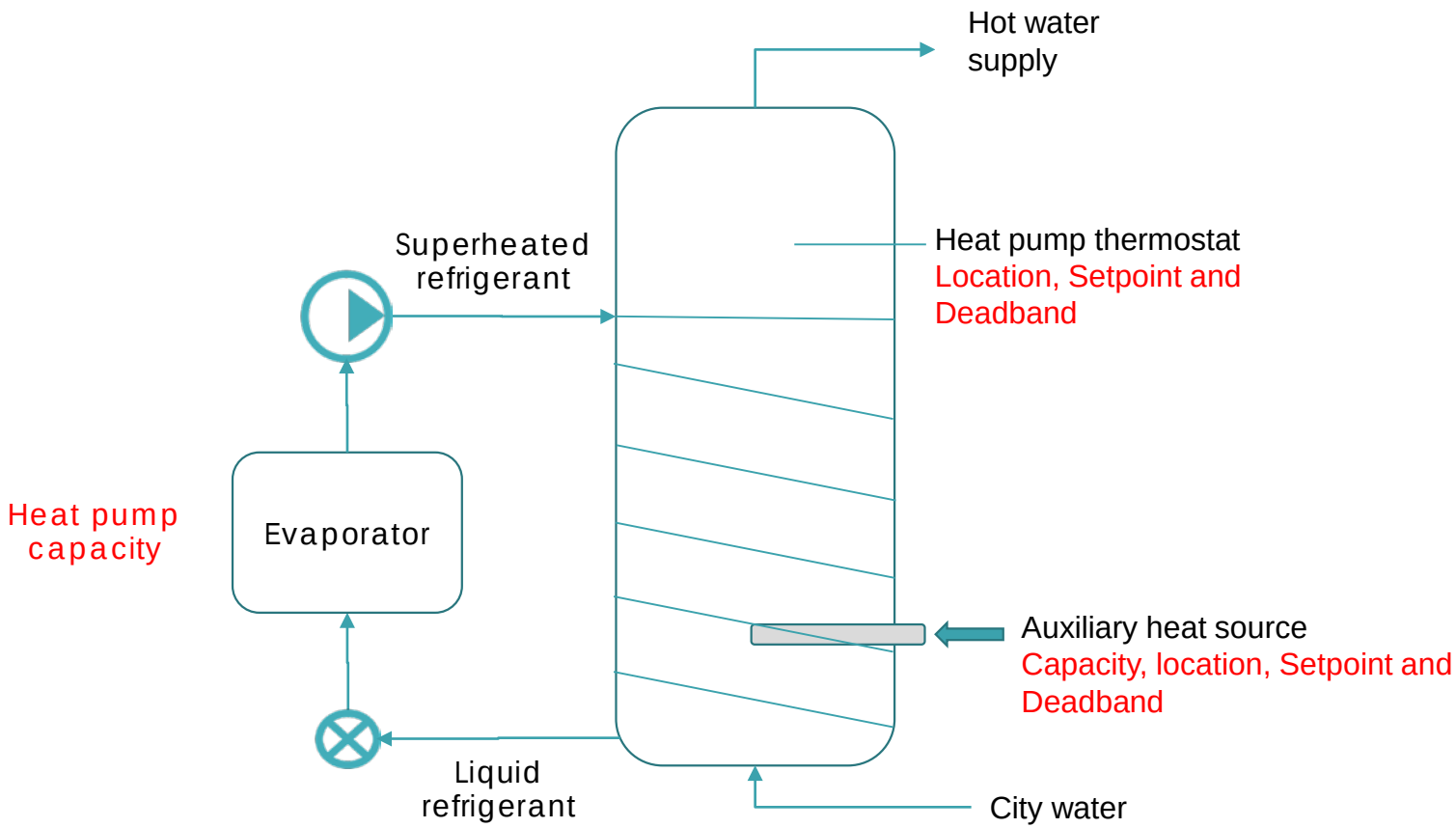
- How to arrive at the optimum?



