# California Statewide Gas Emerging Technologies – GAHP Performance Mapping

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Confidential

# Project Collaborators

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# Agenda

- Background – GAHPs in California
- Objectives
- Equipment Commissioning/Test Plan
- Steady State Performance Experimental Data
- Load-Based (Transient) Performance Experimental Data
- EnergyPlus Modeling
- Recommendations

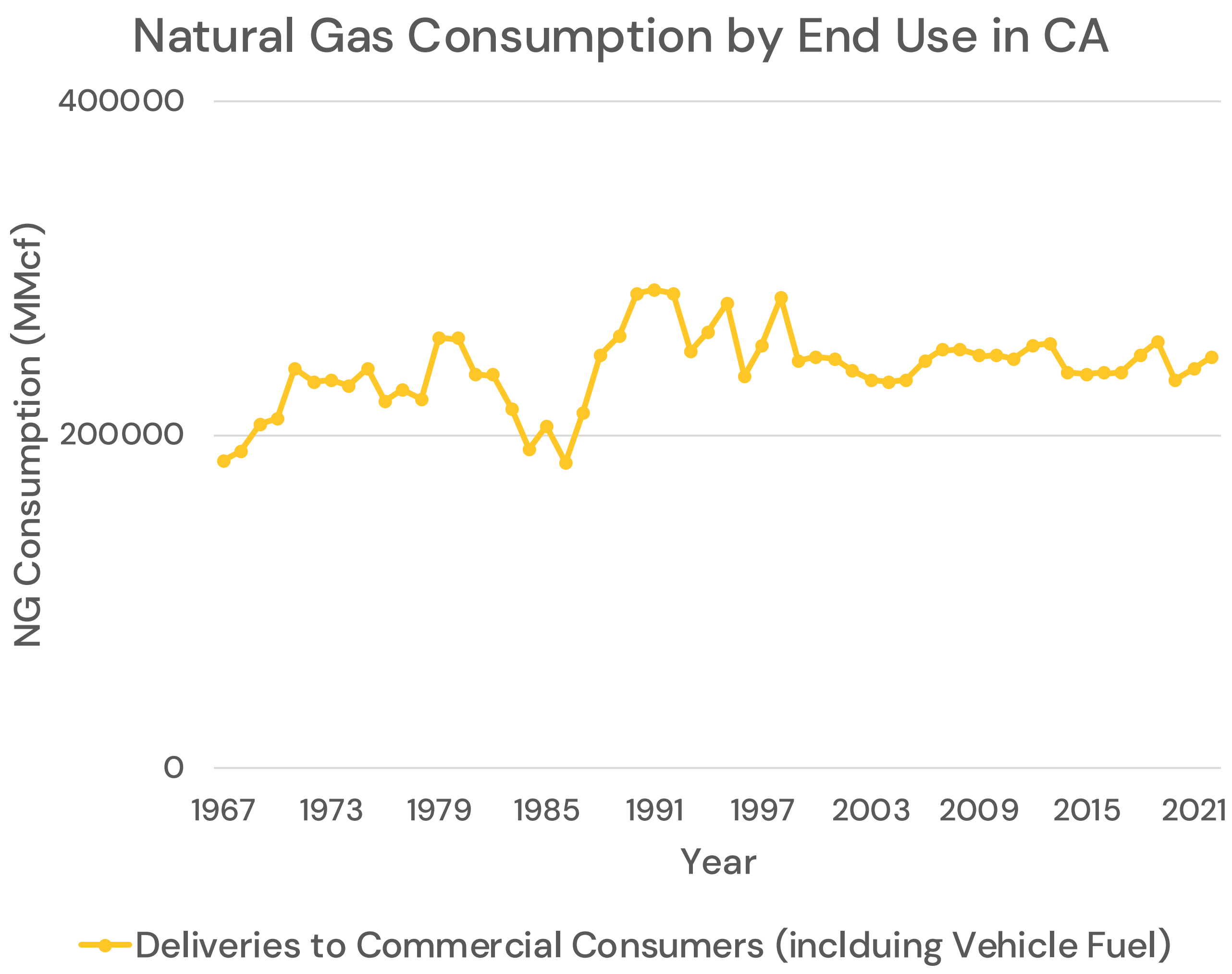


# Gas Absorption Heat Pumps

Background/application of Gas Absorption Heat Pump (GAHP) utilization and California legislation.

# California on Emissions Control

- Water heating is the largest end-use of natural gas in California
- Natural Gas Consumption by End Use in the Commercial sector




| California Bills & Legislation |
|---|
| SB 1477 (Building Decarbonization/Space Heating/Water Heating) |
| California Long Term EE Strategic Plan (CLTEESP) |
| AB 758 (Comprehensive EE in Existing Buildings Law) |

- Focus sector: Multifamily (commercial) low-rise (5 stories or less)

# Objectives

- Improve low uptake at the sector level
  - Primarily as it relates to the commercial sector
- Improve low uptake at the technology level
- Technology performance in a controlled environment
  - Equipment commissioning
  - Steady state evaluation
  - Part Load (Transient) evaluation
- Develop performance mapping curves
- Contribute to EnergyPlus modeling data

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# Equipment Commissioning & Test Plan

# Equipment Installation and Commissioning

- Robur GAHP-A system


| Variable | Tolerance |
|---|---|
| Flow Rate [GPM] | ±2.0% |
| Outside Air Temperature (OAT) [°F] | ±1.0°F |
| Return Temperature (RT) [°F] | ±1.0°F |
| Supply Temperature [°F] | ±1.0°F |
| Firing Rate (Energy Input) [kBtu/h] | ±2.0% |
| Heating Output [kBtu/h] | ±2.0% |

# Target Conditions – Steady State

- Robur GAHP-A system


| Variable | Testing Range | Number of Points within Testing Range |
|---|---|---|
| Flow Rate [GPM] | 13.6 GPM & 7.0 GPM | 2 |
| Outside Air Temperature (OAT) [°F] | 0°F-110°F | 10 |
| Return Temperature (RT) [°F] | 95°F-120°F | 3 |
| Propylene Glycol [vol%] | 35 vol% | 1 |

# Target Conditions – Part Load (Transient)

- Robur GAHP-A system


| Variable | Testing Range | Number of Points within Testing Range |
|---|---|---|
| Flow Rate [GPM] | 13.6 GPM & 7.0 GPM | 2 |
| Outside Air Temperature (OAT) [°F] | 0°F-110°F | 10 |
| Return Temperature (RT) [°F] | 95°F-120°F | 3 |
| Propylene Glycol [vol%] | 35 vol% | 1 |
| **ON Runtime [hr.]** | **0.1–0.9 hr.** | **6** |
| **OFF Time [hr.]** | **0.2–1.0 hr.** | **3** |

