ET Summit 2025

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ENERGY TRANSITION
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Heat Pump Performance in California

Hydrogen-Natural Gas Blend Fired Water Heating Applications

SoCalGas
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solutions that transform

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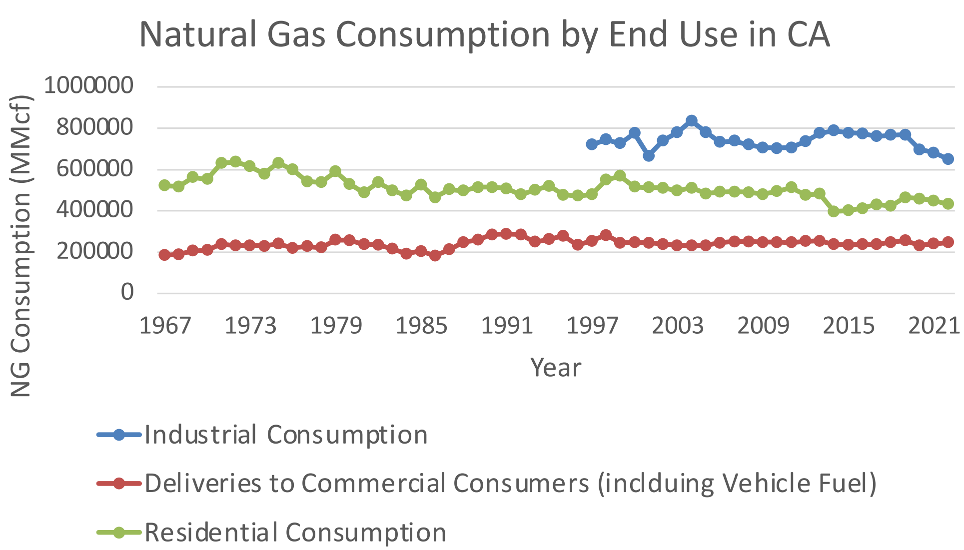
Agenda

- Gas Absorption Heat Pumps (GAHP) in California
  - Hydrogen fuel blending
- Lab Study Objectives
- Test Plan
- Steady State Performance Experimental Data
  - Emissions Analysis
- Load-Based (Transient) Performance Experimental Data
- EnergyPlus Modeling
- Recommendations

California on Emissions Control

- Water heating is the largest end-use of natural gas in California
- Natural Gas Consumption by End Use in the Industrial, Commercial, and Residential 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)

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

Hydrogen Blending

- Hydrogen blend at 5% → 95% natural gas + 5% hydrogen
- Limitations with regards to hydrogen blending is primarily associated with increase in operating costs
- On-site max hydrogen blending across various regions:

Country	Max Hydrogen Blend
USA (excluding Hawaii)	5%
USA (Hawaii only)	15%
Canada	5%
Europe	20%
Australia	5%

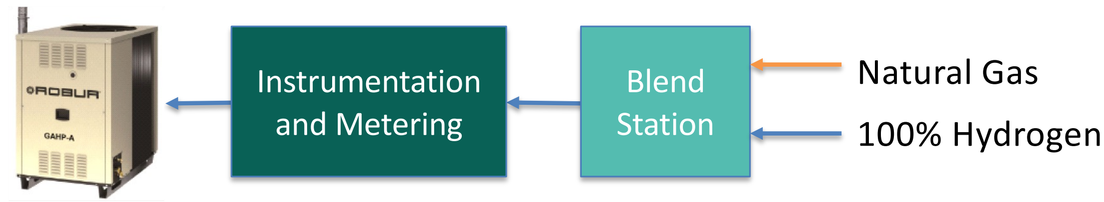
CPUC (2022). "CPUC Issues Independent Study on Injecting Hydrogen Into Natural Gas Systems." CPUC Issues Independent Study on Injecting Hydrogen Into Natural Gas Systems (ca.gov) & SoCal Gas (2024). "H2 Blending." H2 Blending | SoCalGas

