

## Water Heating with Gas Engine Driven Heat Pumps

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# Residential Energy Consumption

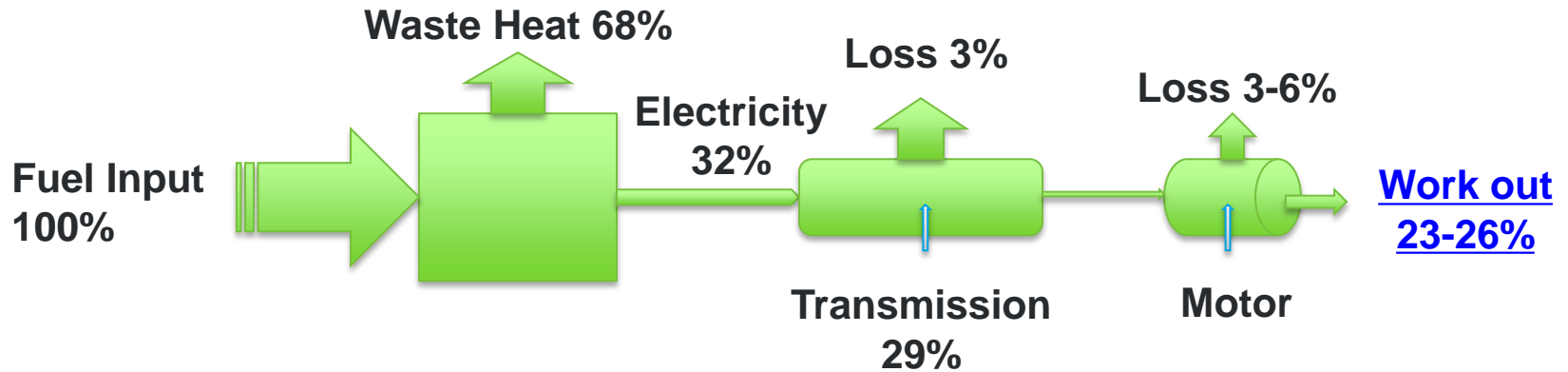
- Residential sector is a major primary energy consumer accounting for 23% of U.S. primary energy consumption
  - Space cooling, heating and water heating account for 57%



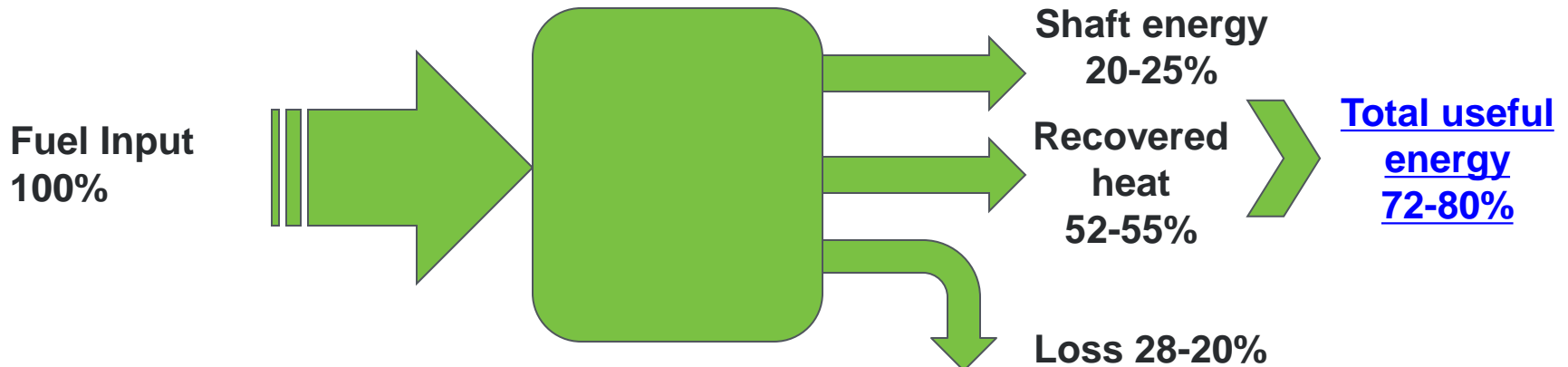
**Residential Buildings Primary Energy Consumption (Quads)**

# Conventional vs. Gas Heat Pumps

- For conventional heat pumps, energy is converted twice:



- For IC engine driven heat pumps:



# Overall Project Goals

## Reduce primary energy consumption

- Cooling COP of 1.3, Heating COP of 1.5
- Reduce water heating energy consumption by 80%
- 25% primary energy usage reduction

## Protect the environment

- Reduce carbon emissions by 25%
- Reduce nitrogen oxide by 30%
- Reduce sulfur dioxide by 95%

## Improve energy security and support U.S. economy

- Improves reliability of electric grid by reducing peak power demand by 85%
- Uses natural gas as a fuel, an abundant U.S. energy resource
- Energy cost savings for the consumer

# System Description

<b>Engine</b>	<b>4 cycle, 1 cylinder, 8 hp rated output</b>
<b>Engine speed range</b>	<b>1200 to 3600 rpm</b>
<b>Fuel type</b>	<b>Natural gas or propane</b>
<b>Compressor type and flow rate</b>	<b>Scroll type, 60.5 cc/rev.</b>
<b>Rated overall Cooling Gas COP</b>	<b>1.25 at 95 °F ambient temp.</b>
<b>Rated overall Heating Gas COP</b>	<b>1.45 at 47 °F ambient temp.</b>
<b>Rated heat recovery efficiency</b>	<b>&gt;45% (LHV)</b>
<b>Water heating Capacity</b>	<b>Supplemental 60 gallon per day domestic hot water</b>