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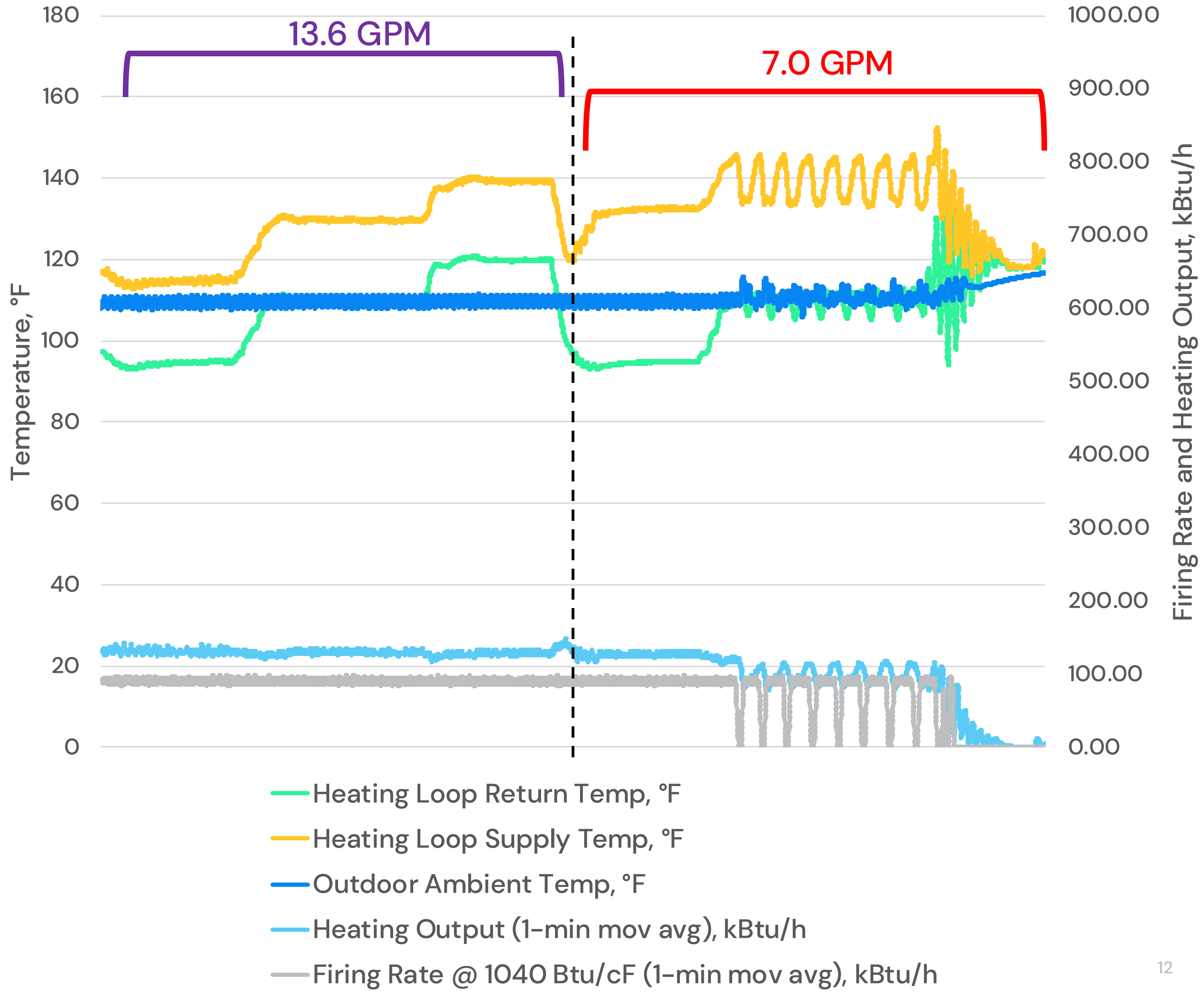
# Experimental Results – Steady State

# Steady State Performance Mapping

- Maximum OAT operating conditions

| Target Conditions | | |
|---|---|---|
| Outside Air Temperature (OAT), °F | Glycol Flow Rate, GPM | Return Temperature (RT), °F |
| 110 | 13.6 | 95 |
| | | 110 |
| | | 120 |
| | 7.0 | 95 |
| | | 110 |
| | | 120 |

- Timeseries ~ 6 hours
- Oscillations (short cycling) begin @ RT of 110°F
  - Supply temperature exceeds max @ ~140°F at low flowrate contributes to short cycling
  - Operate according to application

