Gas Emerging Technologies (GET) Program

Adsorption Gas Heat Pump Lab Tests

2026

Project Collaborators

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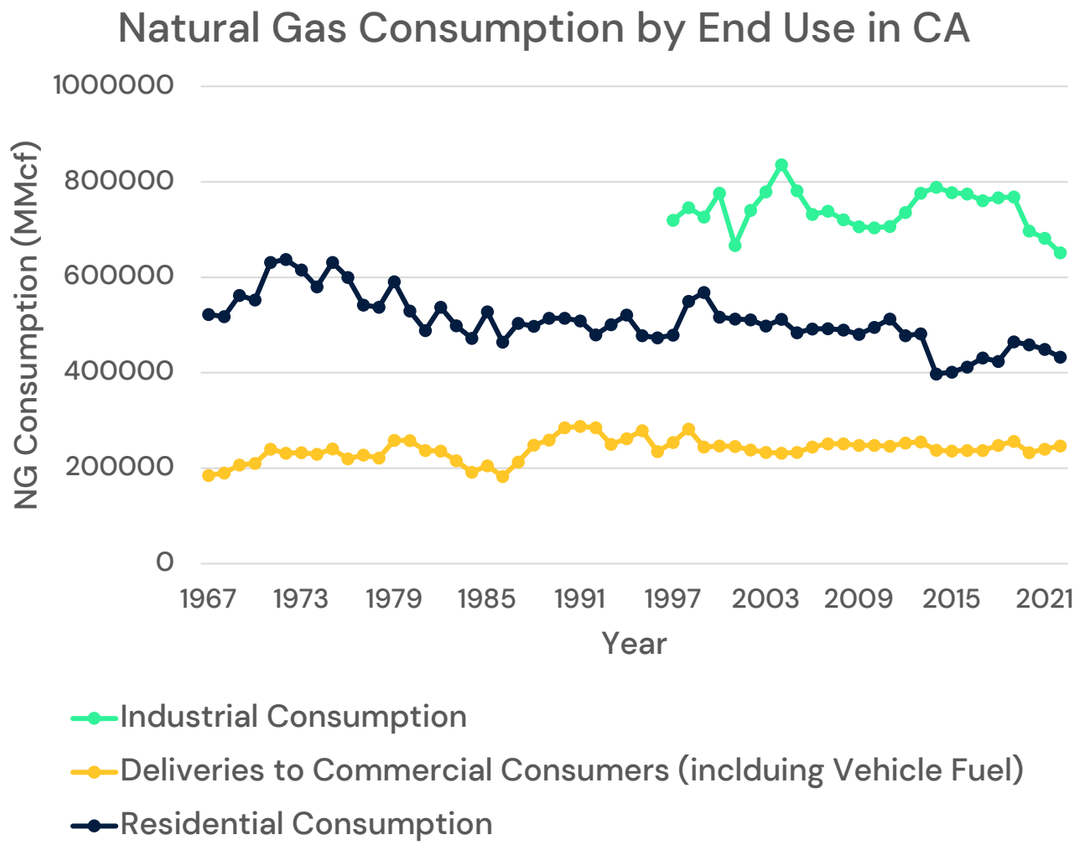
Agenda

- Water Heating in California
- Objectives
- Test Plan
- Unit Validation
- Laboratory Testing
- Technoeconomic Analysis
- 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

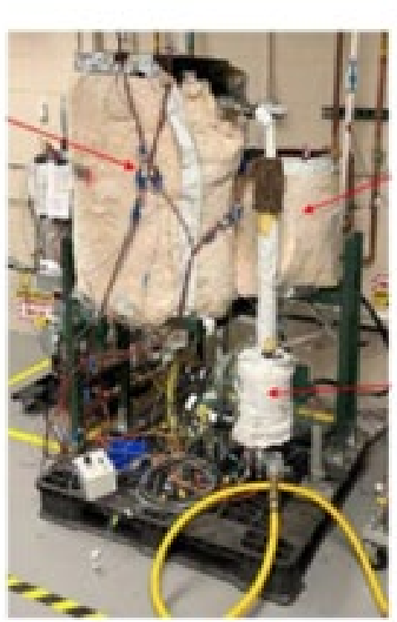


California Legislation
Title 24 Building Energy Efficiency Standards – requires the use of high-performance appliances in both new construction and retrofitted homes
TECH Clean CA – provides incentives and rebates that promote the adoption of high-efficiency water heating technologies

- Focus sector: Residential

Gas-Fired Adsorption Gas Heat Pump (AHPWH)

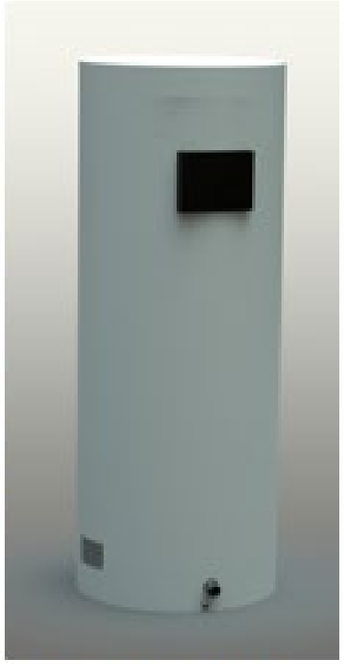
- Focus shifting to development of highly efficient Thermal Heat Pumps (THPs) for residential water heating
  - Manufacturer A: Gas-fired Adsorption Gas Heat Pump (AHPWH)
    - First, Second, Third Alpha and First Beta prototypes