# RGHP Key Components

**Condenser**



**Open drive  
scroll  
compressor**

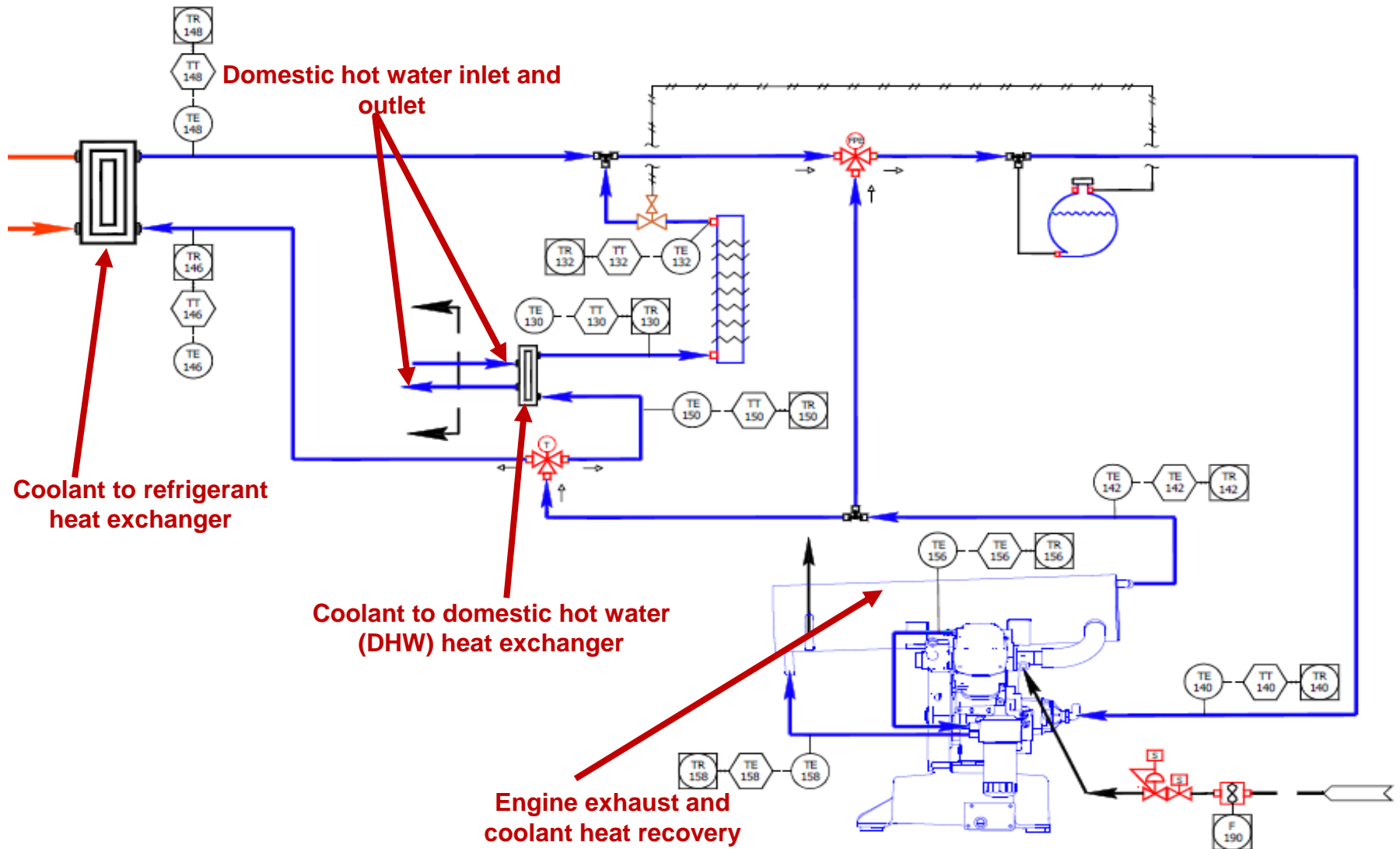
**Shell and tube  
exhaust to coolant  
heat exchanger**