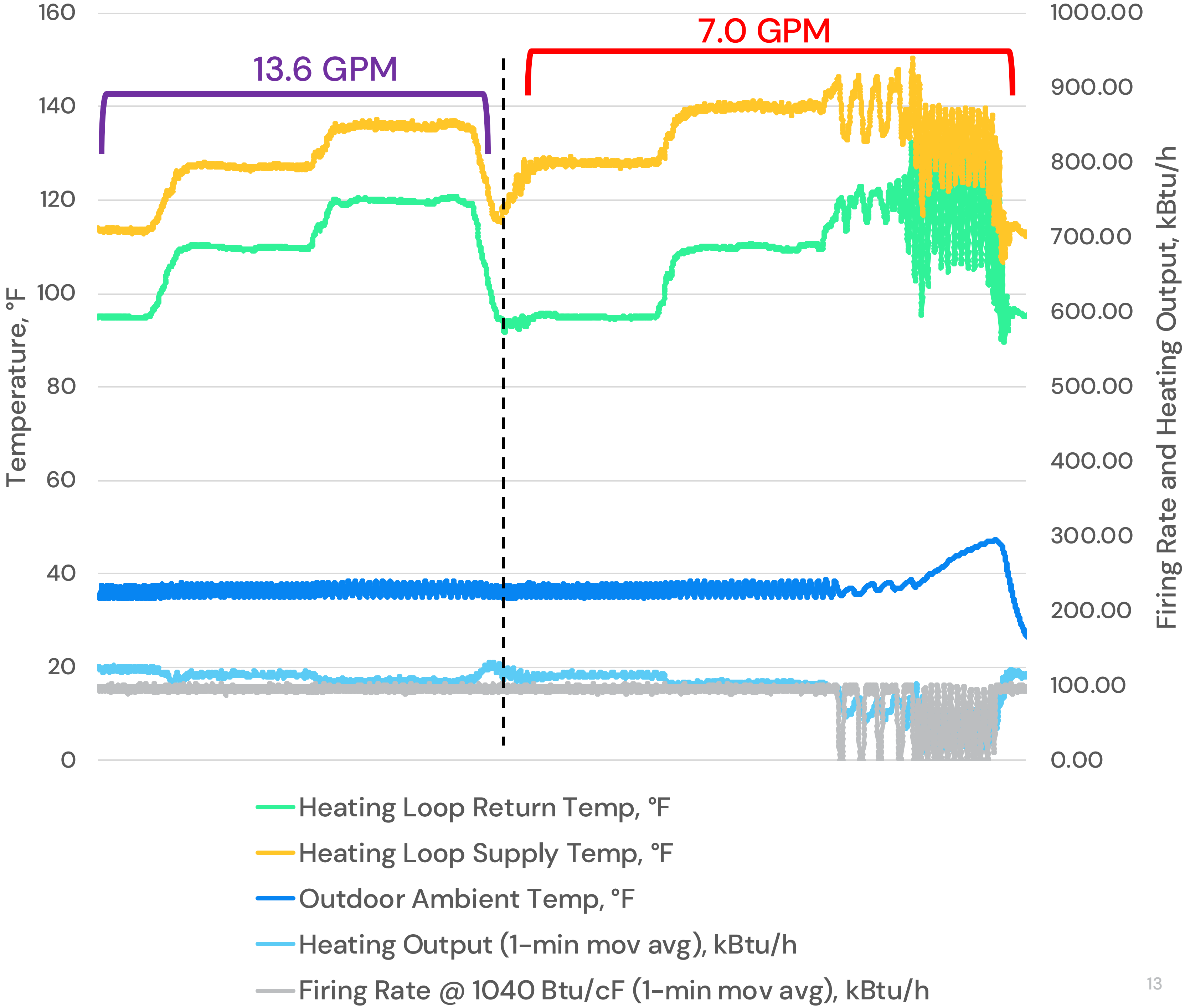


# Steady State Performance Mapping

- Minimum OAT operating conditions

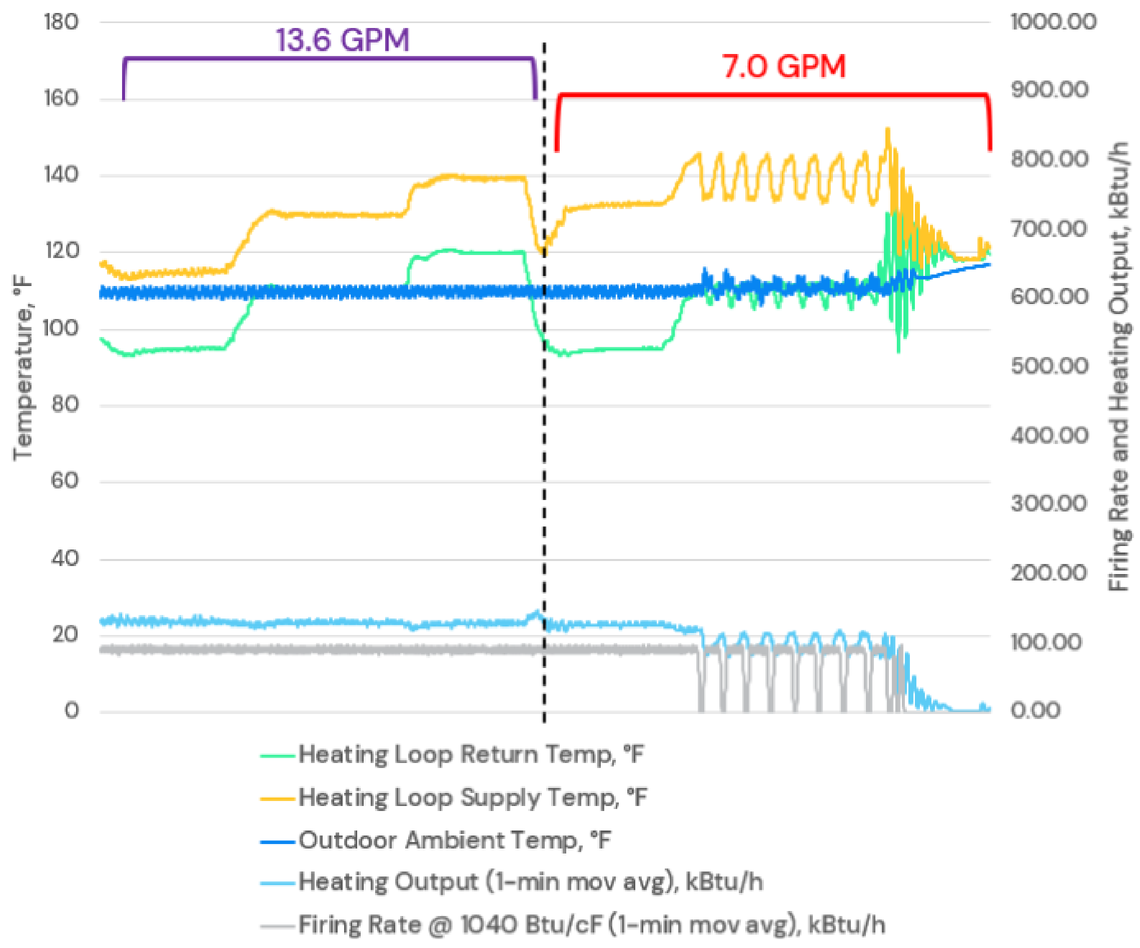
| Target Conditions | | |
|---|---|---|
| Outside Air Temperature (OAT), °F | Glycol Flow Rate, GPM | Return Temperature (RT), °F |
| 35 | 13.6 | 95 |
| | | 110 |
| | | 120 |
| | 7.0 | 95 |
| | | 110 |
| | | 120 |

- Timeseries ~ 6 hours
- Oscillations (short cycling) begin @ RT of 120°F
  - Supply temperature exceeds max @ ~140°F at low flowrate contributes to short cycling
  - Operate according to application