Objectives

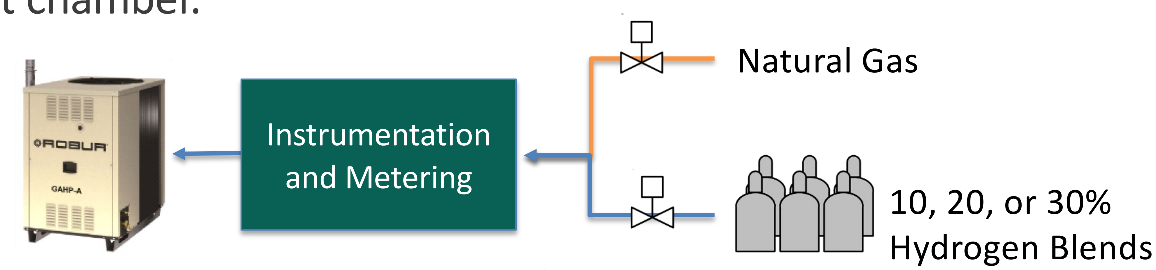
- Improve low uptake at the sector level
  - Primarily as it relates to the commercial sector
- Improve low uptake at the technology level
- Technology performance in a controlled environment
  - Steady state evaluation
  - Part Load (Transient) evaluation
- Emissions evaluation with hydrogen fuel blends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

Hydrogen-Blend Test Set Up

- Original Plan: Utilize blend station using station using 100% Hydrogen to the needed blends.



- *Revised Plan: Utilize cylinders with 10%, 20%, and 30% Hydrogen blends.
  - *This addresses regulations and safety concern of potential 100% hydrogen in an enclosed test chamber.



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

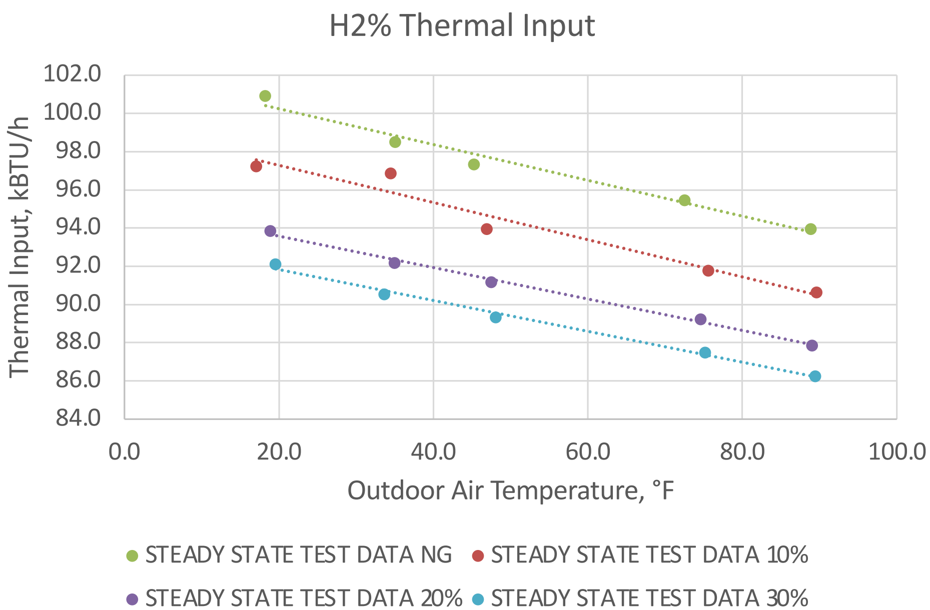
Variable	Testing Range	Number of Points within Testing Range
Flow Rate [GPM]	13.6 GPM	1
Outside Air Temperature (OAT) [°F]	17°F-90°F	5
Return Temperature (RT) [°F]	110°F	1
Propylene Glycol [vol%]	35 vol%	1
Hydrogen Blend [vol%]	0-30 vol%	4

