ET Summit 2024

Presented by

Heat Pump Performance in California:

Fuel-Fired Water Heating Applications

Madeline Talebi
Energy Engineer
ICF

ICF

GTI ENERGY
solutions that transform

Project Collaborators

ICF

Steven Long, P.E.
Director of Engineering (West)

Alfredo Gutierrez, P.E.
Engineering Manager

Madeline Talebi
Energy Engineer

GTI Energy

Jason LaFleur
Senior Manager

Alejandro Baez Guada
Principal Engineer

Lee Van Dixhorn
Senior Engineer

Ari Katz
Senior Engineer

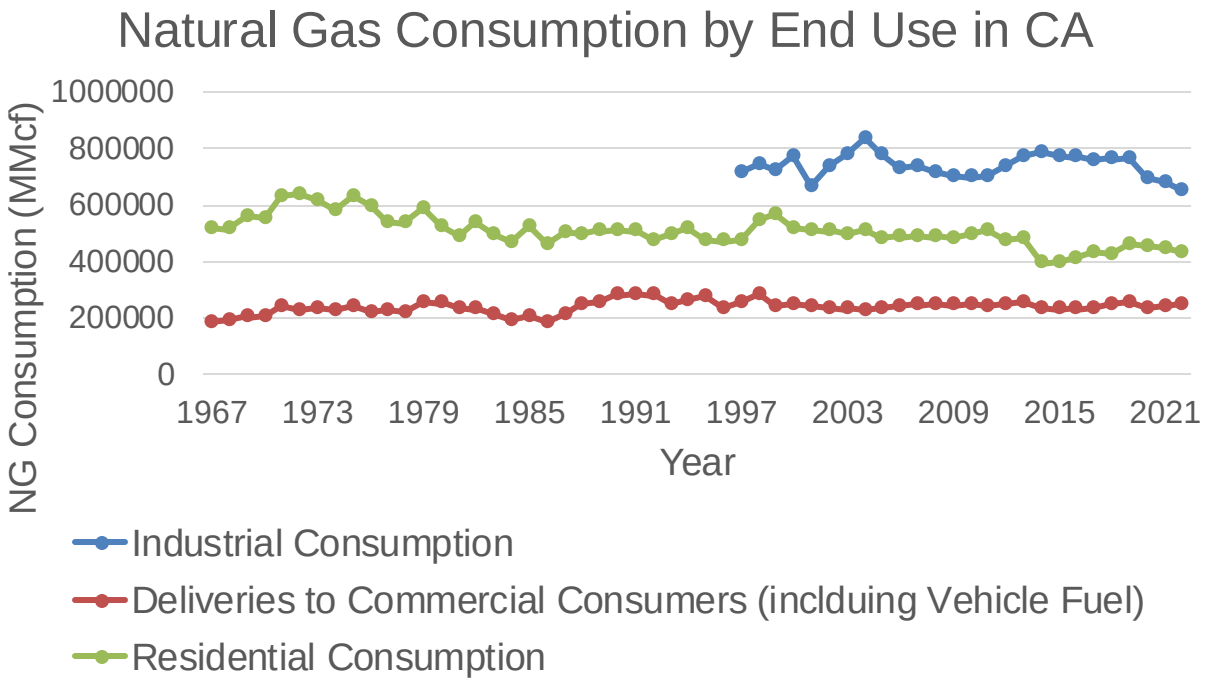
Alex Fridlyand, Ph.D., P.E.
Senior Program Manager

Agenda

- Gas Absorption Heat Pumps (GAHP) in California
- Equipment Commissioning/Test Plan
- Steady State Performance Experimental Data
- Load-Based (Transient) Performance Experimental Data
- EnergyPlus Modeling
- Next Steps
- Key Takeaways and Future Studies

California on Emissions Control

- Water heating is the largest end-use of natural gas in California



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)

US Energy Information Administration. "Natural Gas Consumption by End Use." https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm

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

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%

Robur. "Installation, use and maintenance manual" (2020).

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

Robur. "Installation, use and maintenance manual" (2020).