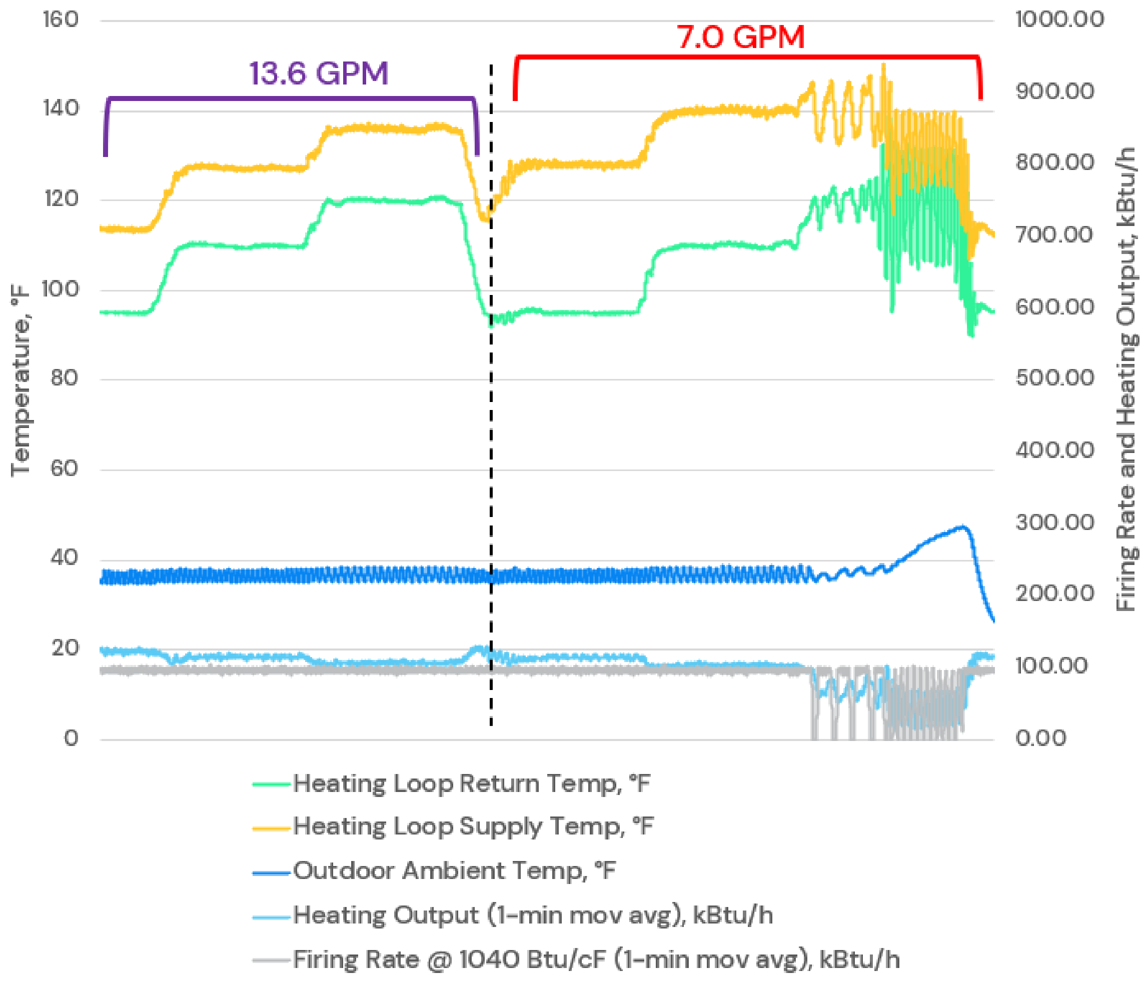


# Steady State Performance Mapping

Target OAT @ 110°F

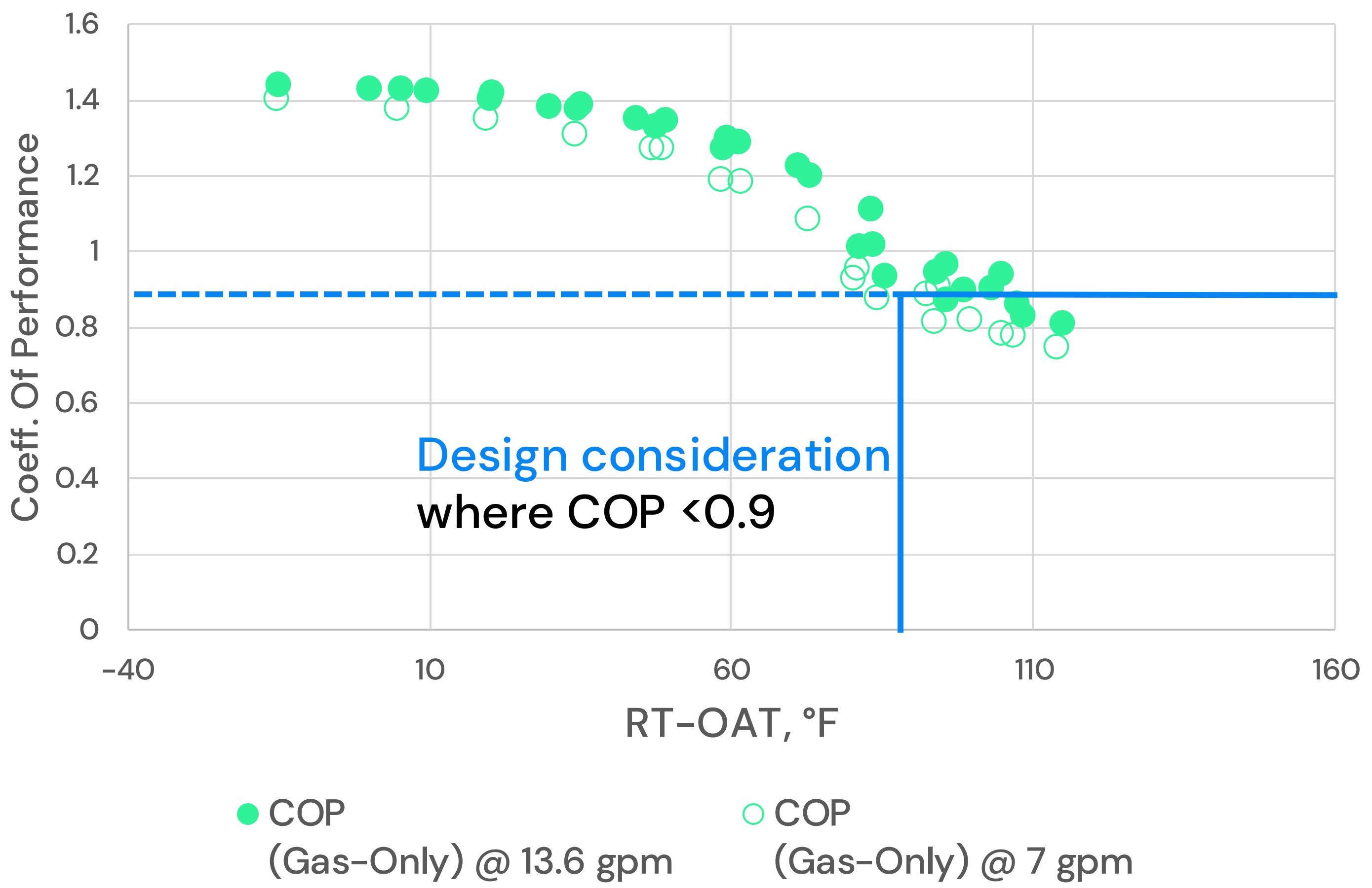


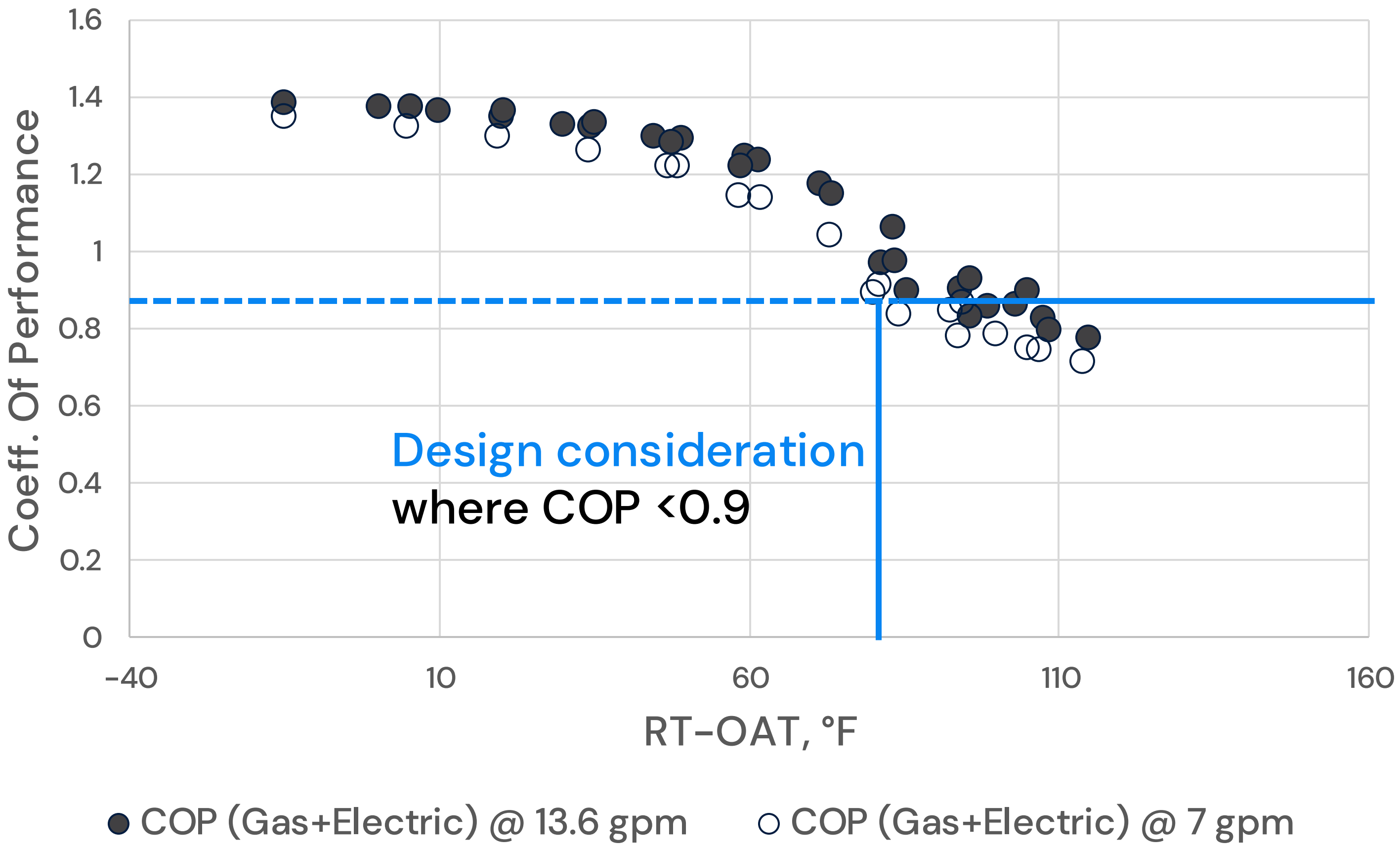

Target OAT @ 35°F




- Side by side comparison between OAT @ 110°F and OAT @ 35°F
  - Short cycling when flowrate is reduced to 7.0 GPM → Supply Temp >140°F
  - Reduction in heat capacity at lower flowrates (7.0 GPM) relative to higher flowrates (13.6 GPM)