First Alpha

Second Alpha

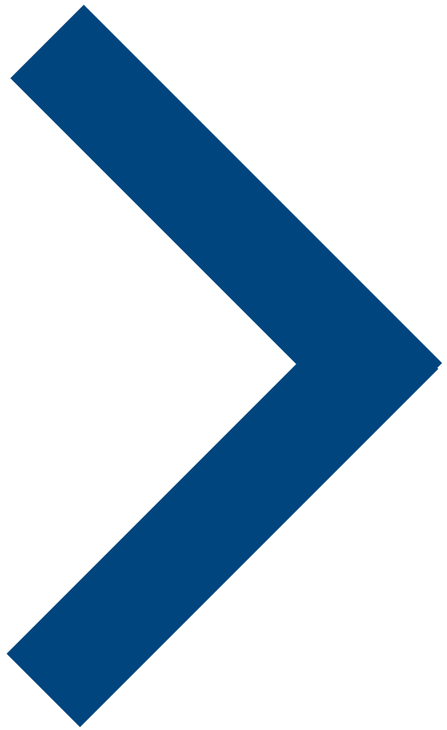
First Beta



Expected final product

Objectives

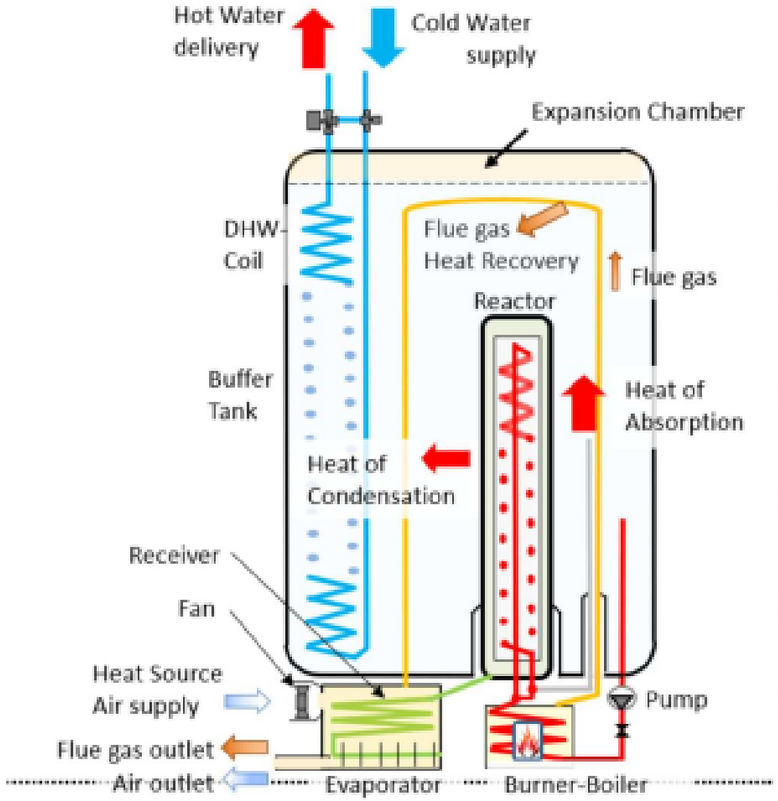
- Improve low uptake at the sector level
  - Primarily as it relates to the residential sector
- Continue technology development toward TRL 9
- Technology performance and validation in a controlled environment
- Technoeconomic analysis as it relates to the CA market
- Recommendations for prototype improvement

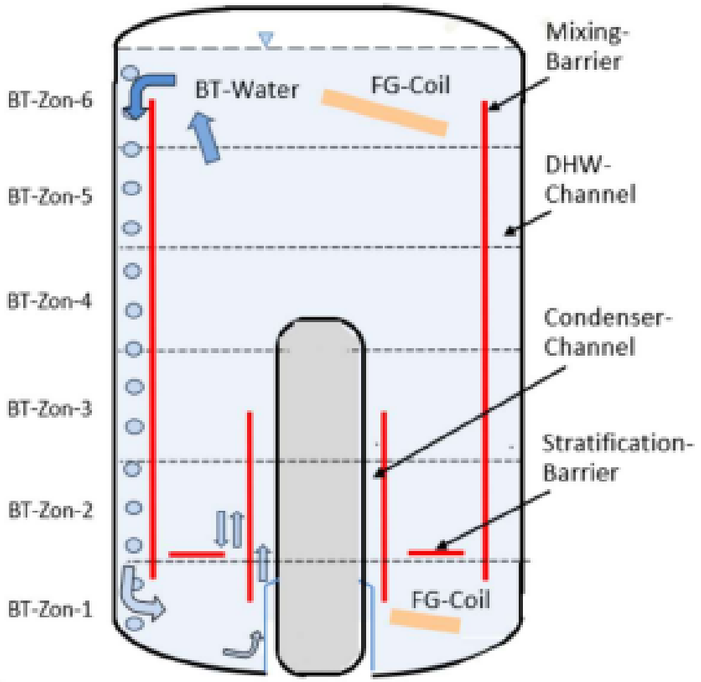


System Description

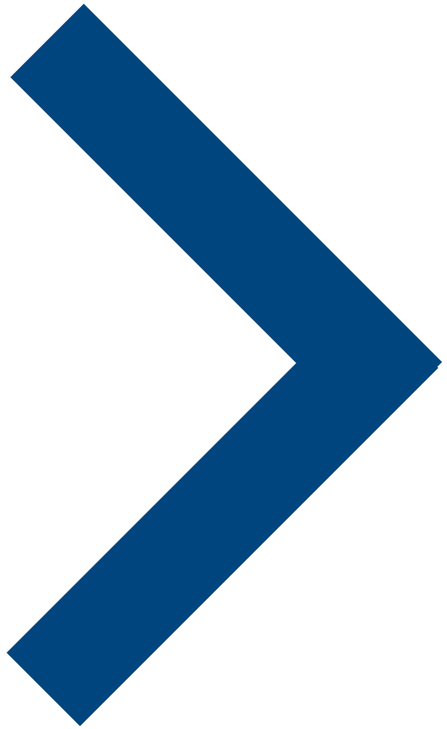
Schematic and Design Parameters

Main Processes/Mechaism
Reactor Heating – Desorption Phase
Pump Loop – Reactor Cooling
Heat Lift – Adsorption Phase