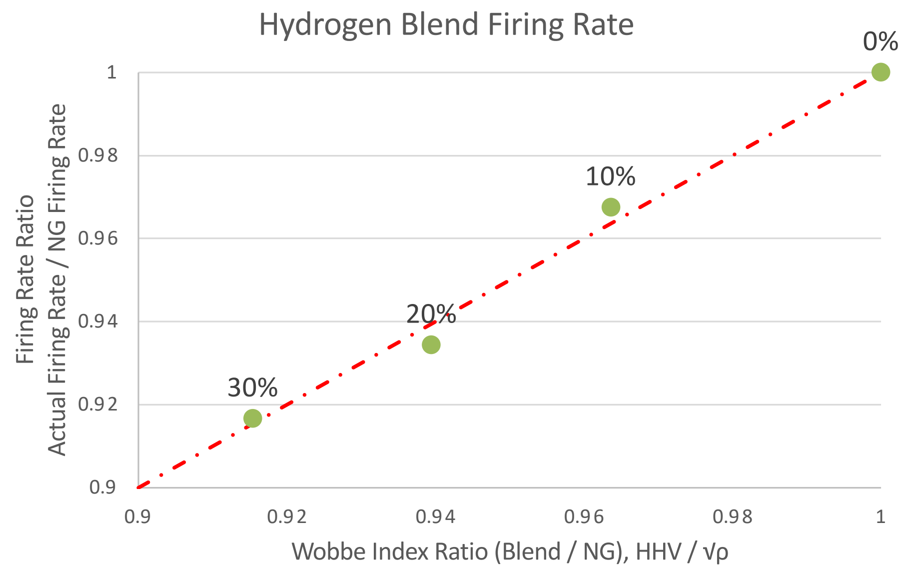
Target Conditions – Part Load (Transient)

- Robur GAHP A system

Variable	Testing Range	Number of Points within Testing Range
Flow Rate [GPM]	13.6 GPM	1
Outside Air Temperature (OAT) [°F]	17°F-90°F	5
Return Temperature (RT) [°F]	110°F	1
Propylene Glycol [vol%]	35 vol%	1
Hydrogen Blend [vol%]	0-30 vol%	4
ON Runtime [hr.]	**0.1-0.7 hr.**	**5**
OFF Time [hr.]	**0.5 hr.**	**1**

Steady State Performance Mapping

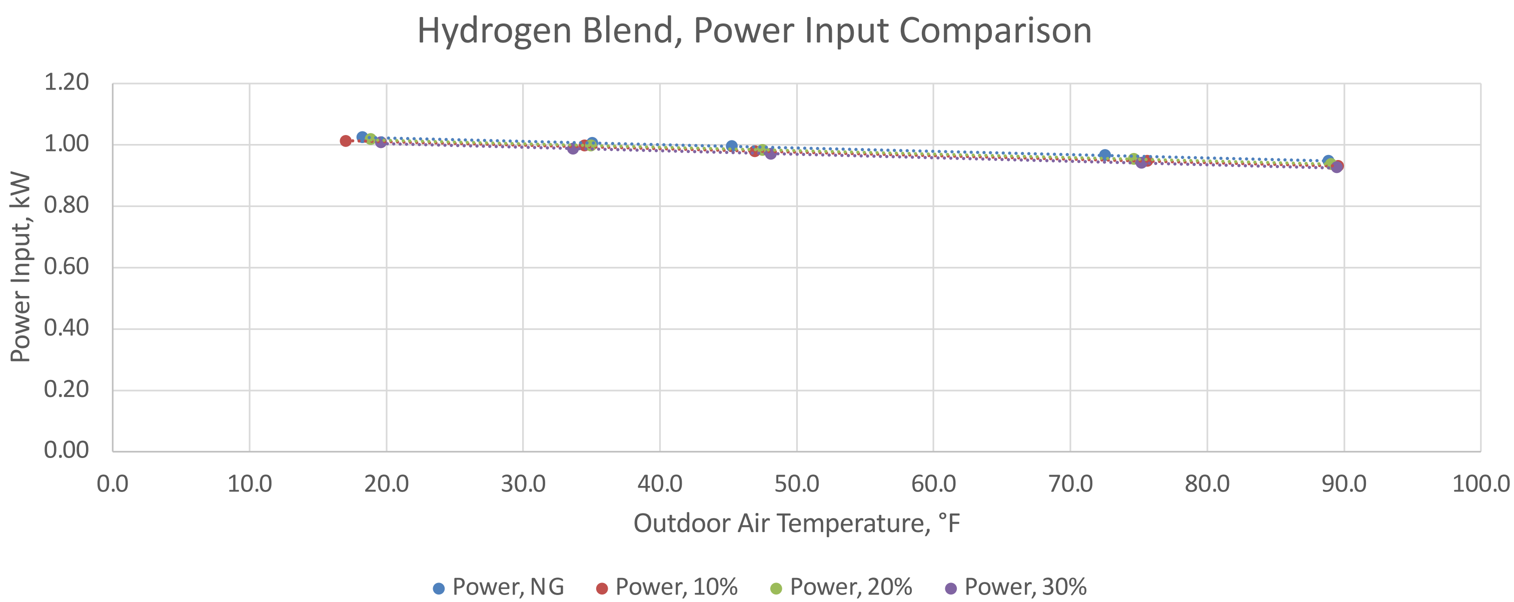




- Decrease in thermal input with increasing OAT → density fluctuations
- Increasing Hydrogen blending → HHV decreases
  - Must also consider how Hydrogen blending affects density