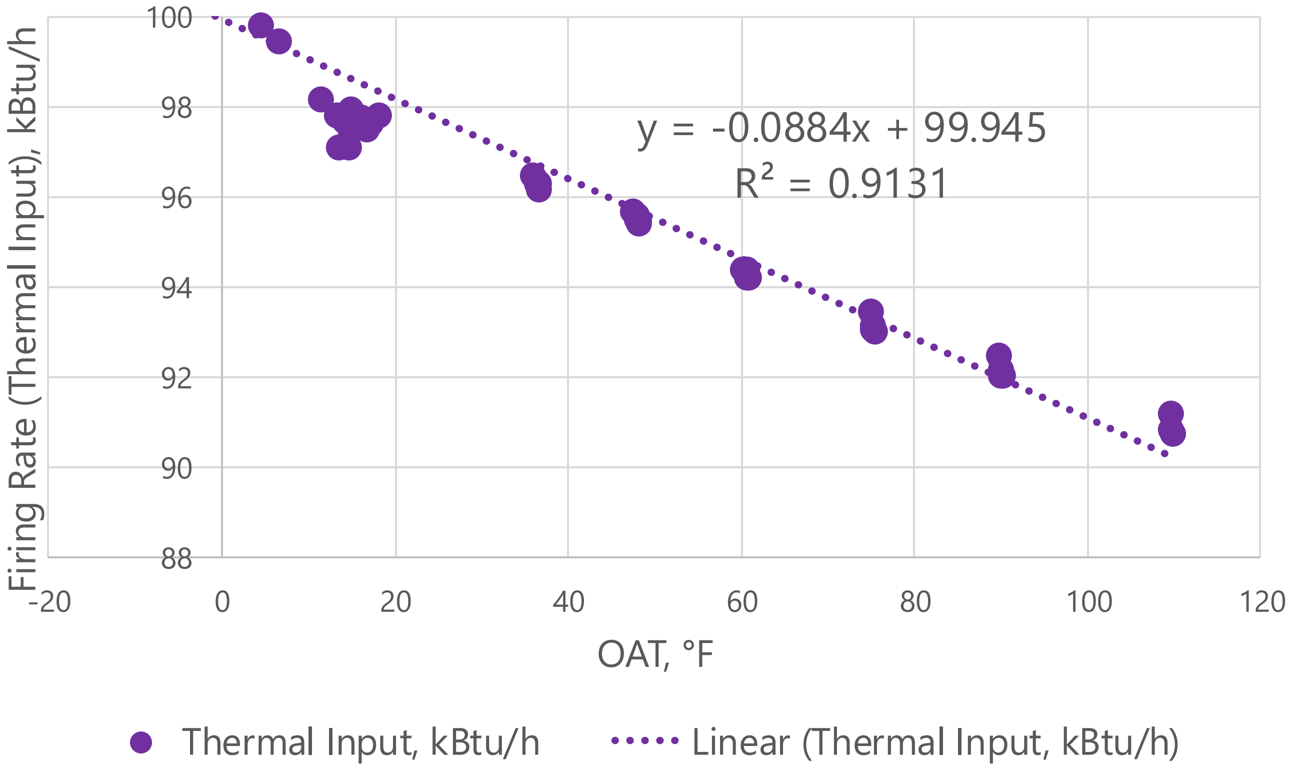
# Steady State Performance Mapping

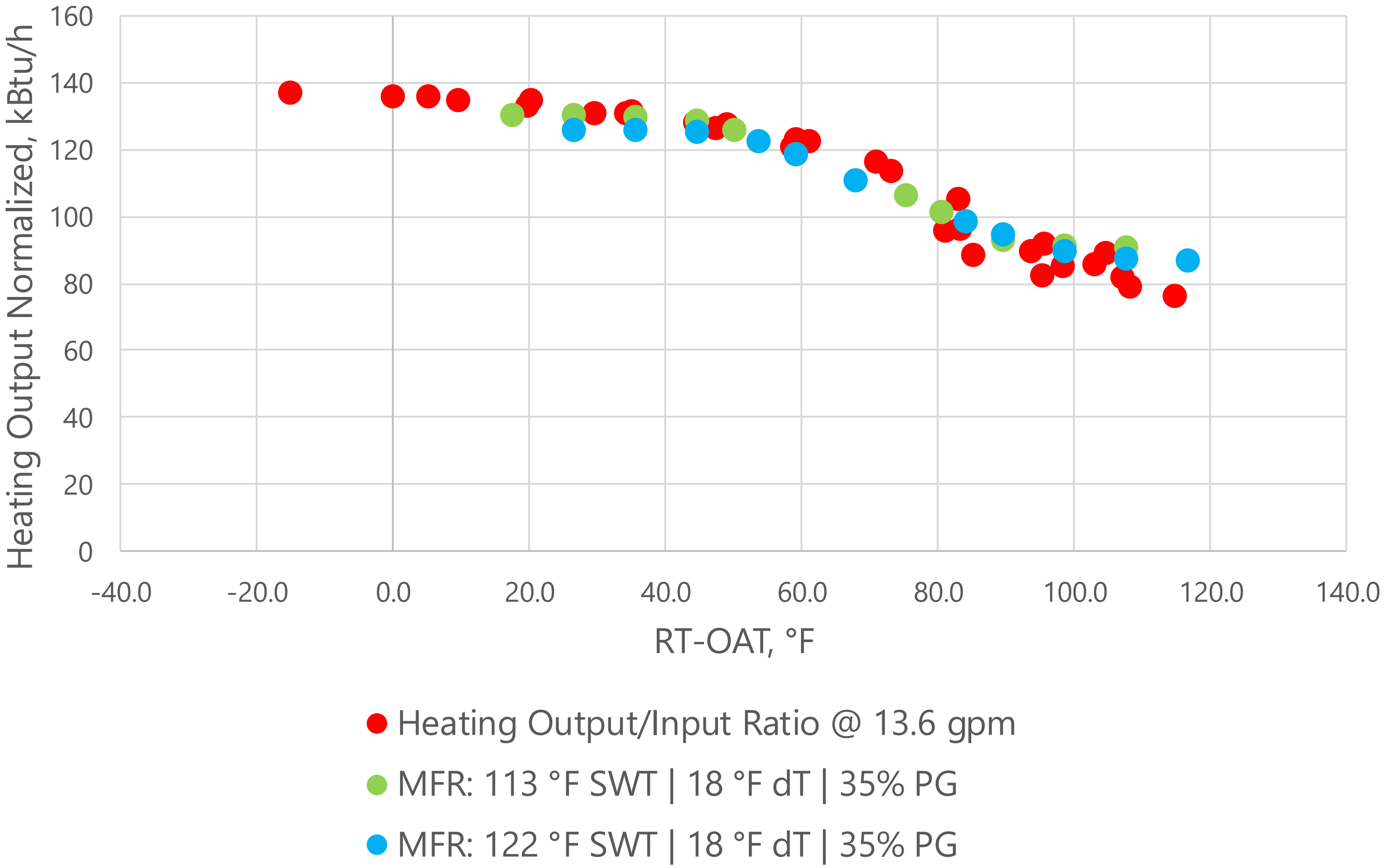



- Side by side comparison for COP (Gas-Only) & COP (Gas+Electric)
  - Electric energy has small impact
  - *Short cycling data excluded
- COP behavior is contingent on (ambient) site conditions and return temperatures
  - Optimal at high ambient and low return temperatures

# Steady State Performance Mapping




- Firing rate decreases with increasing outdoor air temperature
  - Power consumption shows similar behavior
  - Linear curve behavior

- Overlap with manufacturer's data and experimental data implies close alignment

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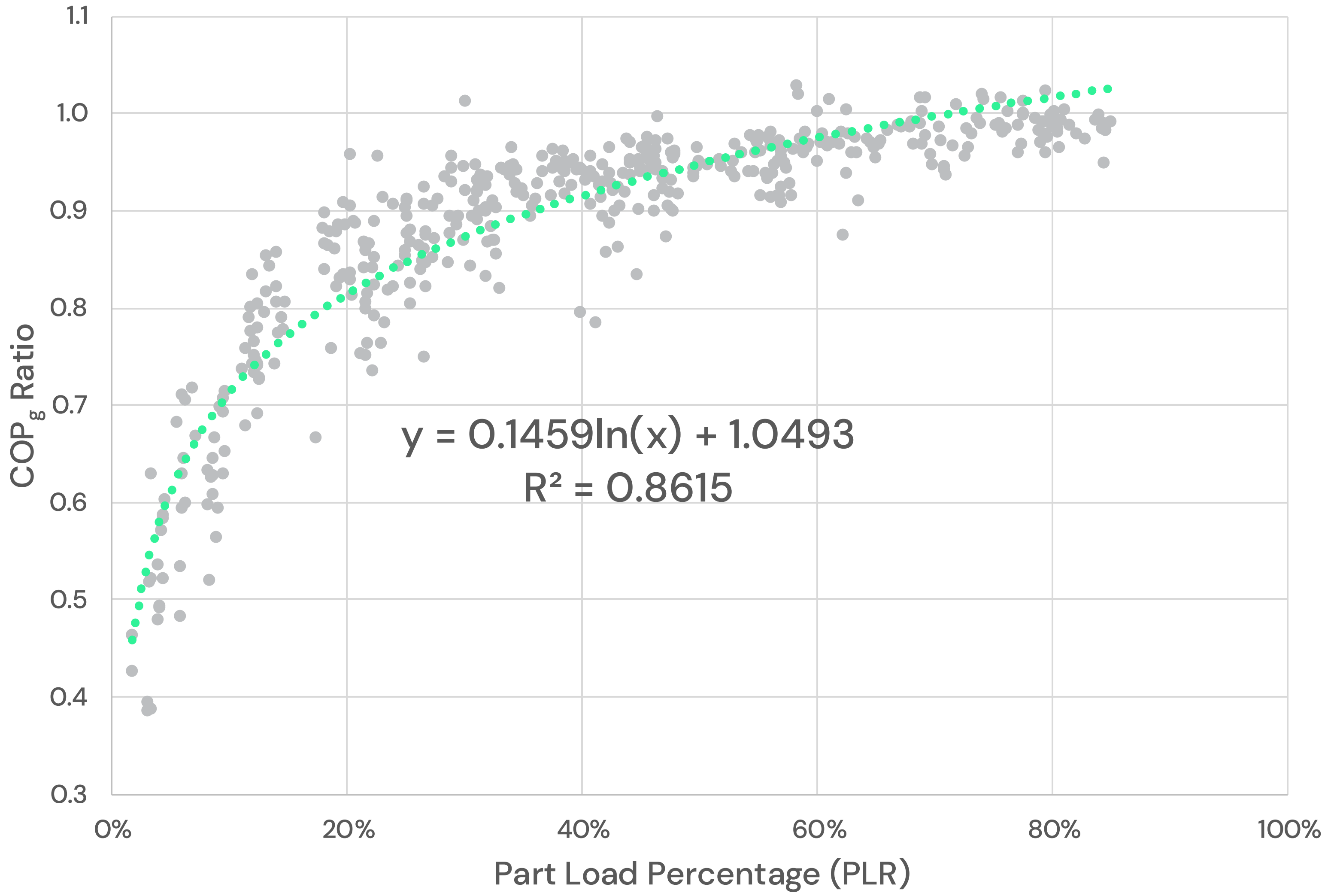
# Experimental Results – Load-Based (Transient)