**IC engine**

**System and  
IC engine  
controller**

# Coolant Flow Schematic



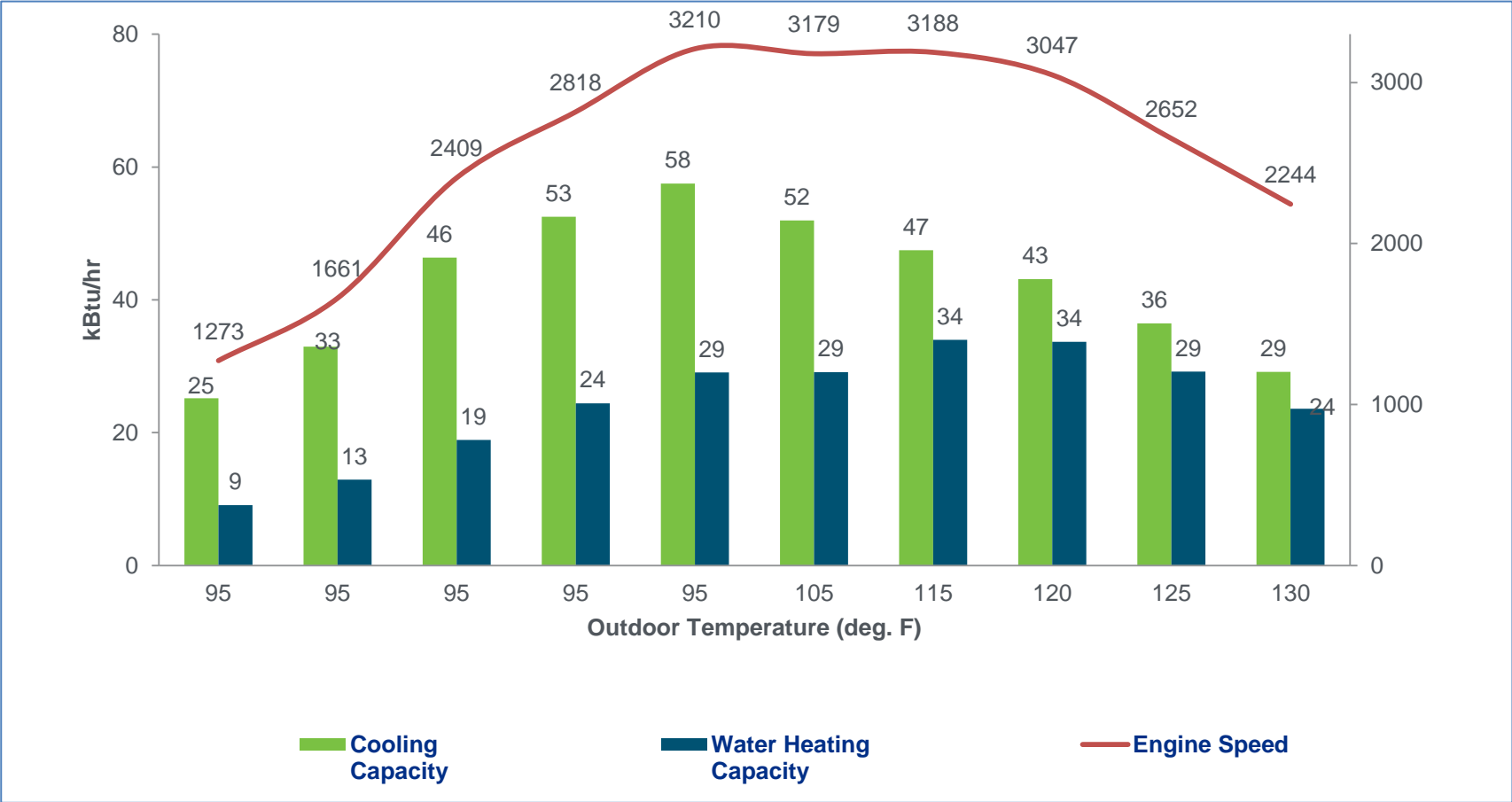
# Experimental Evaluation - Cooling

## Cooling performance with water heating

Engine Speed	Outdoor Air Temperature (°F)	Cooling Capacity (Btu/hr)	Water Heating Capacity (Btu/hr)	Fuel Consumption (Btu/hr)	COP <sub>G</sub>	COP <sub>G</sub> With Water Heating	Waste Heat Recovered (%)
1273	95	25178	9106	16789	1.50	2.05	54.5
1661	95	32935	12919	24084	1.37	1.90	53.6
2409	95	46384	18890	36788	1.26	1.77	51.4
2818	95	52533	24422	46975	1.12	1.64	52.0
3210	95	57527	29068	55158	1.04	1.57	52.7
3179	105	51967	29133	57096	0.91	1.42	51.0
3188	115	47462	33978	62231	0.76	1.31	54.6
3047	120	43118	33702	62249	0.69	1.23	54.1
2652	125	36449	29198	54789	0.67	1.20	53.3
2244	130	29146	23605	45399	0.64	1.16	52.0