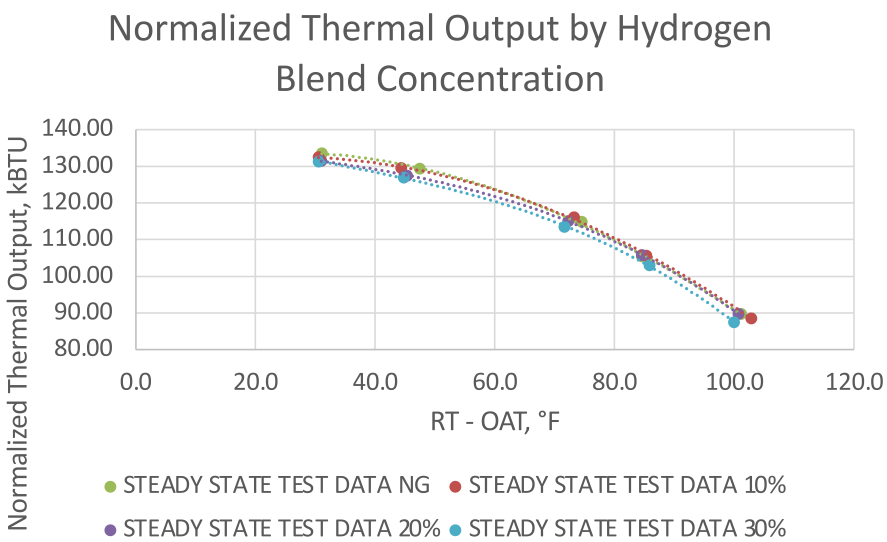
- Wobbe Index (WI) → denote gas replacement equivalency (includes both HHV and density)
  - Capacity decreases with increasing hydrogen blend percentages

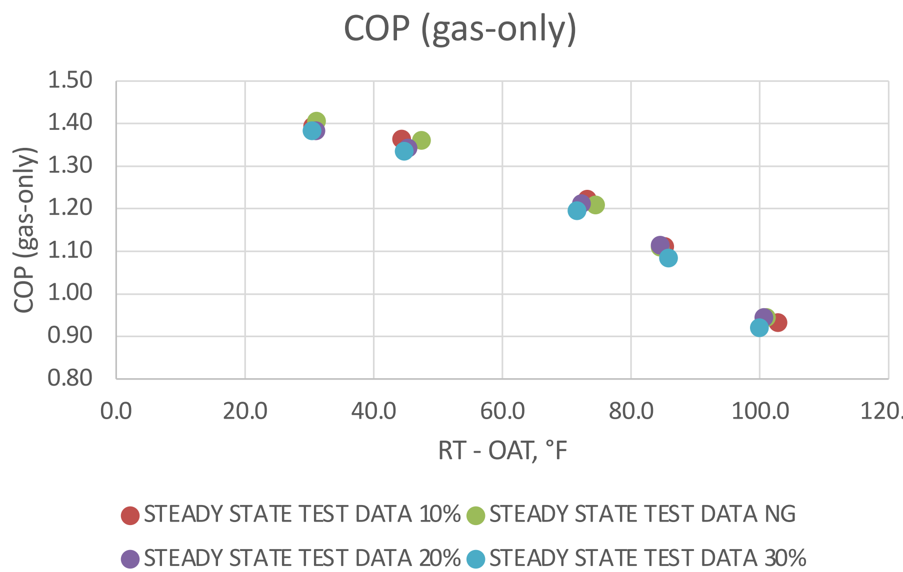
Steady State Performance Mapping



- Similar to the NG testing, power input has minimal impact and a negligible change with increasing hydrogen blend percentage
  - COP (gas only) for comparison between hydrogen blends