Target Conditions – Part Load

- Robur GAHP-A system

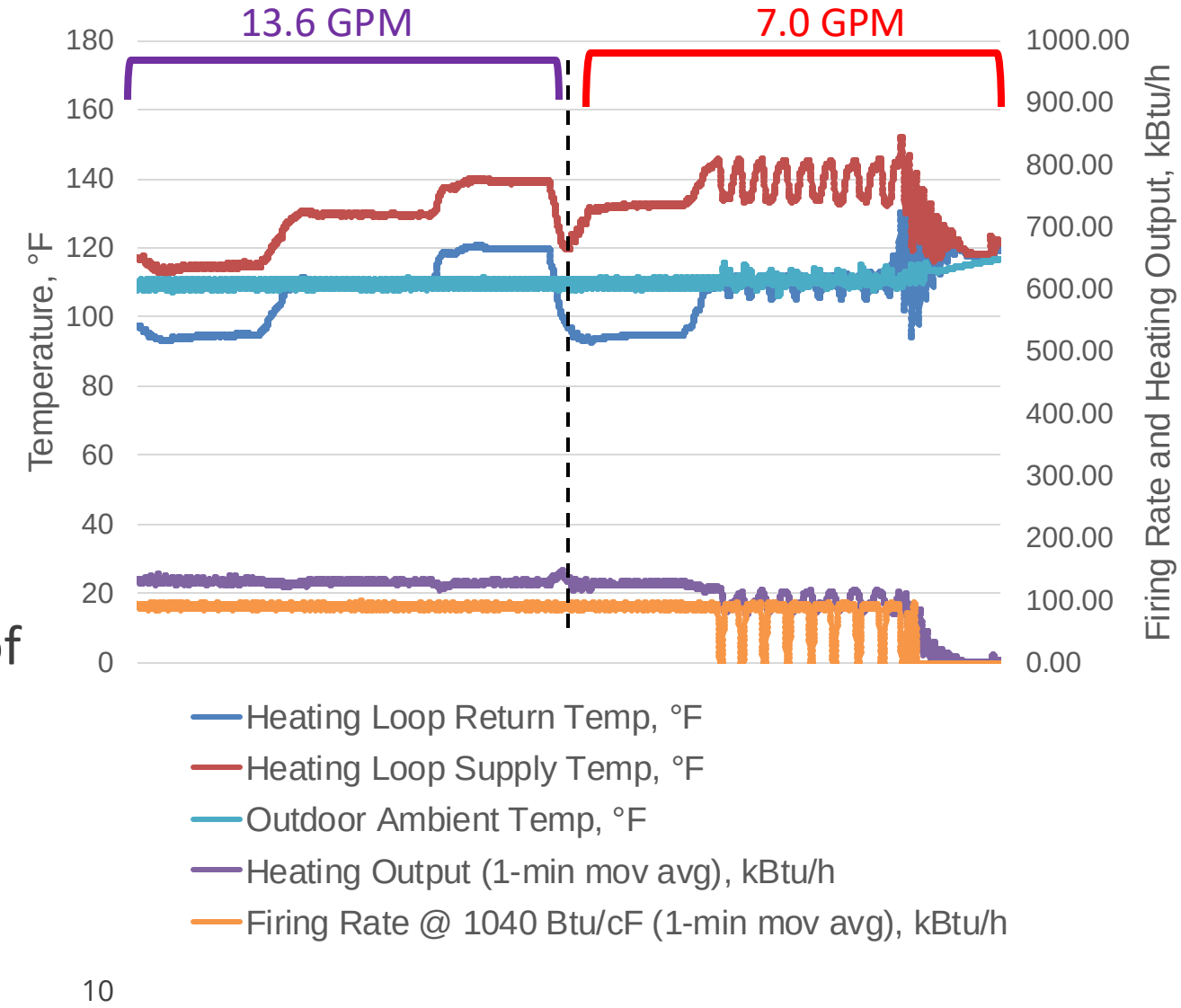
Robur. "Installation, use and maintenance manual" (2020).