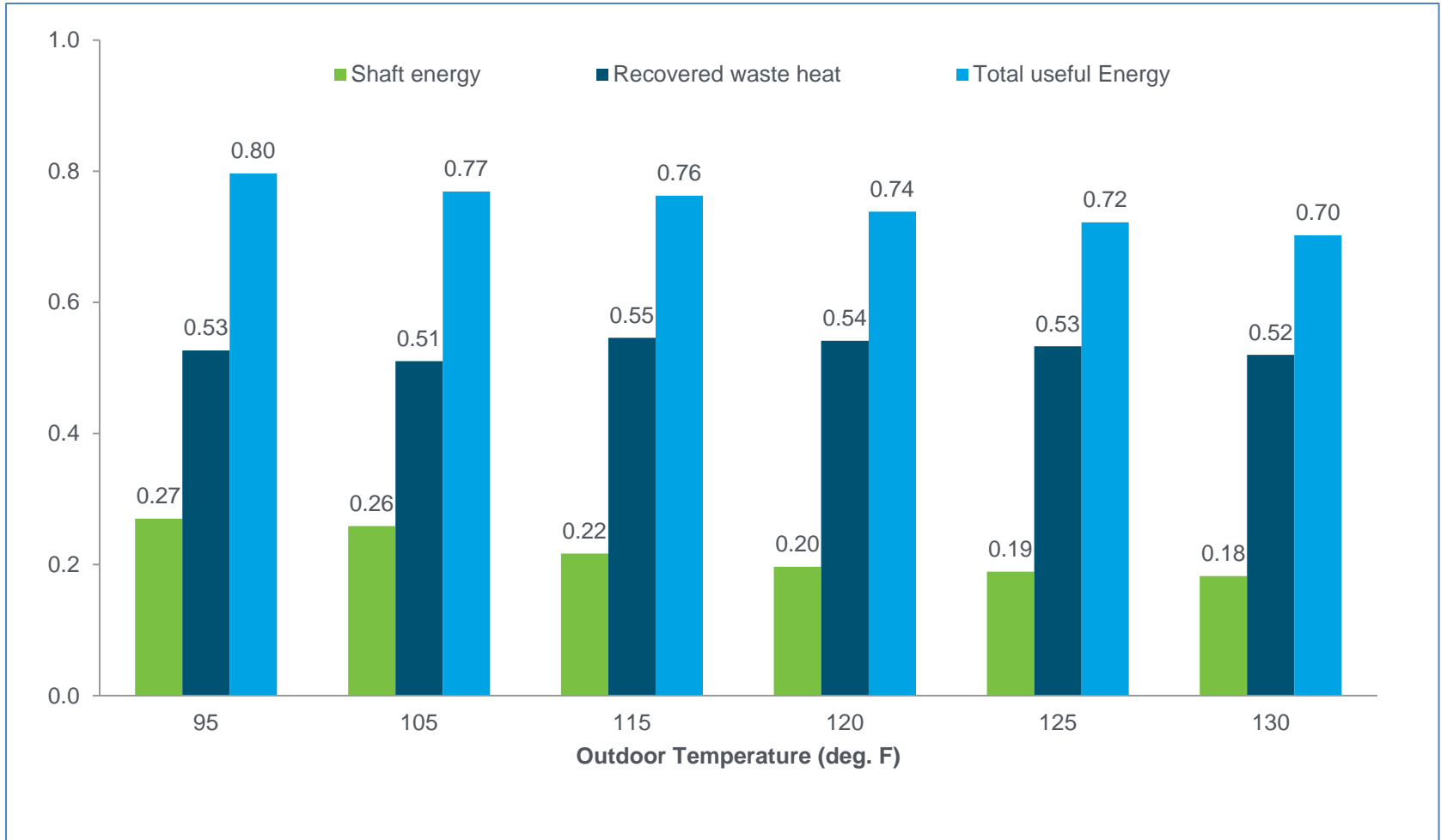


# Experimental Evaluation - Cooling



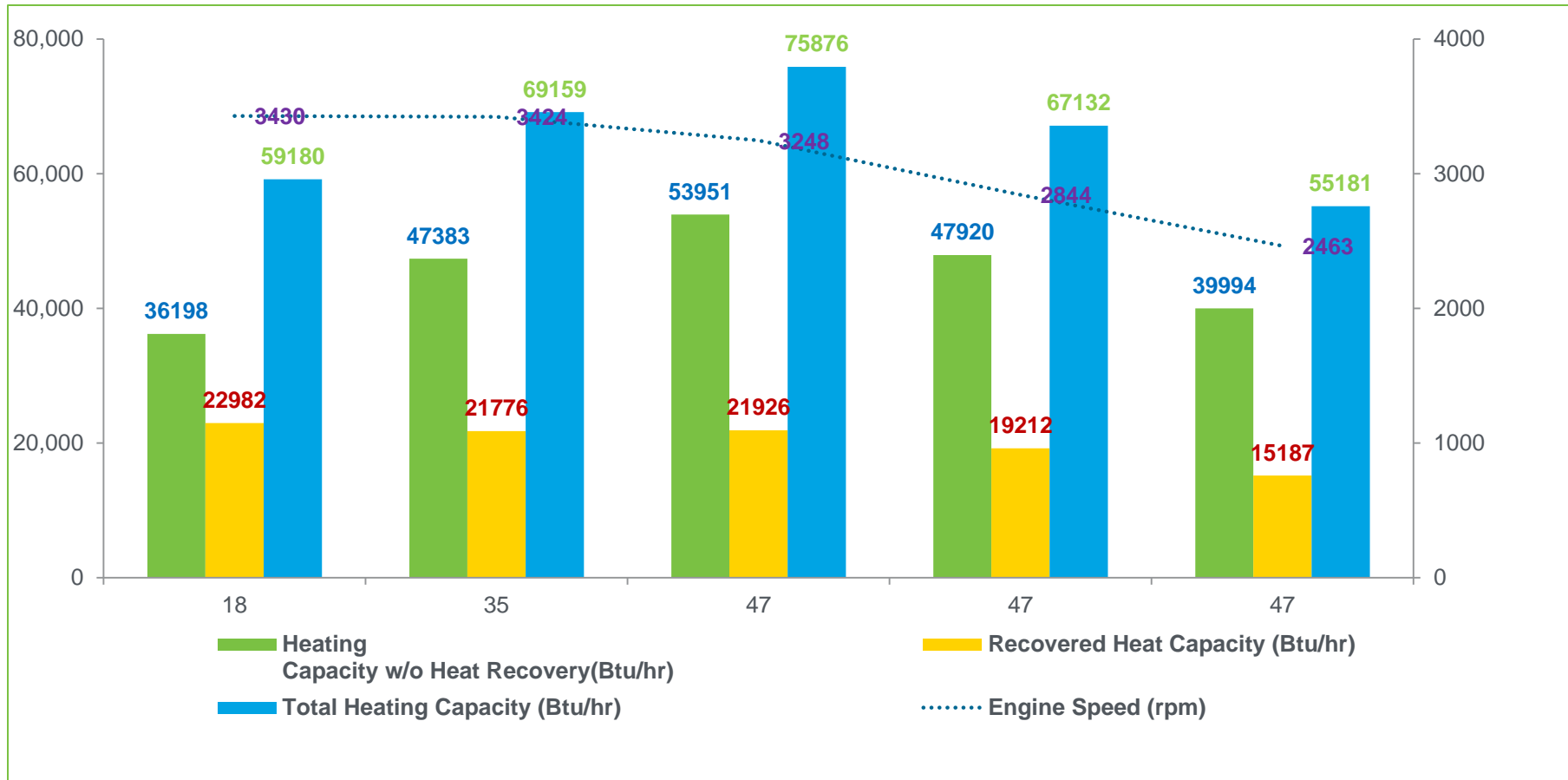
Cooling performance with water heating