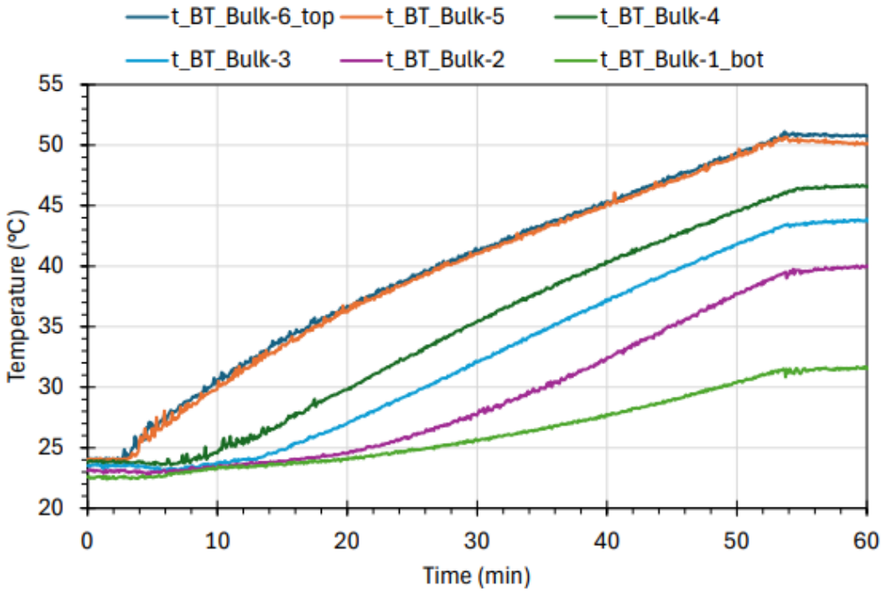
Parameter	Value
Tank Size	~ 40 gallon water (150 liter)
Footprint	28x28 in
Height	59 in
Burner Output Range	5 – 34 kBtu/hr (1.5 – 10 kw)
Ammonia Charge	1.5 kg

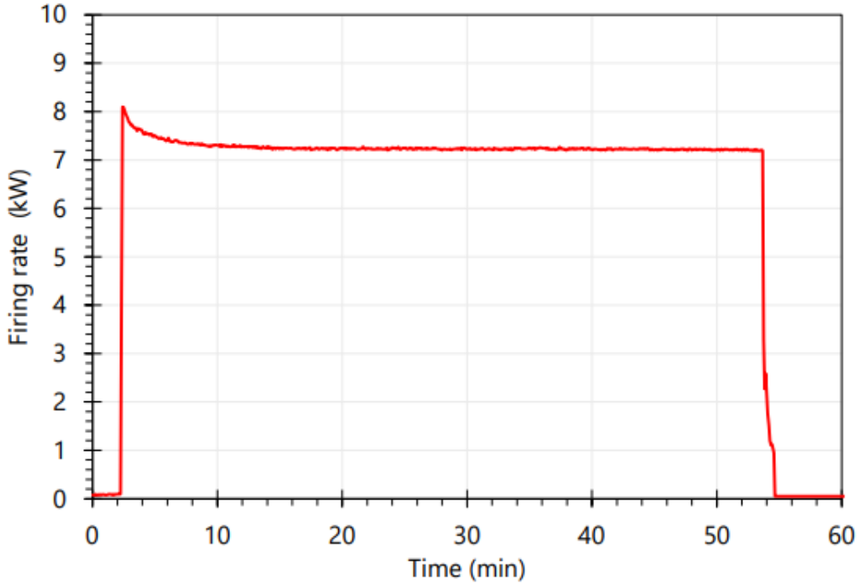


Installation & Commissioning

Direct Firing Test

- Unit equipped with sensors and instrumentation to measure energy efficiency and emissions