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**

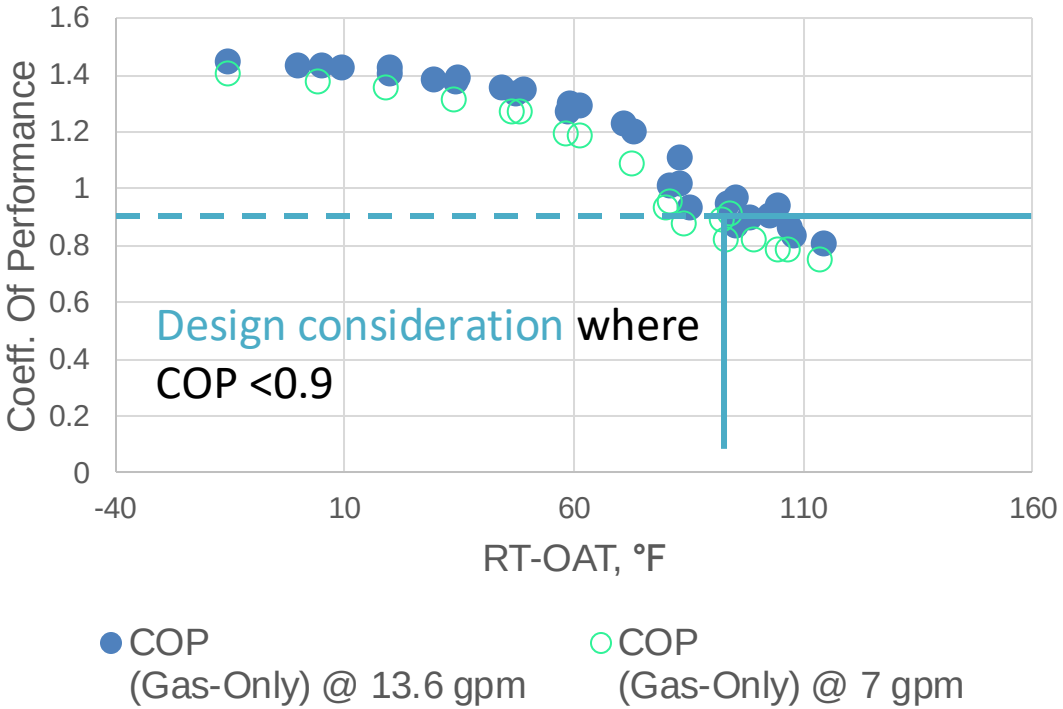
Steady State Performance Mapping

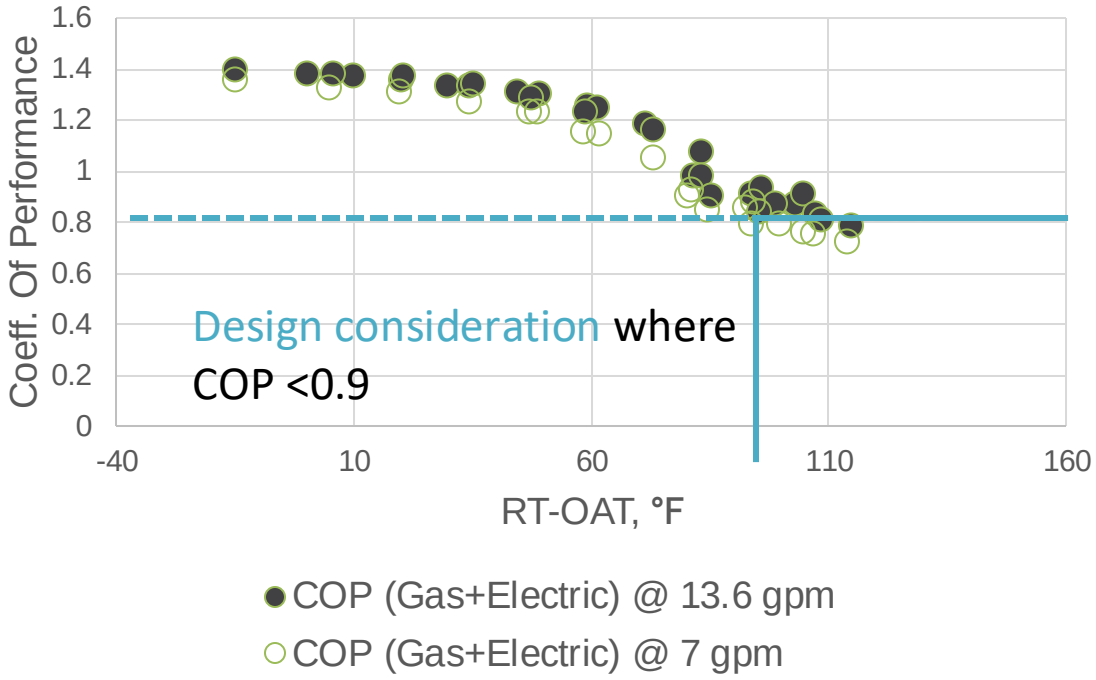
Target Conditions		
Outside Air Temperature (OAT), °F	Glycol Flow Rate, GPM	Return Temperature (RT), °F
110	13.6	95
		110
		120
	7.0	95
		110
		120