# Experimental Evaluation - Cooling



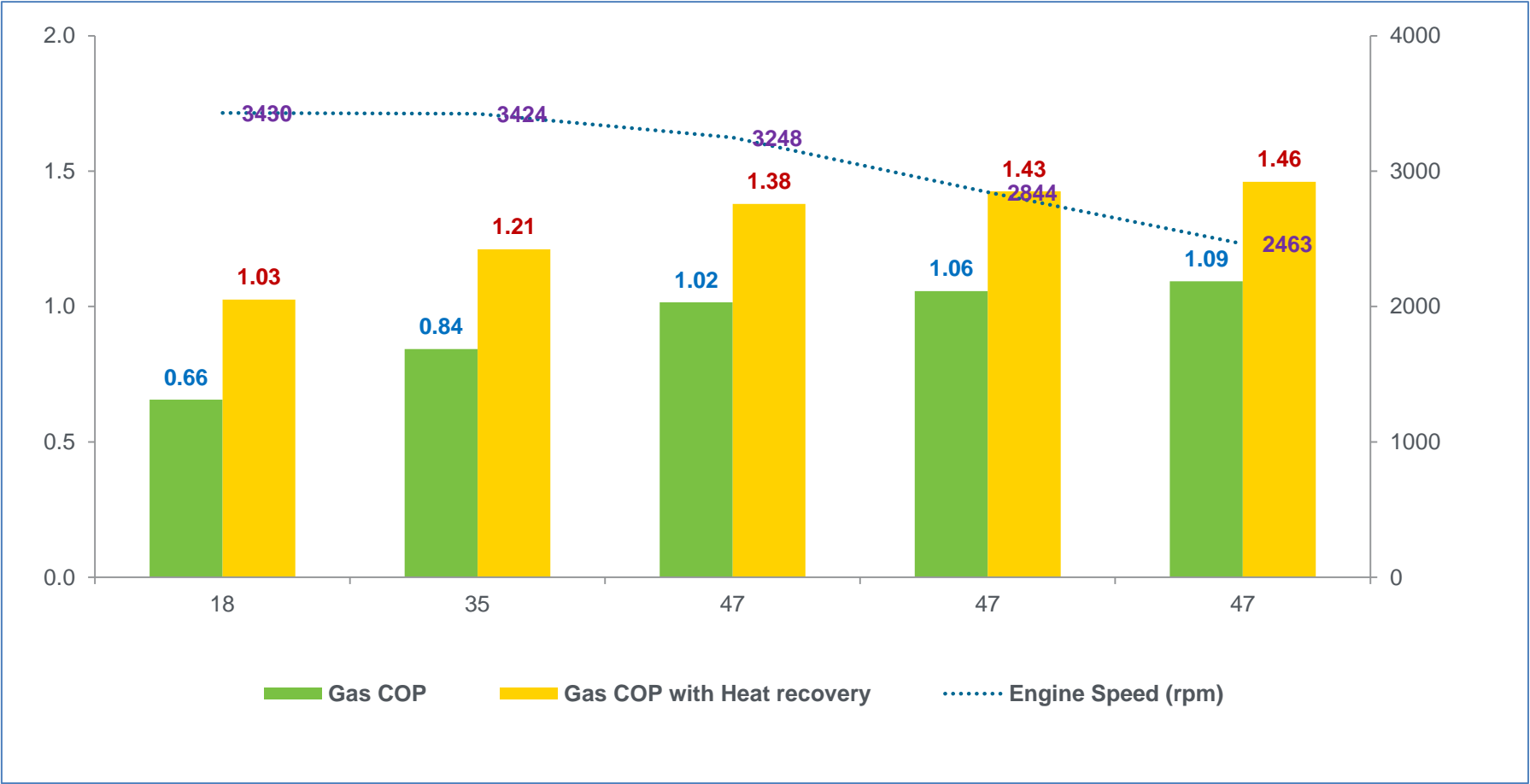
**Fraction of fuel input converted to useful energy at multiple load**