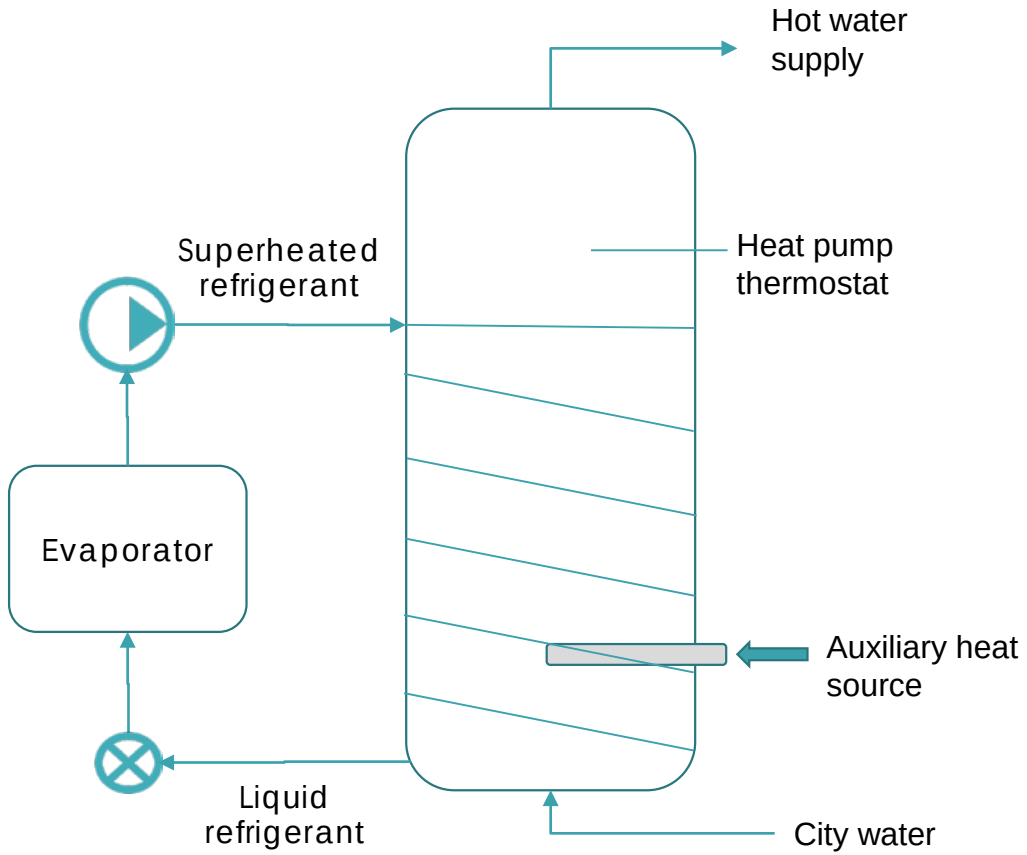
Representation of general trend

Optimization – variables to optimize



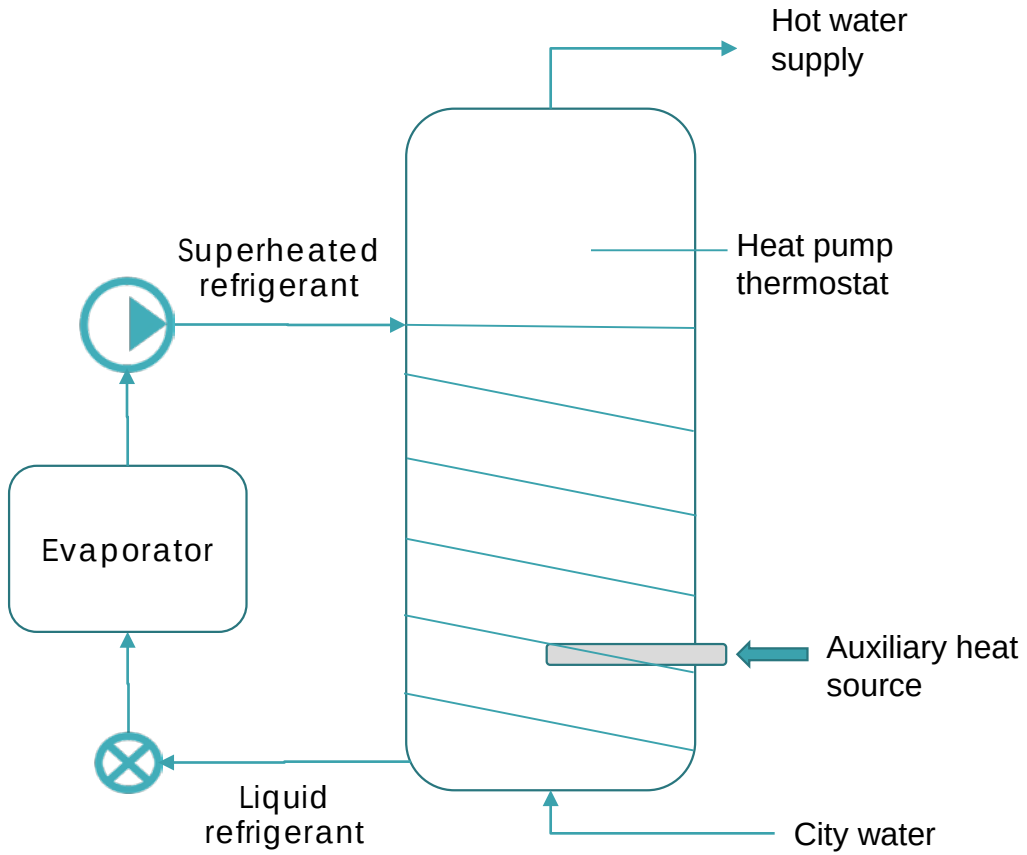
Optimization – business as usual

- Experimentation
  - Try different combinations and record the outcome.
  - Strongly dependent on expertise
  - Resource intensive (lots of labor, time and material.)