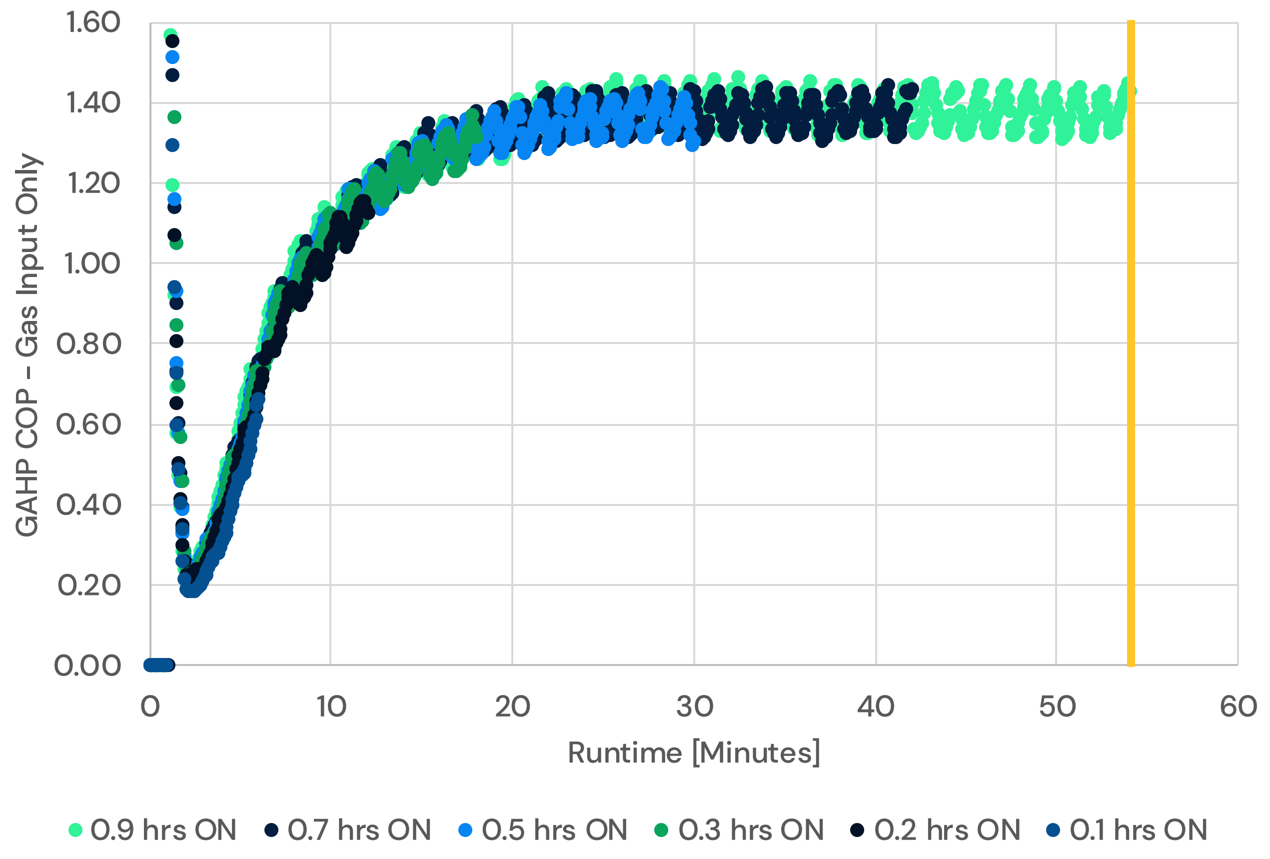
# Load-Based Performance Mapping

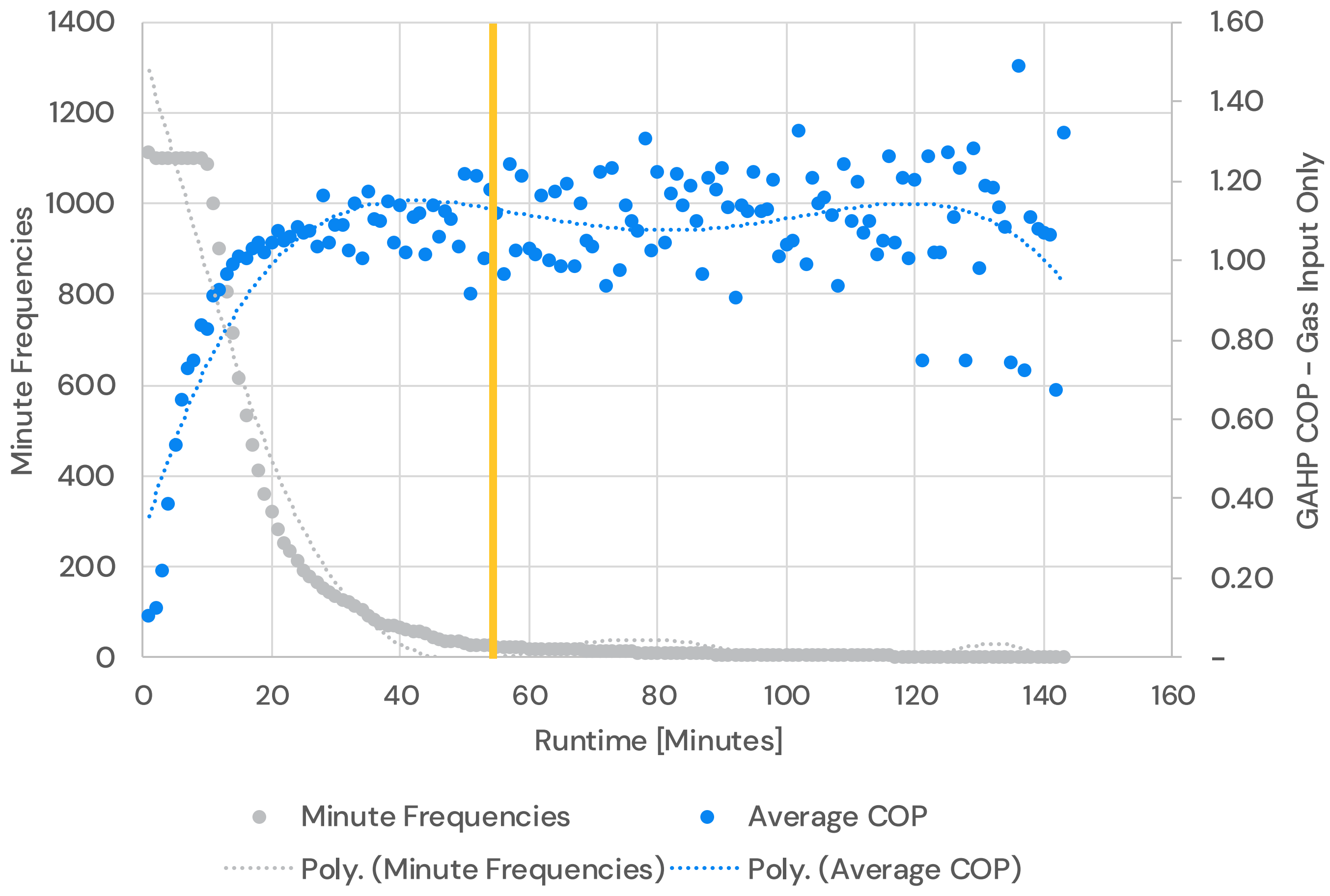
- Steady state experimental data = max capacity when calculating PLR
  - COP Ratio (derate) → efficiency relative to the load
- Data used to develop correction factors for part load (cycling) performance



# Field Test Comparison (Preliminary)

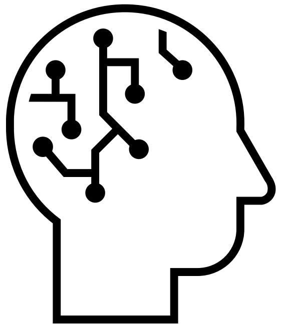
- Lab Data [left] compared against preliminary field data [right]
  - COP steady state reached in ~20 minutes



# EnergyPlus Modeling

# EnergyPlus Modeling Integration



- Objective: forecast…

(1) Energy Consumption

(2) Utility Bills

(3) Greenhouse Gas Emissions

- Targeted audience:

(1) California Policymakers

(2) Program Designers

(3) Software Developers

(4) Manufacturers

# EnergyPlus Modeling Integration

- Modeling parameters developed and plotted with experimental data
  - Modeling parameters can be predicted within ±5%
- Key parameters (simplified below):