# Experimental Evaluation - Heating



Heating performance as a function of ambient temperature

# Experimental Evaluation - Heating

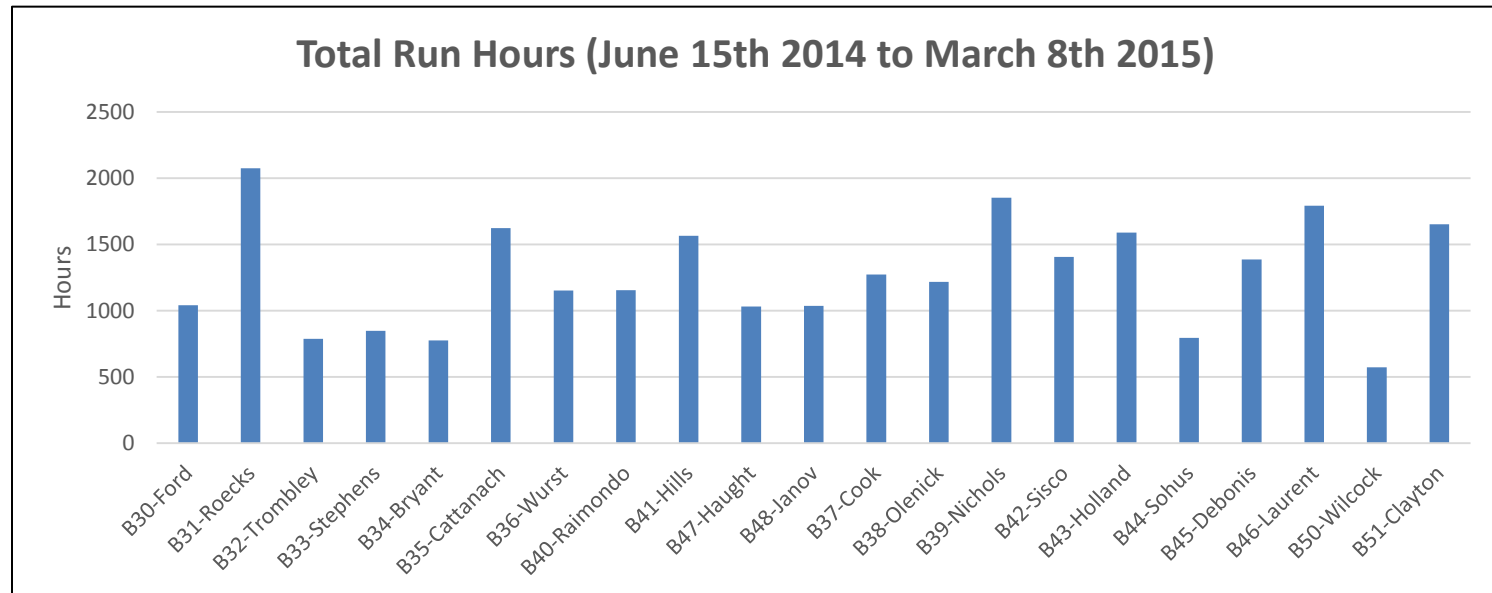


Heating COP as a function of ambient temperature

# Field Demonstration

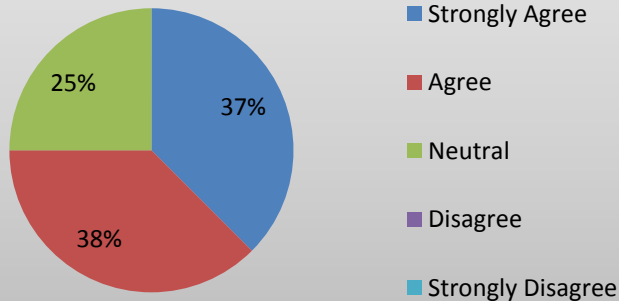
## Field Units

- Installed in May and June 2014
  - 28,425 total accumulated hours
- 122,124 total start command

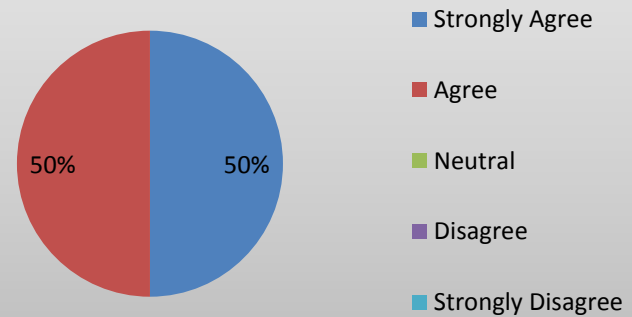


# Customer Survey Results

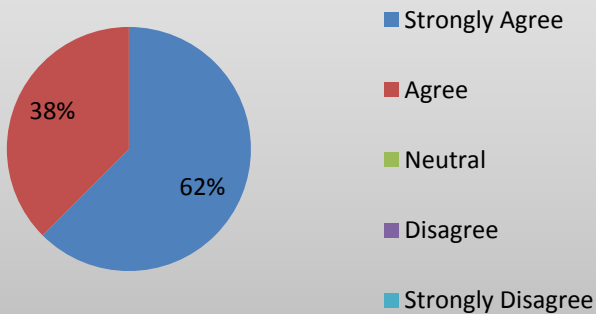
## System/Unit operation is not intrusive



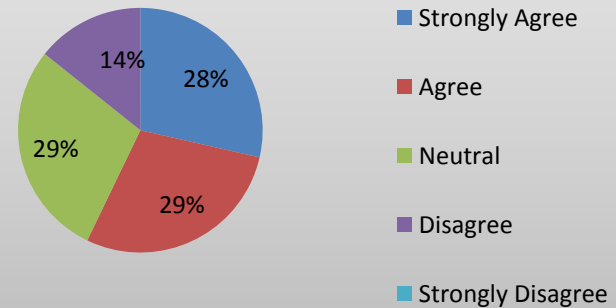
## System/Unit operation meets your expectations