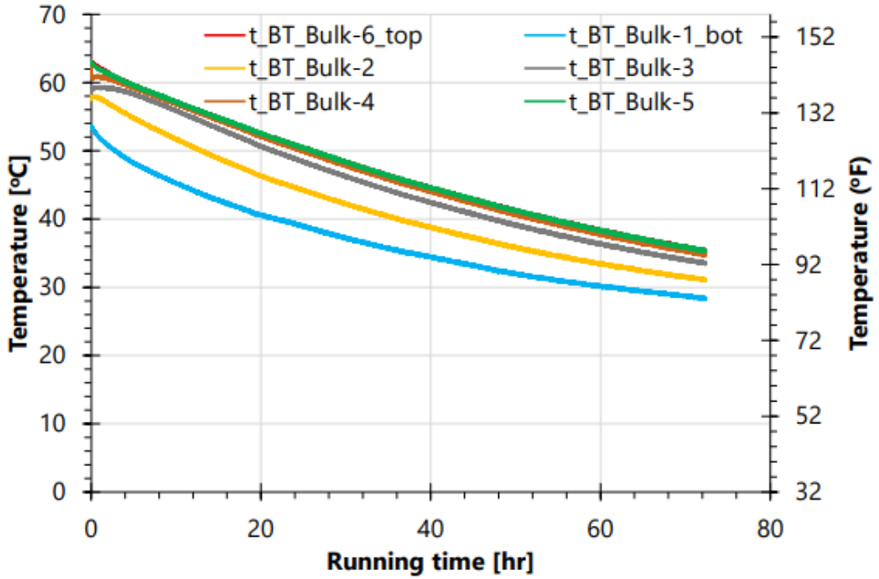


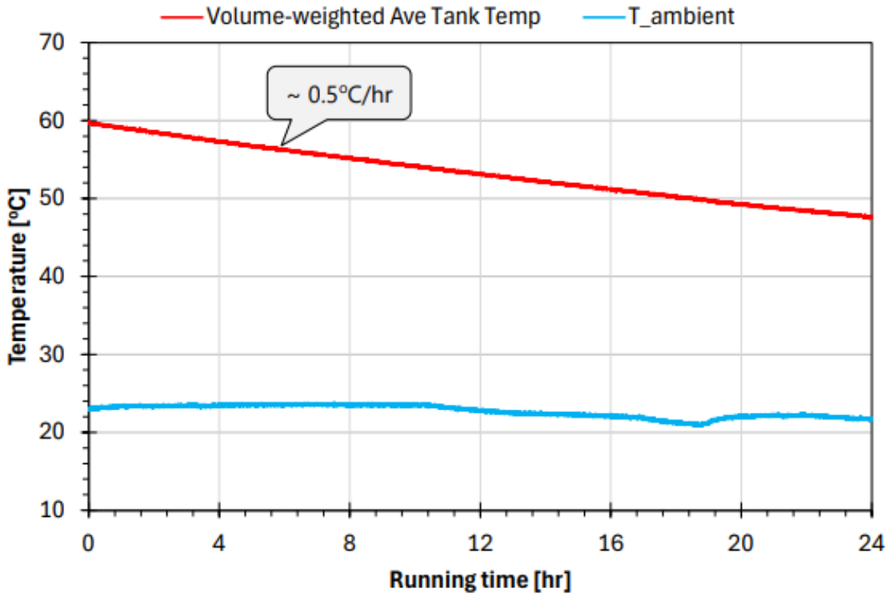


- [Left] Figure: tank temperature stratification successfully established
- [Right] Figure: firing rate of ~25 kBtu/hr (7.3 kW)

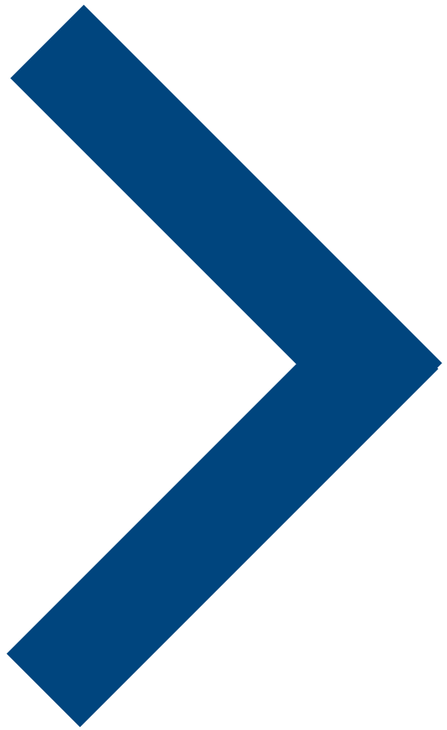
Buffer Tank Standby Test

- Unit equipped with sensors and instrumentation to measure energy efficiency and emissions





- [Left] Figure: burner deactivation → water temperature decrease of 21.6°F (12°C) over 24-hrs
- [Right] Figure: cooling rate + energy = heat transfer coefficient of 5.79 Btu/hr·°F (11 kJ/hr·°C)

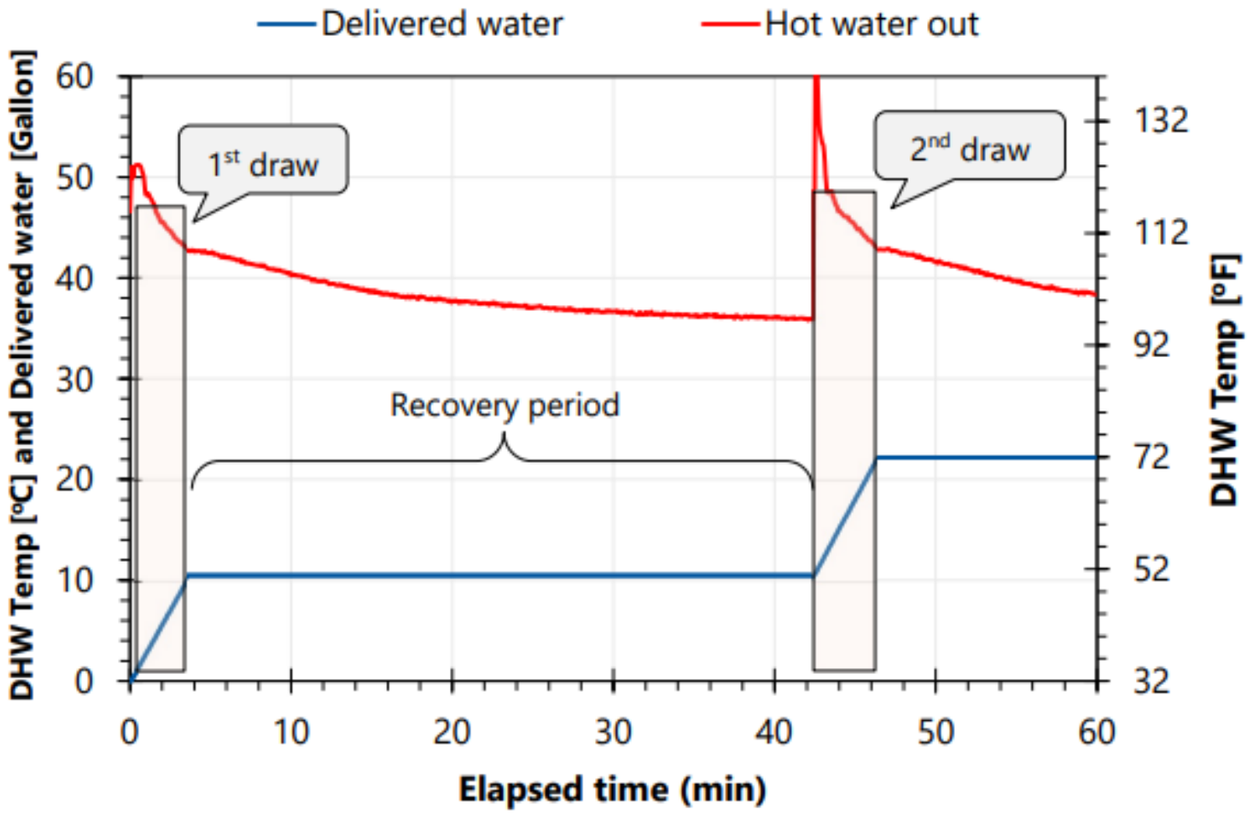


Equipment Evaluation

First Hour Rating (FHR) Testing

- Test used to determined draw pattern (i.e., small, medium, or large)