- 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

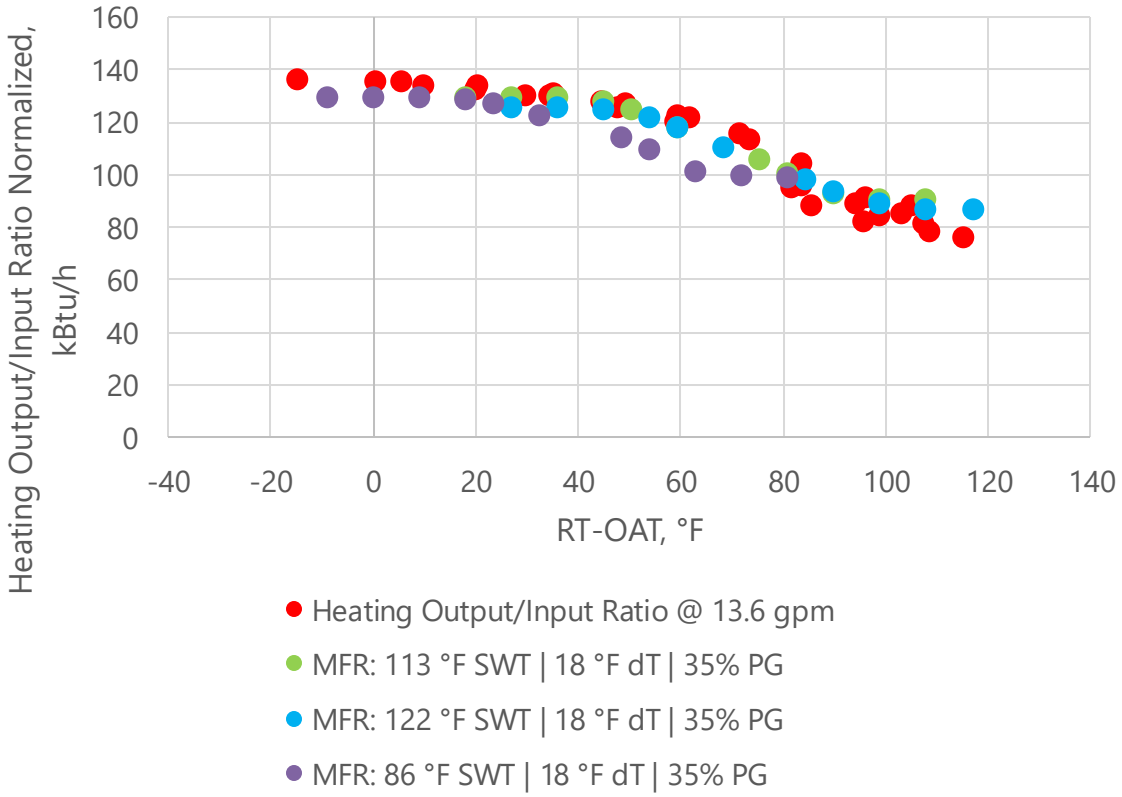


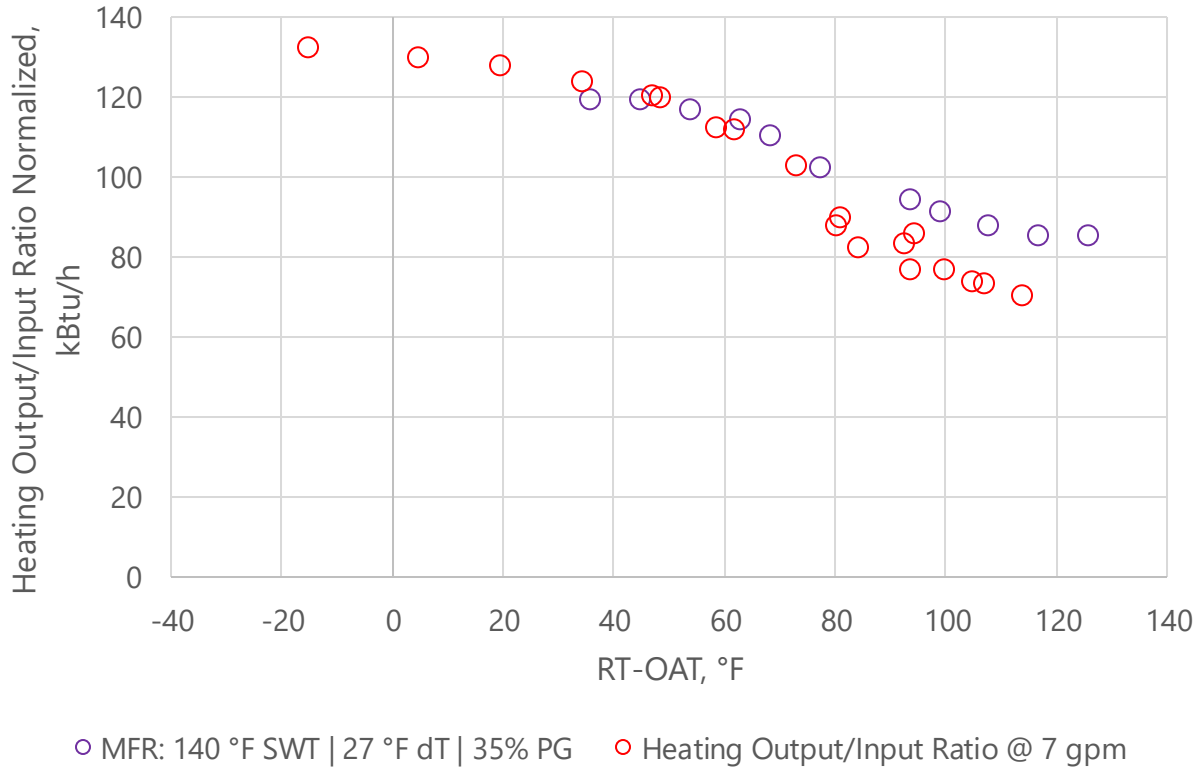


- Side by side comparison for COP (Gas-Only) & COP (Gas+Electric)
  - Electric energy has small impact
  - *Short cycling data excluded
- COP behavior is contingent on (ambient) site conditions and return temperatures
  - Optimal at high ambient and low return temperatures

Steady State Performance Mapping

- Red dots illustrate experimental data compared against manufacturer's data
  - Overlap: close alignment between experimental and manufacturer data