Steady State Performance Mapping

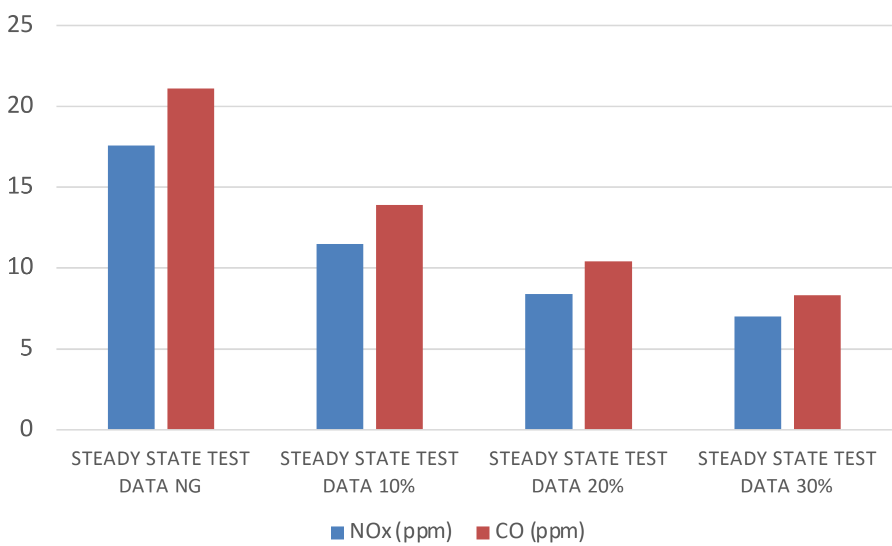


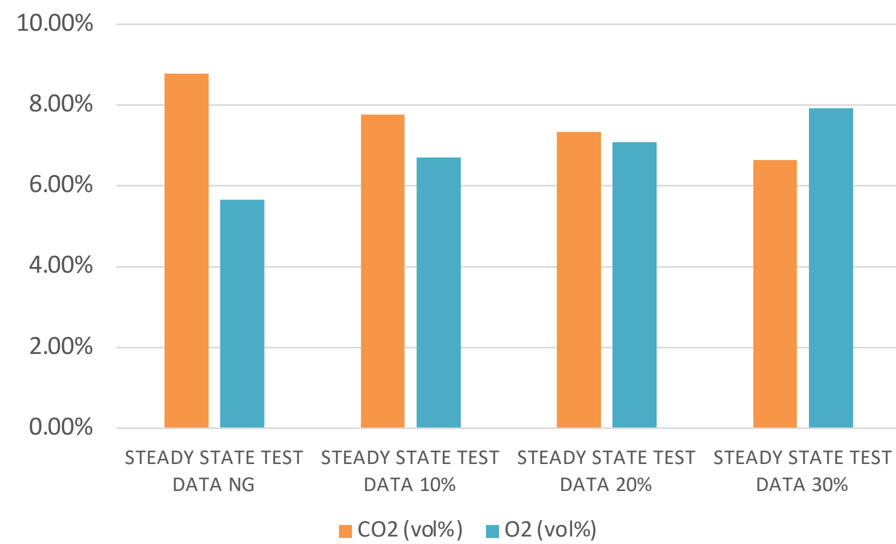


- Normalized data shows close alignment and minimal change with increase hydrogen blend percentage
  - From a prior study, this also correlates well with the manufacturer's published data

- COP (gas-only) is consistent with each of the hydrogen blend tests
  - System performance not affected by hydrogen blending