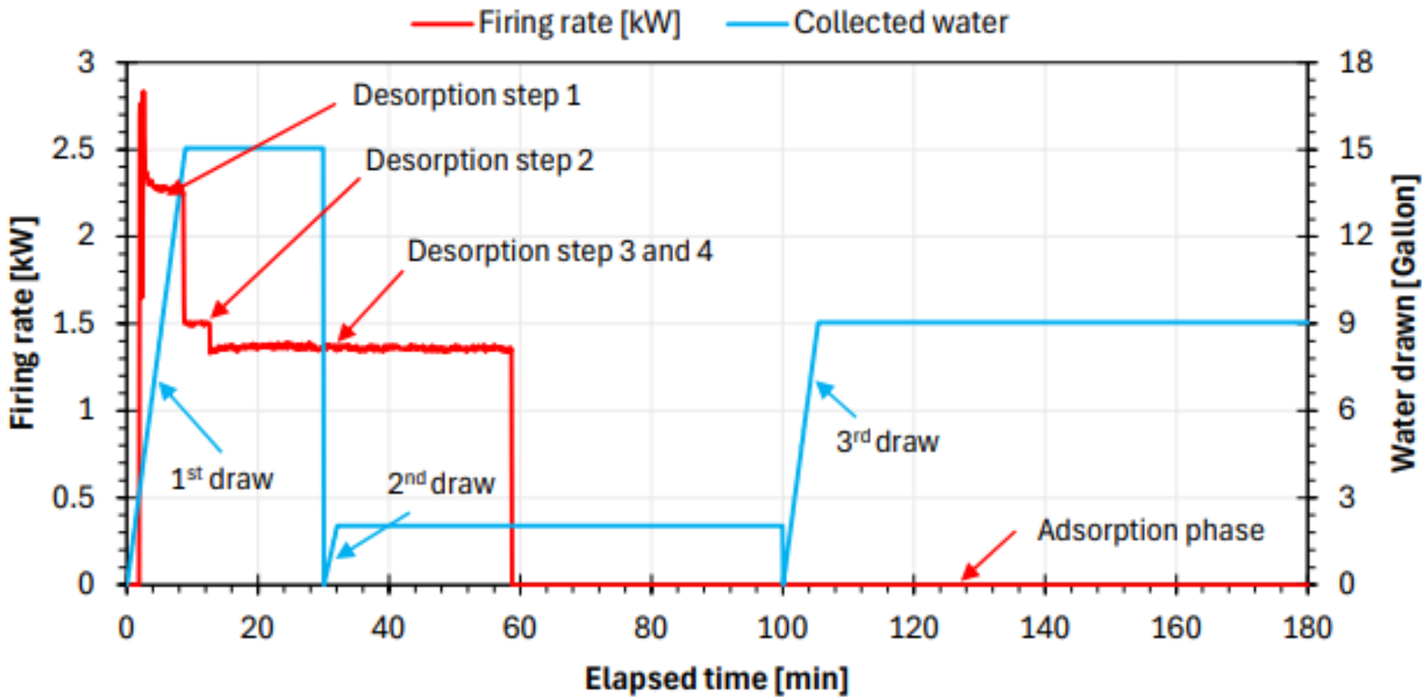
Draw	Total Volume	Firing Rate	Draw Pattern
Experimental Draw (1st + 2nd)	22.2 gal (84 L)	9.5 kBtu/hr (2.8 kW)	Small
Manufacturer Draw	51 gal (193 L)	25 kBtu/hr (7.3 kW)	Medium



←Experimental Draw (1st + 2nd)

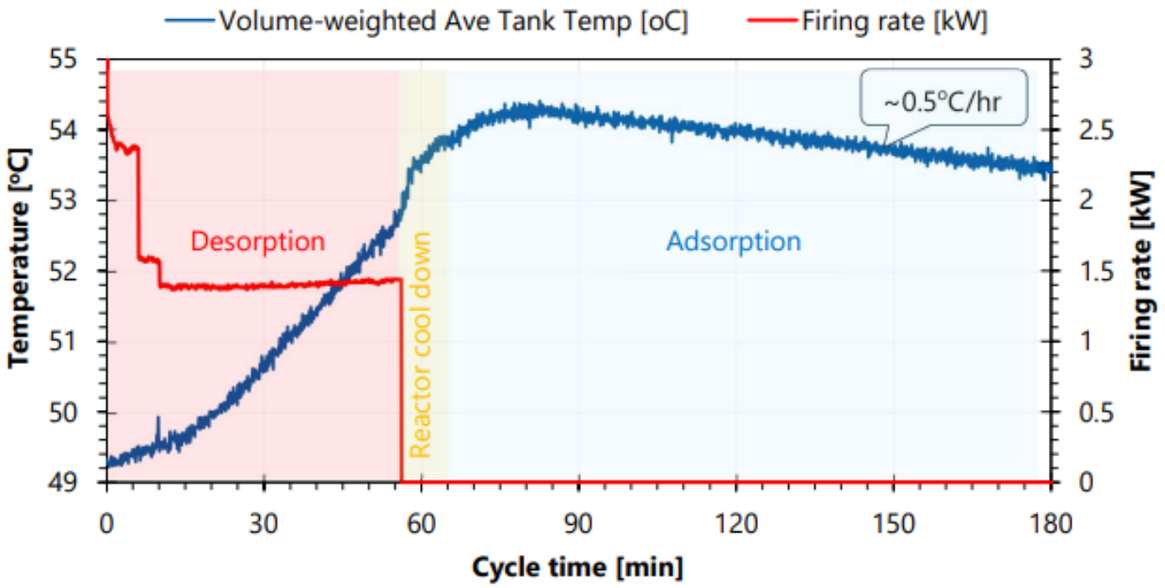
- FHR test conducted under direct firing mode to inform optimization strategies
  - UEF testing is conducted in heat pump mode