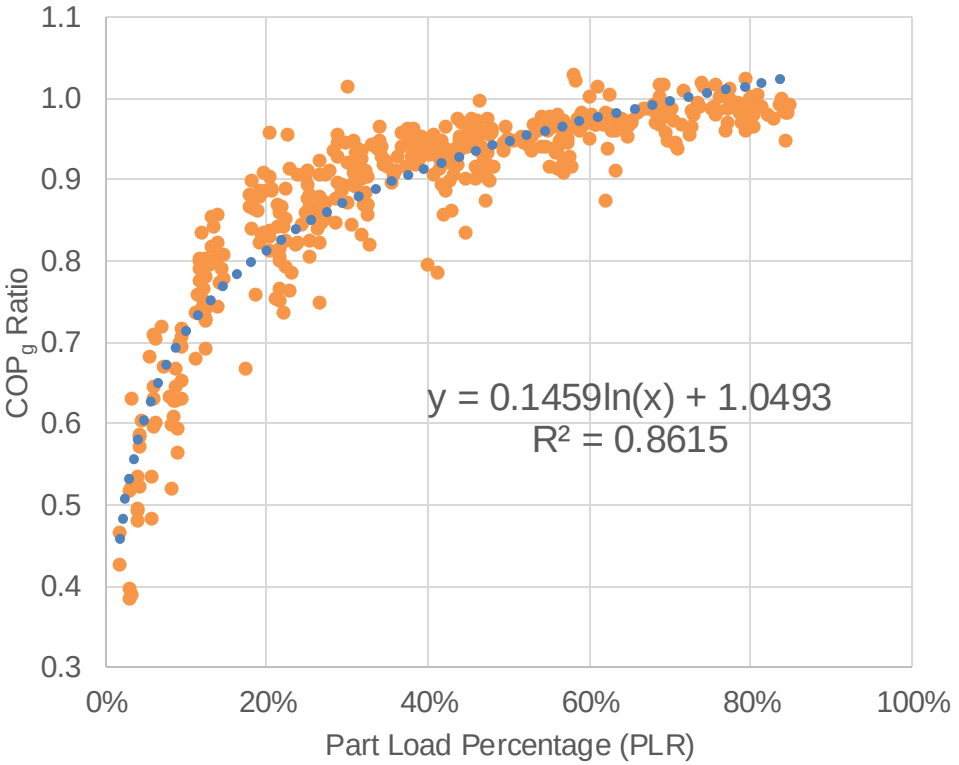




Load-Based Performance Mapping

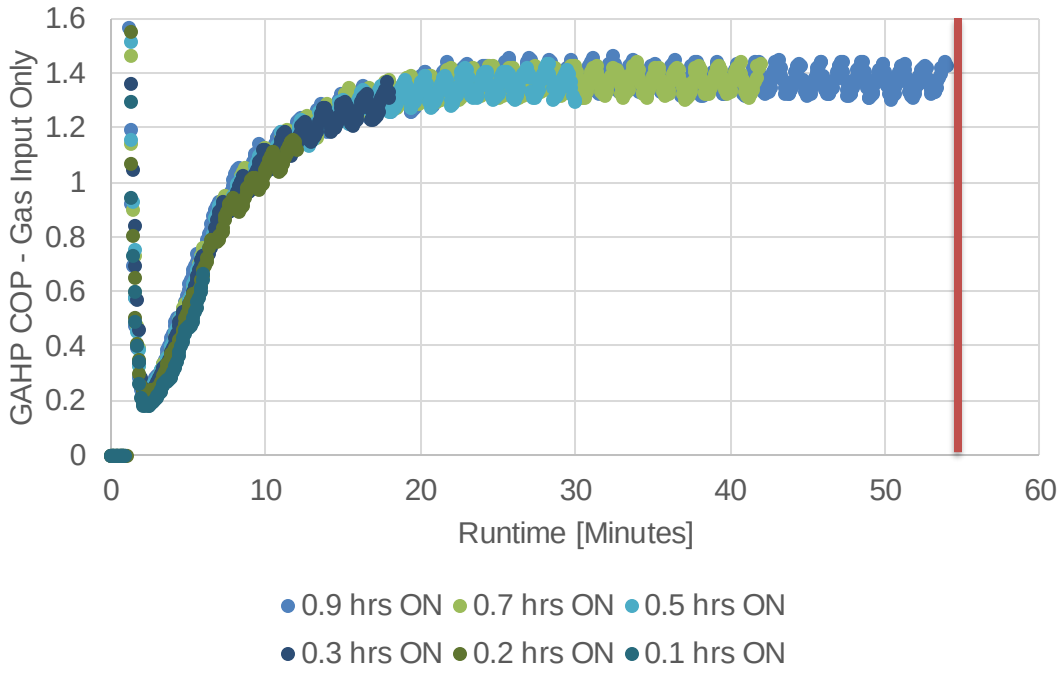
- Steady state experimental data = max capacity when calculating PLR
  - COP Ratio (derate): efficiency relative to the load
- Data used to develop correction factors for part load (cycling) performance
- Limitations in logarithmic trendline, therefore, tabulated