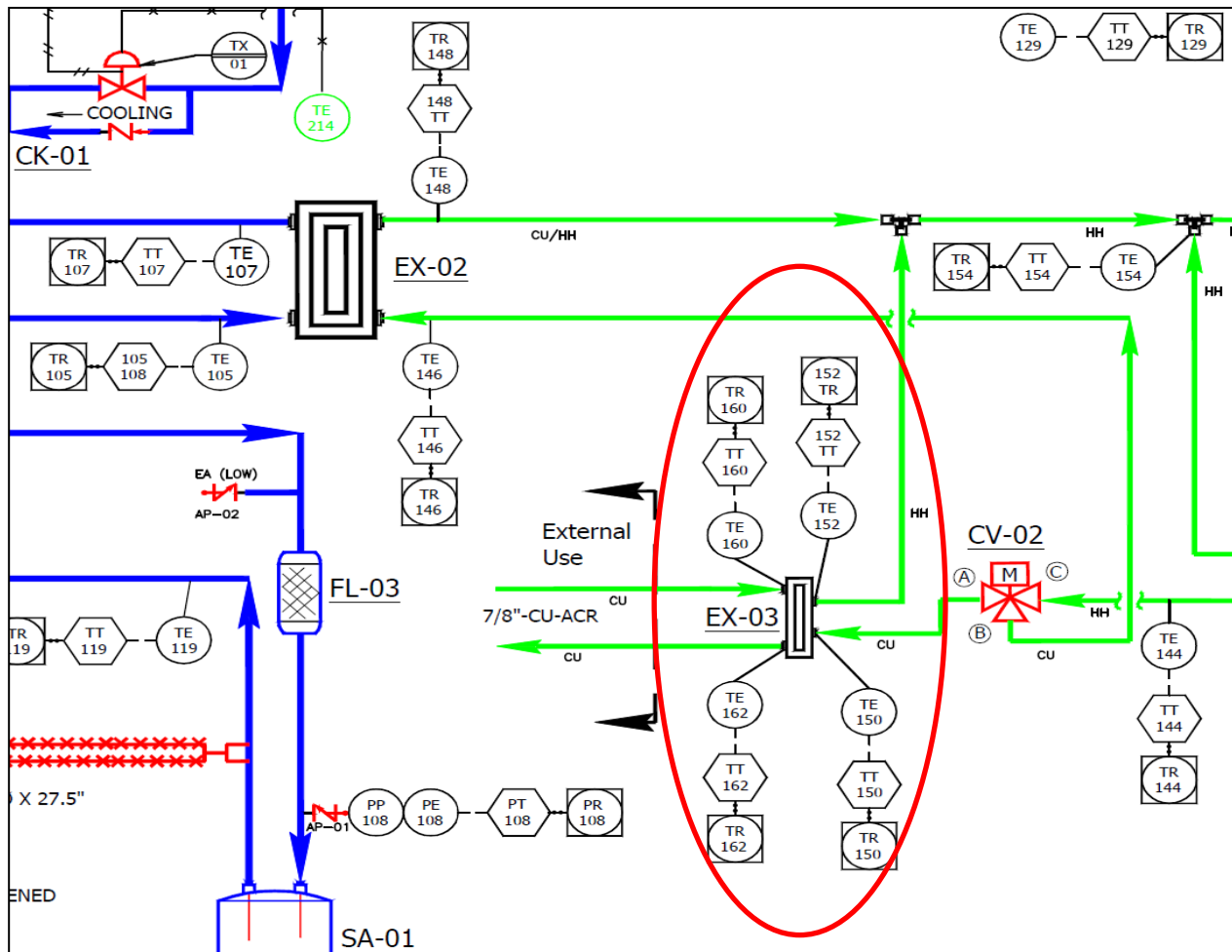
## Comfort level provided is the same or better