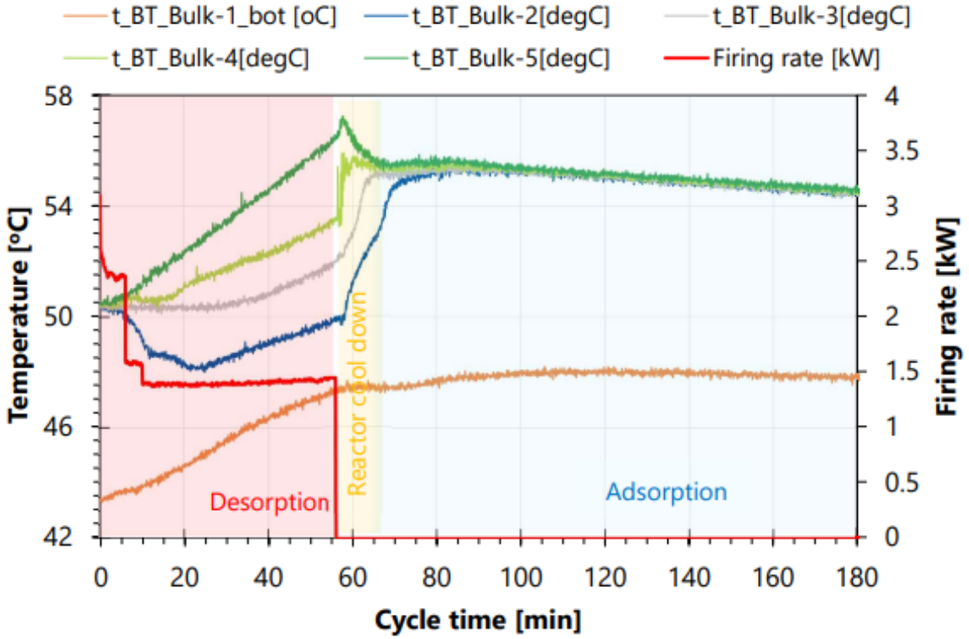
24-Hour Simulated UEF Testing



- Zone 4 thermocouple reduces to 140°F (60°C) → heat pump cycle begins
- First 3 hours of the UEF test (3 hot water draws)
  - Desorption phase (56 min) → reactor cool down (10 min) → adsorption phase (1 hr 54 min)

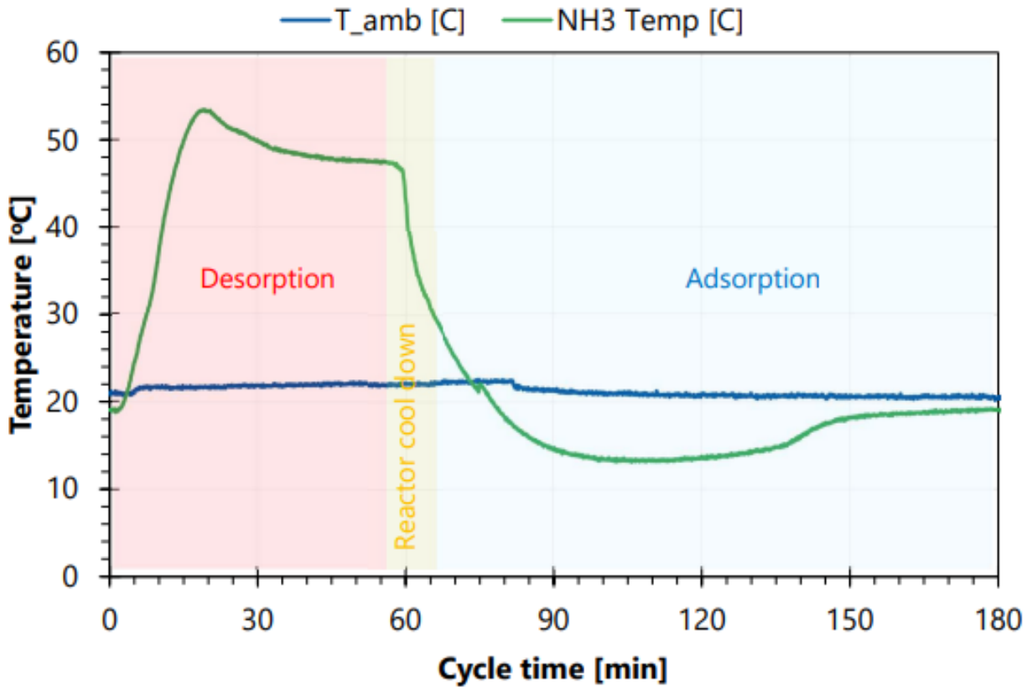
24-Hour Simulated UEF Testing





- [Left] figure – reactor cooling and adsorption begin at approximately same time
  - Once peak temperature reached, temperature steadily decreases at ~0.5°C/hr
- [Right] figure – low temperature lift across 6 thermocouples
  - Low water temperature at bottom zone (t_BT_Bulk-1_bot[degC]) facilitates the adsorption process