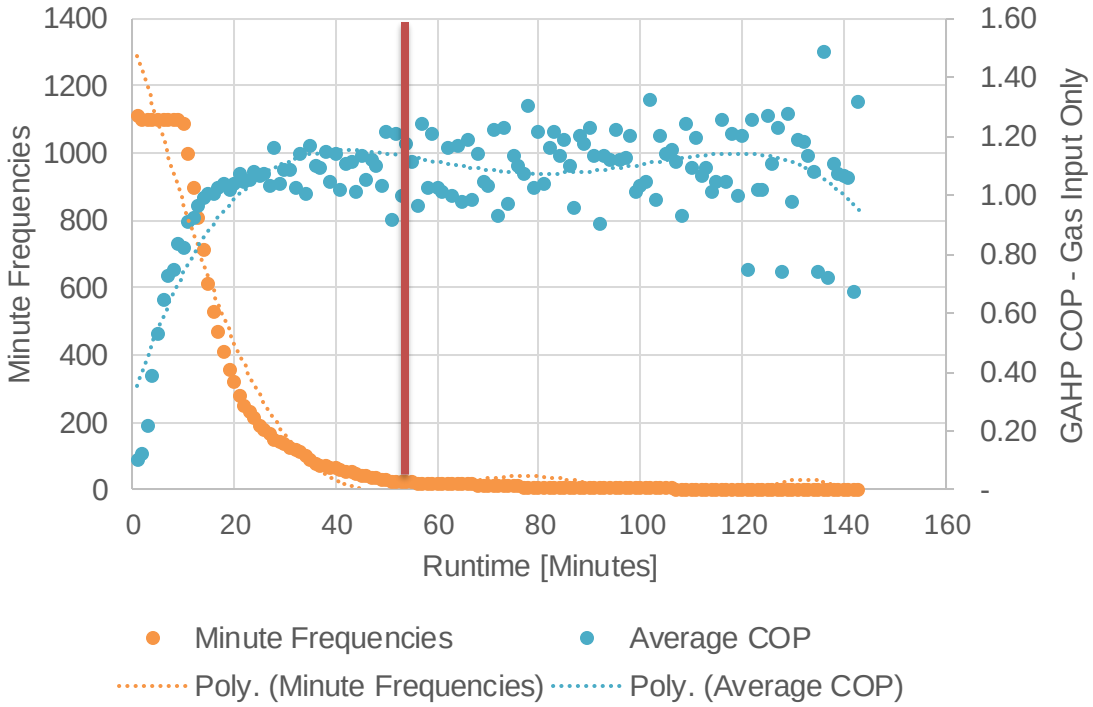
PLR	Values
1%	2.250
5%	1.700
10%	1.450
15%	1.250
20%	1.150
30%	1.070
50%	1.035
75%	1.020
100%	1.000



Field Test Comparison (Preliminary)