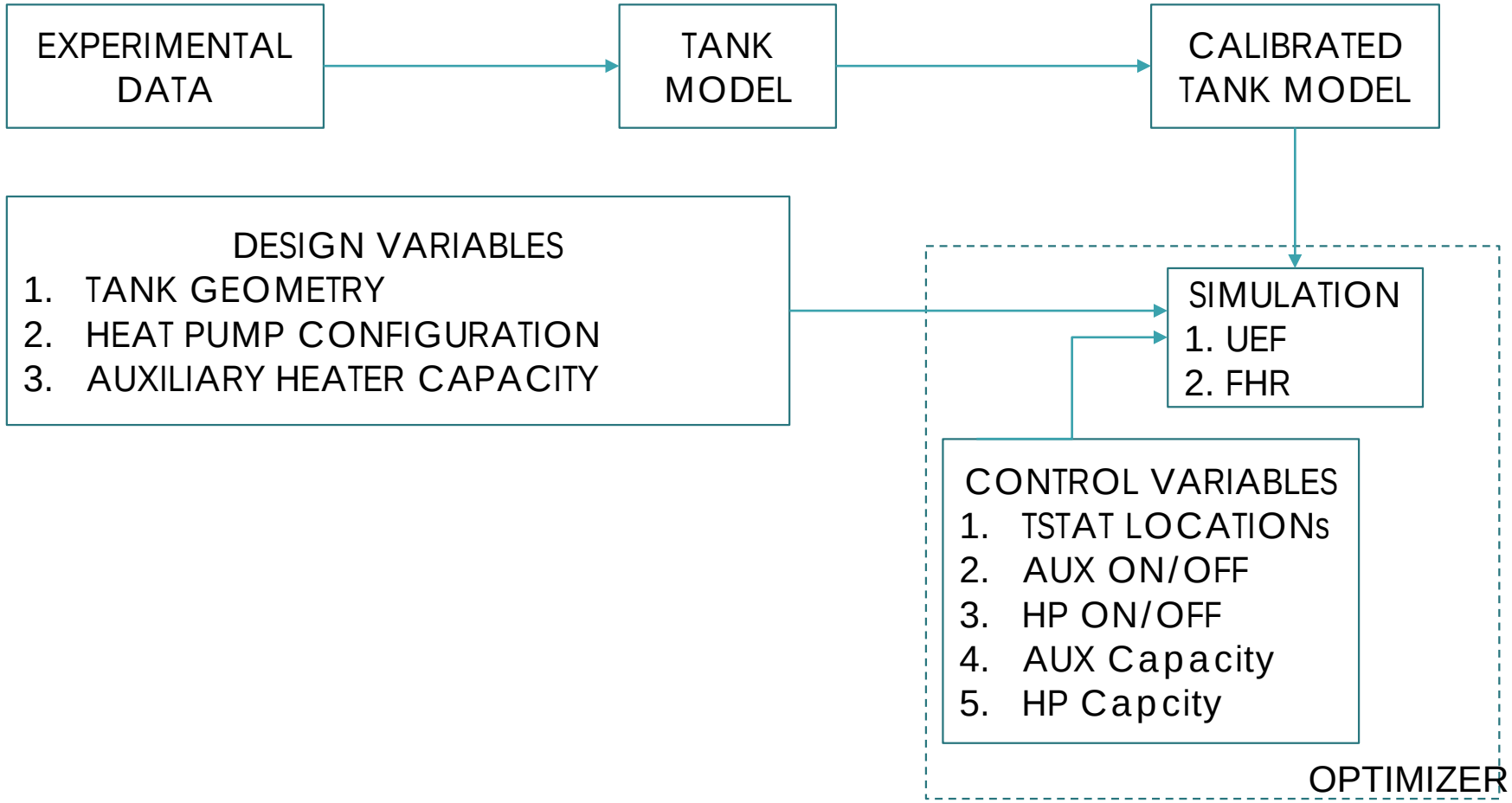


Optimization – what we propose

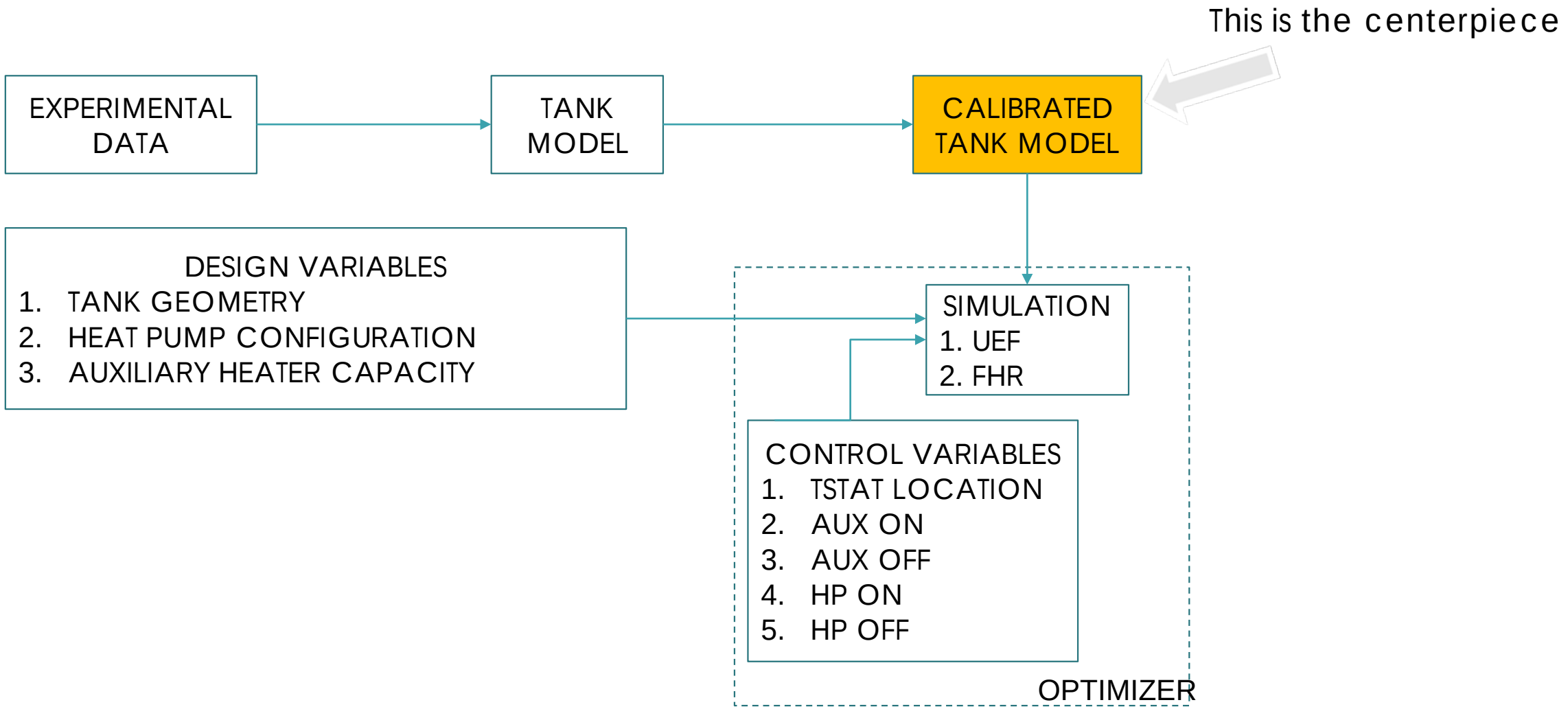
- Systematic approach
  - Model based.
  - Much less dependent on expertise.
  - Capability of examining large number of combinations of design variables



Framework


EXPERIMENTAL DATA
TANK MODEL
CALIBRATED TANK MODEL
DESIGN VARIABLES
1. TANK GEOMETRY
2. HEAT PUMP CONFIGURATION
3. AUXILIARY HEATER CAPACITY
SIMULATION
1. UEF
2. FHR
CONTROL VARIABLES
1. TSTAT LOCATIONs
2. AUX ON/OFF
3. HP ON/OFF
4. AUX Capacity
5. HP Capcity
OPTIMIZER