24-Hour Simulated UEF Testing



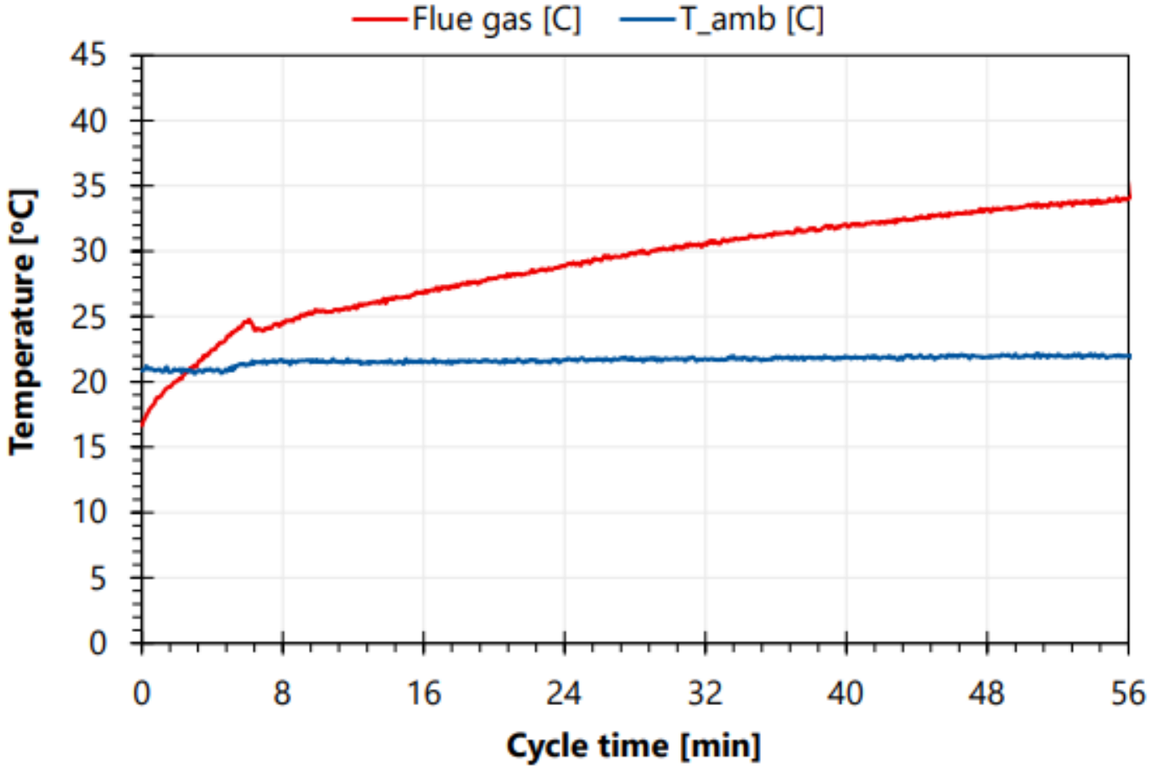
Parameter	Value
Initial Average Tank Temperature	136.8°F (58.2°C)
Final Average Tank Temperature	127.4°F (53.0°C)
Average Ambient Temperature	70.1°F (21.2°C)
Average Discharge Water Temperature	121.3°F (49.6°C)
Average Inlet Temperature	59°F (15°C)

Parameter	Value
Total Gallon Delivered	55.36 gallons
UA	7.14 Btu/hr.-°F (13.5 kJ/hr.-°C)
Recovery Efficiency	68.9%
UEF	0.68

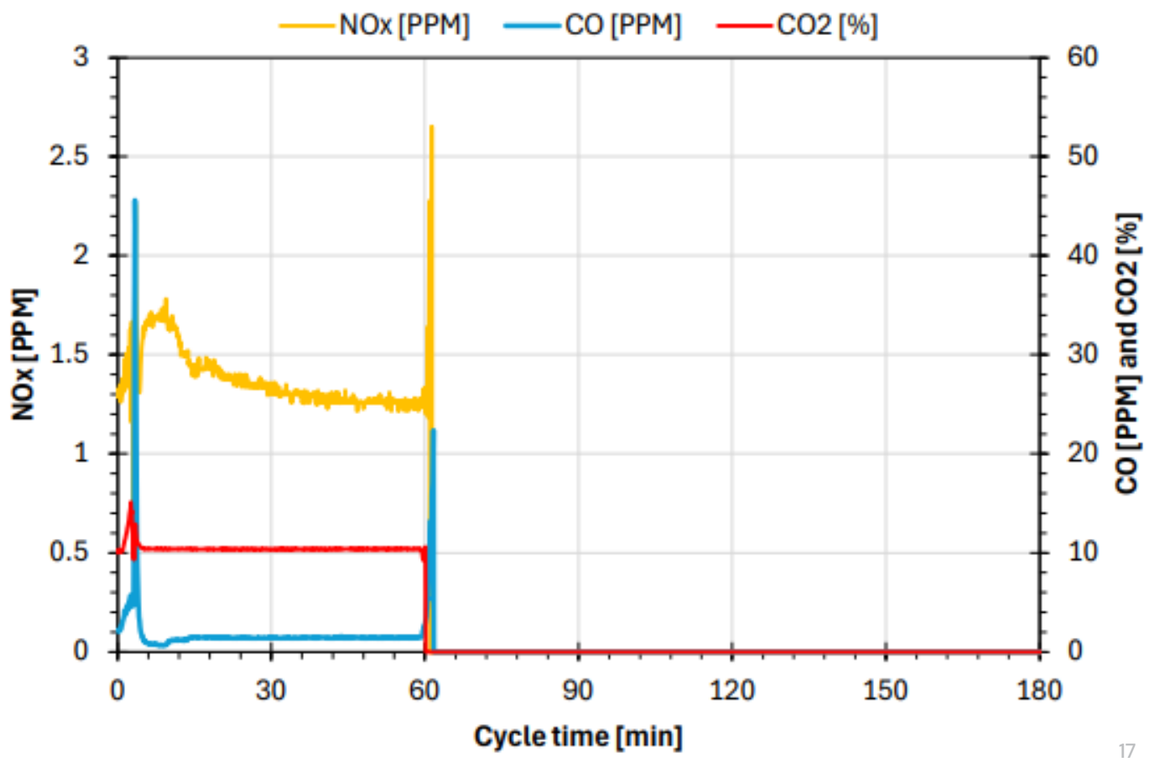
- Ammonia temperature decreased during the adsorption phase
  - Salt adsorbed ammonia vapor from the evaporator but slowed due to the high temperature at the bottom of the tank
  - High tank temperature ultimately inhibited ammonia from being adsorbed to the reactor