Emissions Based on Steady State Data



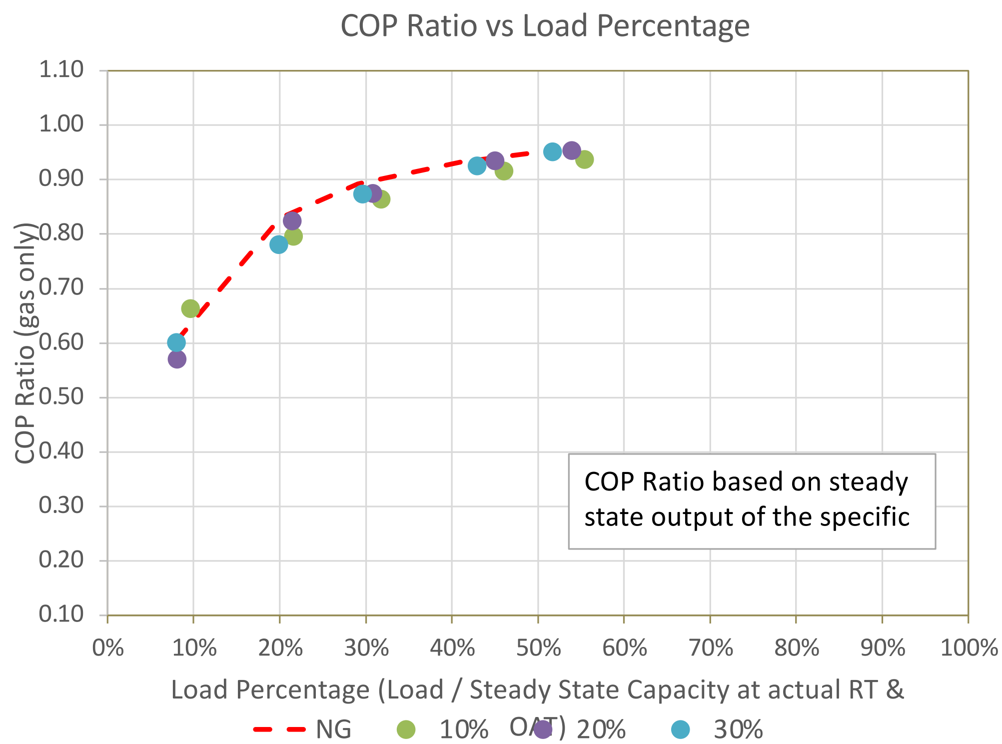


- NOx and CO formation decreased with increasing Hydrogen blend percentage

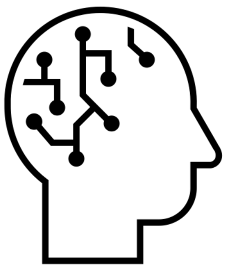
- CO_2 formation decreased with increasing Hydrogen blend percentage
- O_2 formation increased with increasing Hydrogen blend percentage

Load-Based Performance Mapping

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



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

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

    COP_{nom} = Rated GAHP capacity / Rate Gas input

    EIRFT = correction factor based on ambient and return temperature

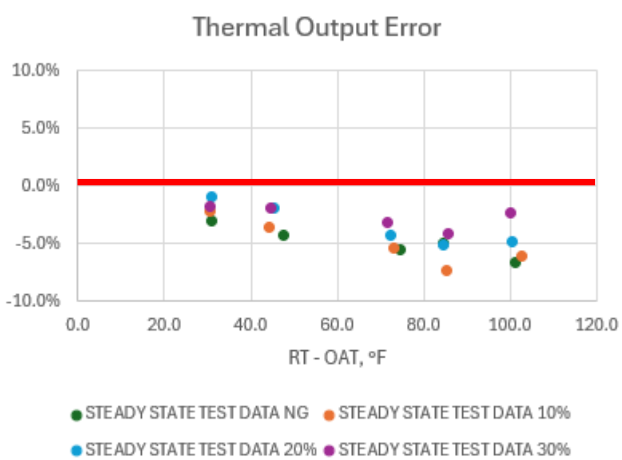
    EIRFPLR = correction factor for cycling (part load)

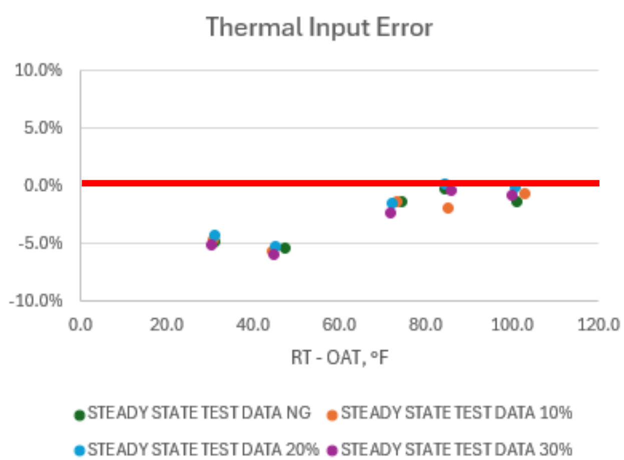
    EIRDEFROST = correction factor for defrost