- Heating Capacity = Rated Capacity x CAPFT

  CAPFT = correction factor based on ambient and return temperature

- Gas Use = [(Load/$COP_{nom}$) x EIRFT x EIRFPLR x EIRDEFROST]/CRF

  EIRFT = correction factor based on ambient and return temperature

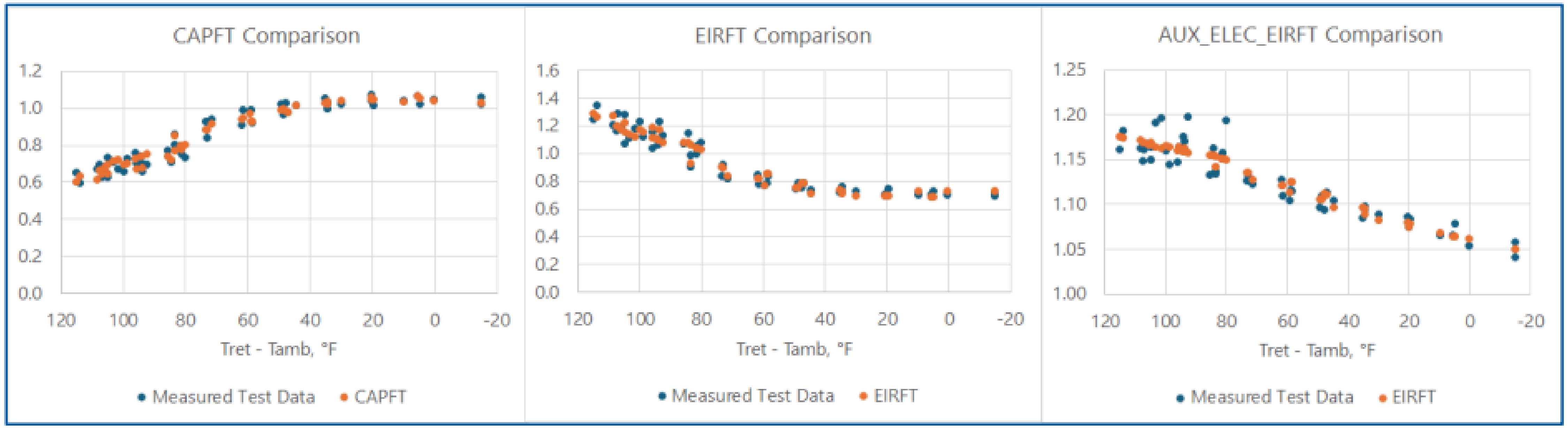
  EIRFPLR = correction factor for cycling (part load)

  EIRDEFROST = correction factor for defrost

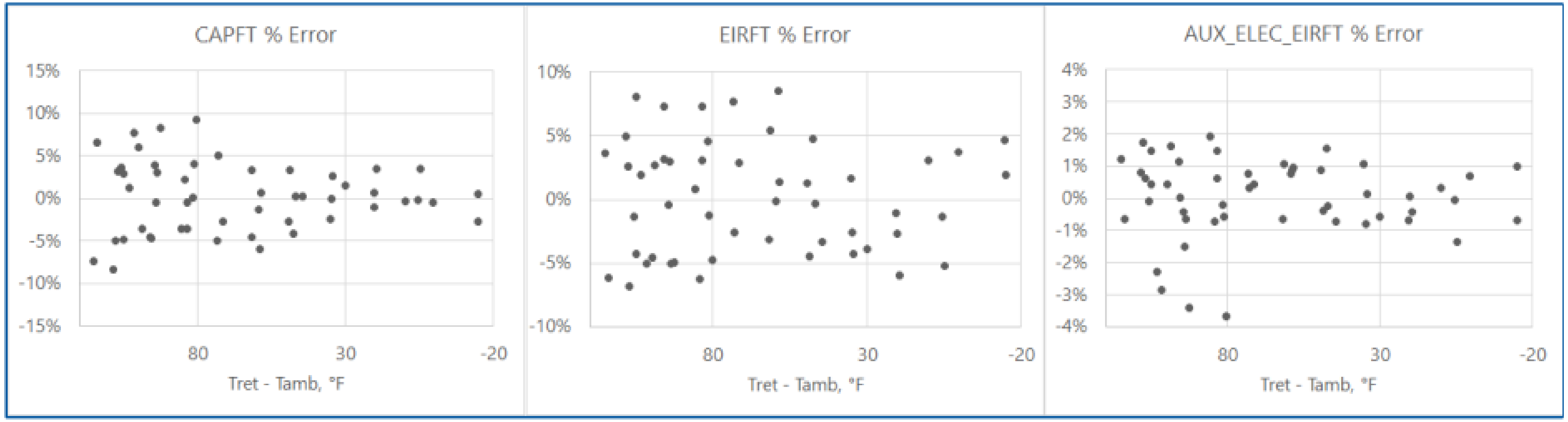
  CRF = correction factor for cycling operation

# EnergyPlus Modeling Integration

Correction between measured (experimental) data and calculated correction factor

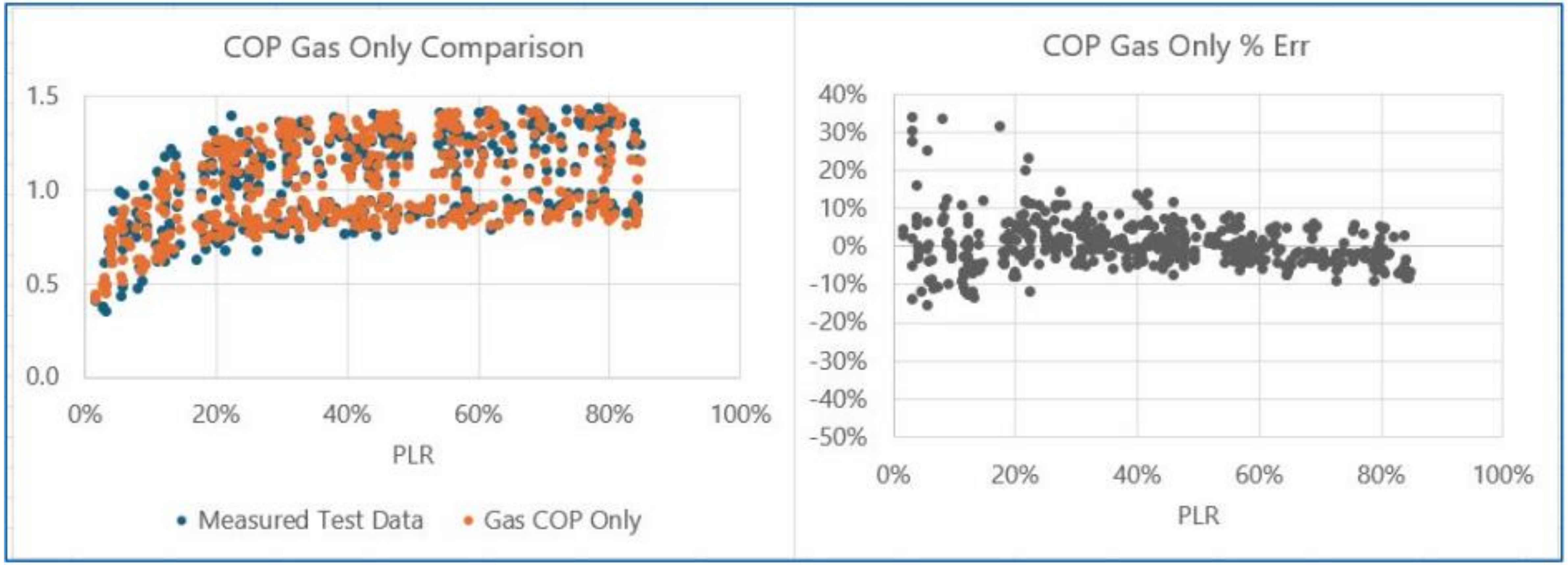



% Error



# EnergyPlus Modeling Integration

- Overall modeling accuracy of COP (Gas Only) is approximately ±6%



# Key Takeaways & Recommendations for Future Studies

## Key Takeaways

1. Robur GAHP-A closely aligns with manufacturer's published data
2. Data suggests to proceed according to application when operating unit at low flowrate (7.0 GPM)
3. Normalized data suggests experimental data is sufficient for modeling integration (±6%)

## Future Studies

1. National Renewable Energy Laboratory (NREL) large scale modeling for EnergyPlus performance curve integration
2. Hydrogen blend testing and performance curve development
3. Additional "market-ready" GAHP experimental testing for EnergyPlus modeling integration

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