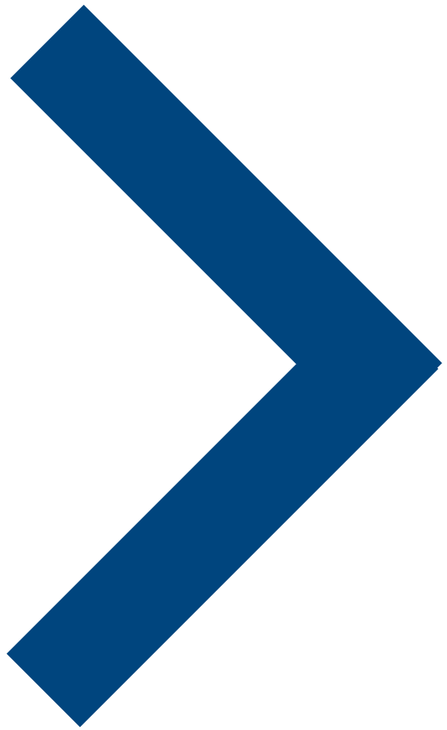
Emission Test

- Behavior during one heat pump cycle
- Flue gases @ 95°F (35°C)
  - Signifies flue gas condensation
    - Below the dew point (typically 130-135°F (54-57°C))



- Behavior during one heat pump cycle
- Emissions remain low
  - CO/NOx spikes: Burner ignition causes high temperatures
- Profile suggest high combustion efficiency





Technoeconomic Analysis

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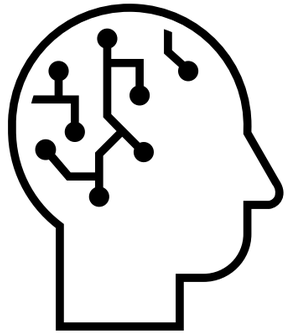
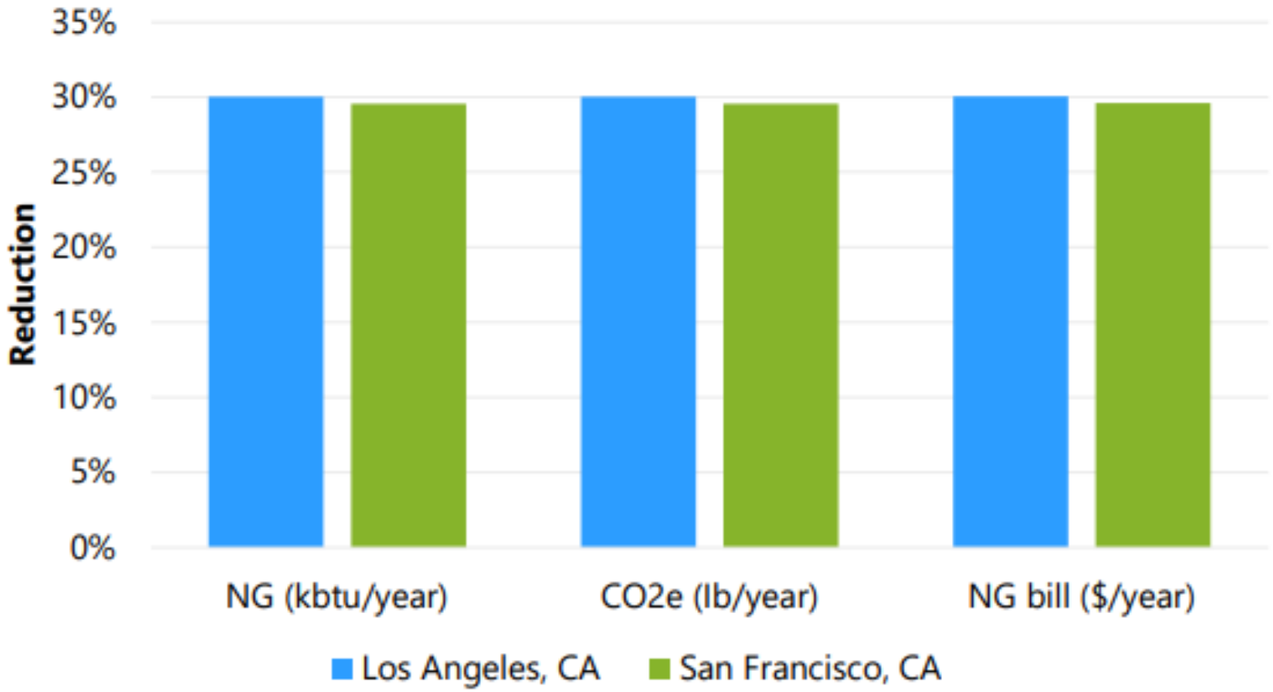


- Objective: forecast…
  1. Energy Consumption
  2. Utility Bills
  3. Greenhouse Gas Emissions
- Analysis utilized BEopt (Building Energy Optimization Tool) software, developed by the National Renewable Energy Laboratory (NREL)
  - Simulates residential building energy performance
  - Assumed → Single-family residential building w/ 4 occupants

Technoeconomic Analysis

- Reduction in energy, emissions, and utility bill
  - Experimental Emerging technology (2nd beta model) UEF = 0.68
    - Not ideal for analysis, therefore, Ideal UEF of 1.1 used in graph below
  - Incumbent technology UEF = 0.66 vs. Ideal Emerging technology (2nd beta model) UEF = 1.1



Key Takeaways & Recommendations for Future Studies

Key Takeaways

1. Overall study aligns with federal initiatives and California decarbonization strategies.
2. The FHR test (under direct fire) resulted in total draw of 22.2 gal (84 L) at 9.5 kBtu/hr (2.8 kW).
3. The unit achieved a UEF of 0.68 with a recovery efficiency of 69% showing promising results in the AHPWH technology space.

Future Studies

1. Improvements related to the burner quality/material/insulation and overall structural design.
2. Studies related to temperature stratification within the buffer tank to optimize adsorption processes and minimize energy losses.
3. Technoeconomic analysis to quantify savings where the AHPWH achieves a UEF > 1.0.

For More Information

Visit CAGasTech.com or contact the GET Program for support and questions.
E: **GET@CAEnergyPrograms.com**

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