Framework


This is the centerpiece
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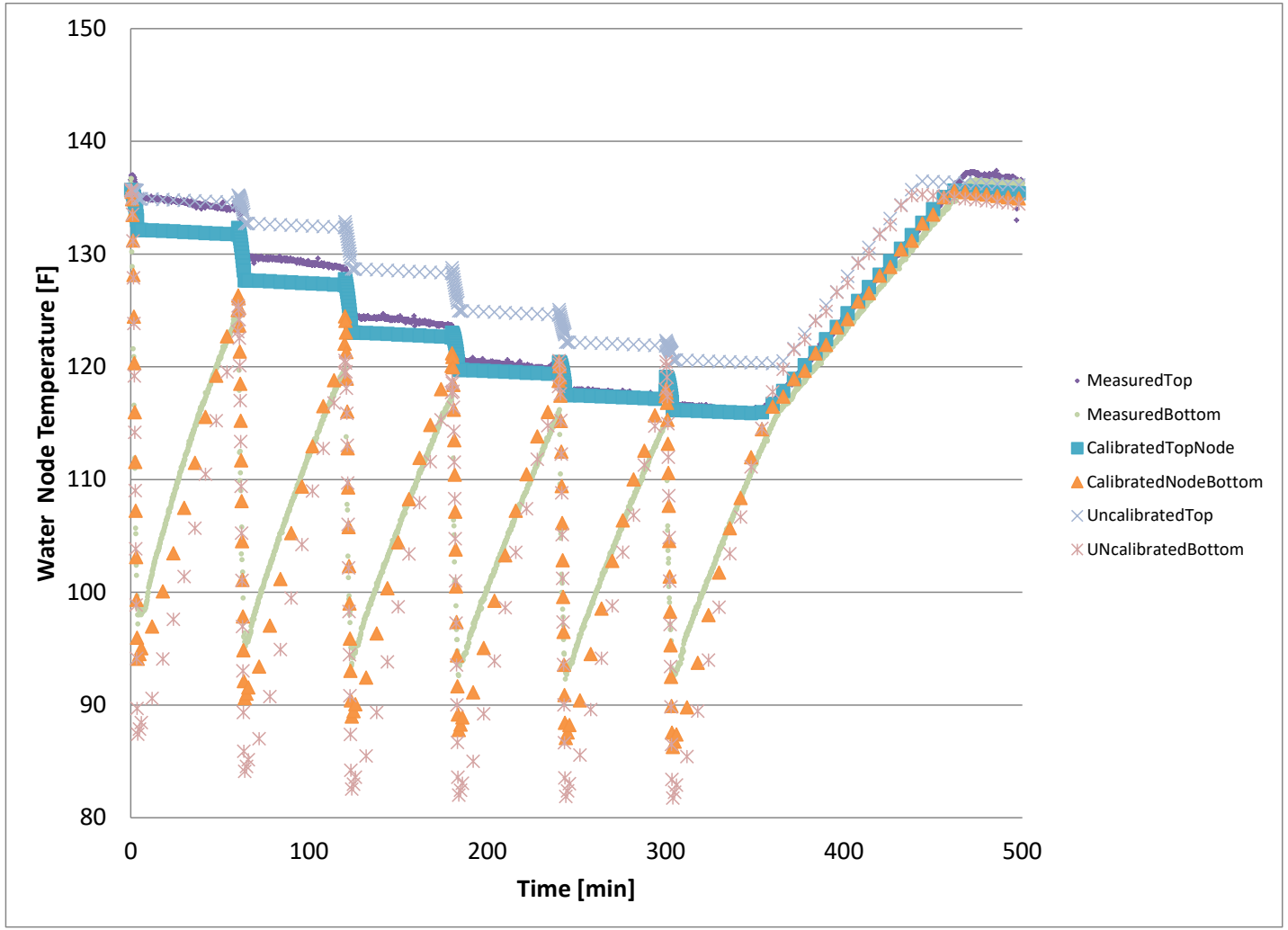
OPTIMIZER

HPWH model



Bo Shen, Kashif Nawaz, Van Baxter, Ahmed Elatar, “Development and validation of quasi-steady-state heat pump water heater model having stratified water tank and wrapped-tank condenser”, International Journal of Refrigeration, Volume 87, 2018, Pages 78-90,

Conclusion

- Simulation is still running (9 days at the time of presenting this material.)
  - Long time is mainly due to the HP simulation
- Potentially improvements
  - I used commercially available optimization package. More customized may be faster.
  - Faster heat pump model.

Acknowledgements

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Questions? Comments?

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