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





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

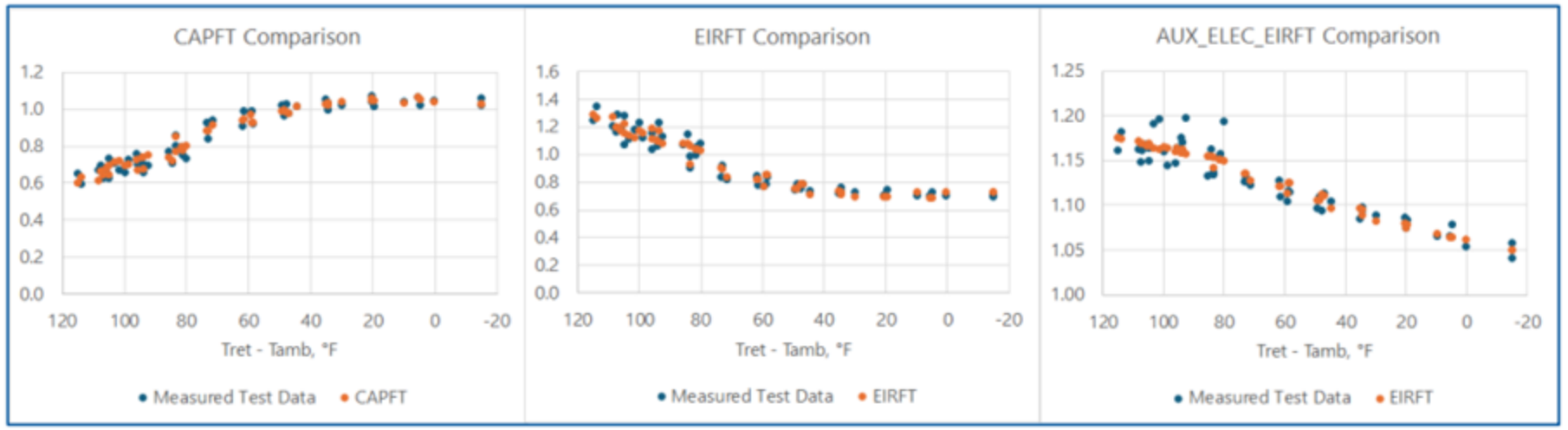
EnergyPlus Modeling Integration

- 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 x EIRFT x EIRFPLR x EIRDEFROST
    - EIRFT = correction factor based on ambient and return temperature
    - EIRFPLR = correction factor for cycling (part load)
    - EIRDEFROST = correction factor for defrost

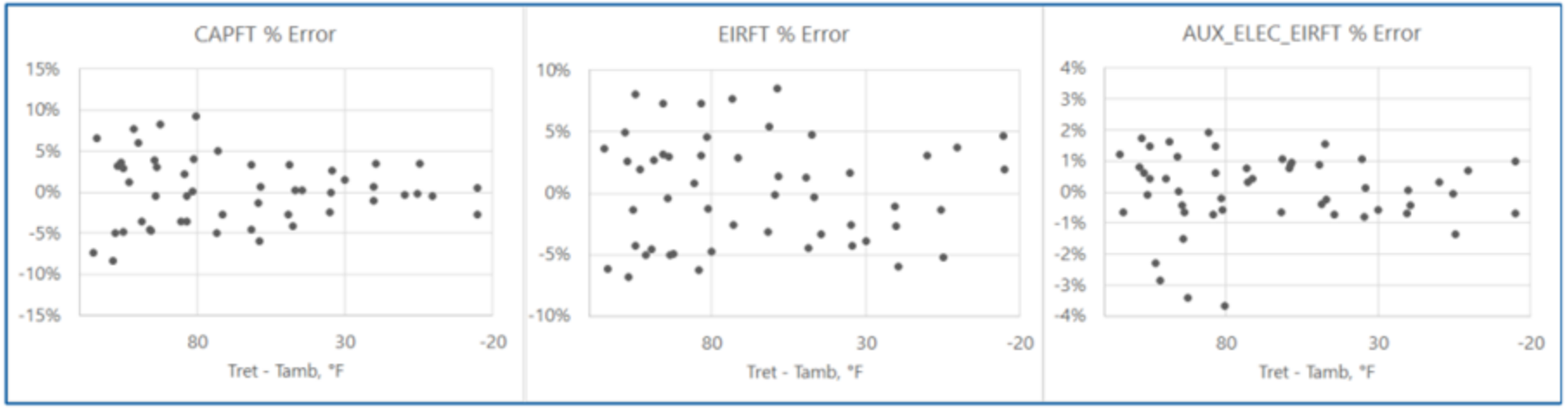
Guada, Alejandro; Van Dixhorn, Lee; Fridlyand, Alex; Katz, Ari. "Robur GAHP A Performance Mapping." GTI Energy, 2023.

EnergyPlus Modeling: Correlation Comparison

Correlation between measured (experimental) data and calculated correction factor



% Error



Guada, Alejandro; Van Dixhorn, Lee; Fridlyand, Alex; Katz, Ari. "Robur GAHP A Performance Mapping." GTI Energy, 2023.

Recommendations

Key Takeaways

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

Future Studies

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

This project was conducted through the ICF implemented, SoCalGas administered California Statewide Gas Emerging Technologies Program.

The project report can be found on cagastech.com

For more information, contact get@caenergyprograms.com

Madeline Talebi

Energy Engineer

ICF

madeline.Talebi@icf.com

LinkedIn

solutions that transform