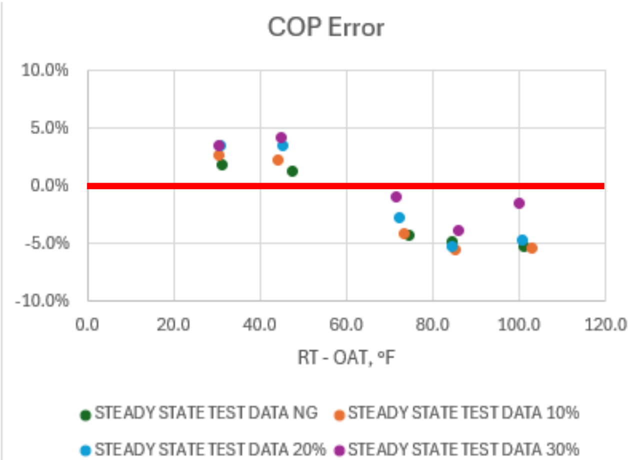
    CRF = correction factor for cycling operation

EnergyPlus Modeling Integration

- Parameter error between measured and modeled data
  - Parameter prediction within ±5%

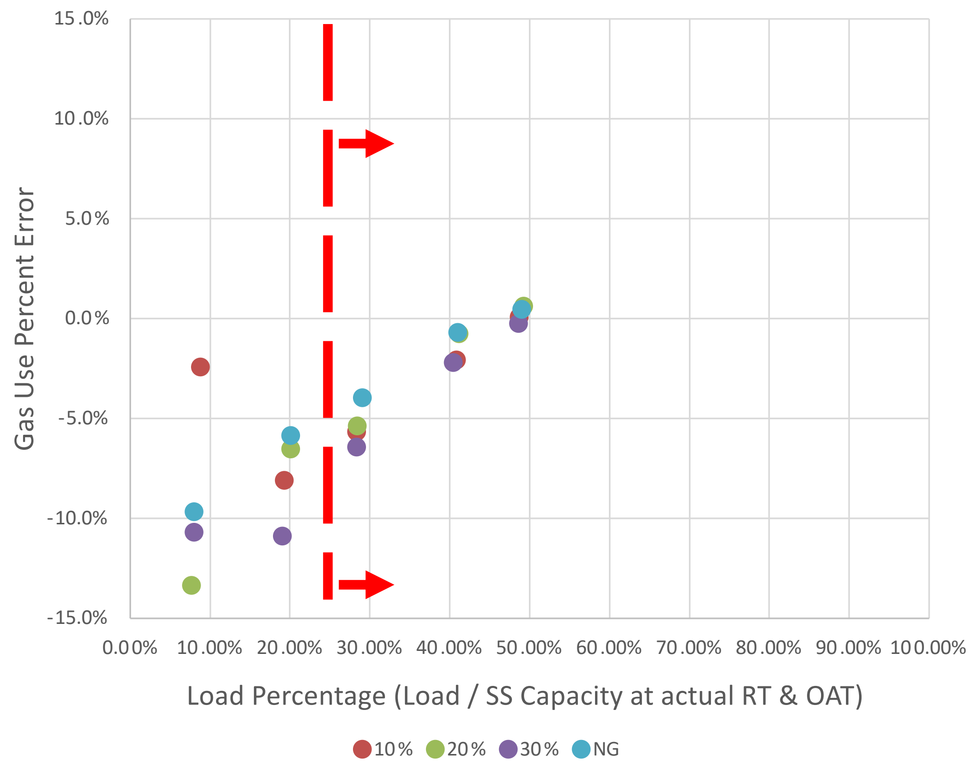






EnergyPlus Modeling Integration

- Overall modeling accuracy based on COP (gas-only) error comparison between measured and modeled data is approximately ±5% above a PLR of 25%



Recommendations

Key Takeaways

1. Robur GAHP-A closely aligns with manufacturer's published data and is minimally affected by an increase in hydrogen blend percentage.
2. Significant emissions benefits present which reduce pollutants while increasing complete combustion species
3. Performance of the GAHP at part loads is mostly independent of the fuel supply (i.e., hydrogen blend percentage)
4. Overall model accuracy of ±5%-10% based on the COP (gas only) measured vs. modeled data

Future Studies

1. Additional "market-ready" GAHP experimental testing for EnergyPlus modeling integration and user-friendly tool development.

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

For more information, contact Program Manager, Ava Donald, at Ava.Donald@icf.com.

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