## Noticeable difference (*improvement*) in water heating

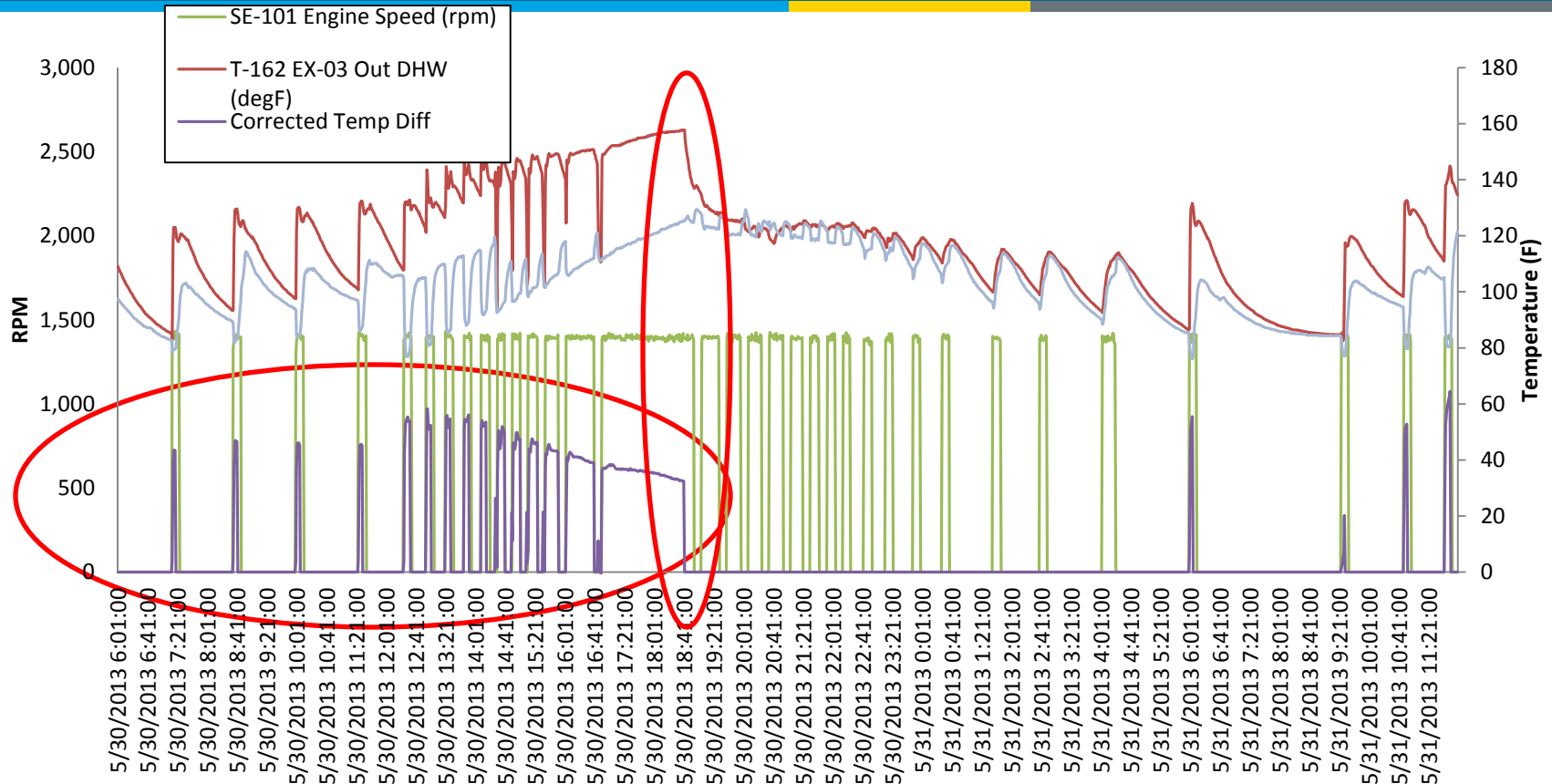


# Field Demonstration



T-160 and T-162 are the inlet and outlet temperatures of the domestic hot water heat exchanger used to measure water heating capacity

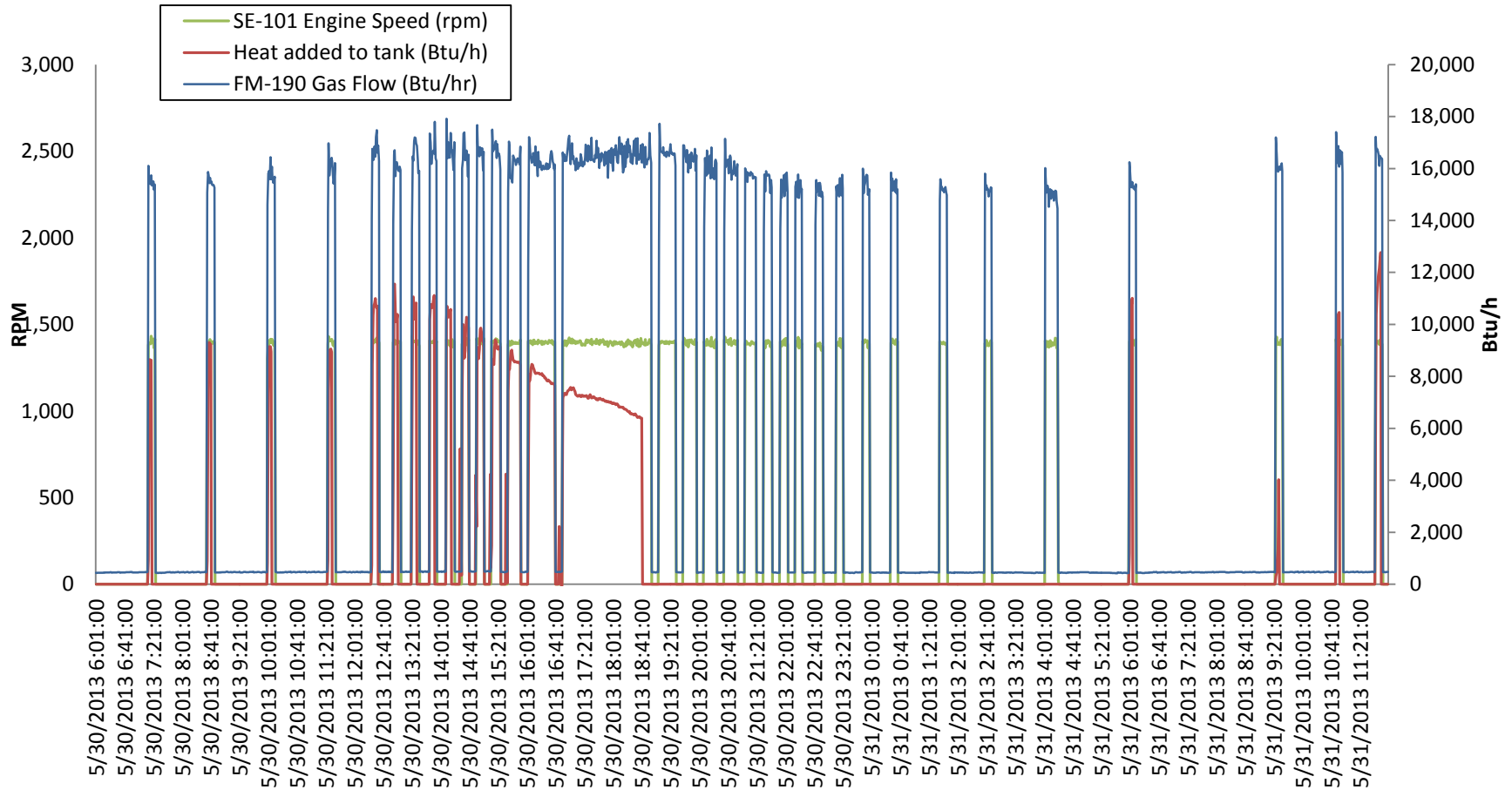
# Field Demonstration



- The graph shows that the pump is running and a temperature differential (heat recovered)
- When the secondary storage water tank reaches around 140° F, the pump would turn off.



# Field Demonstration



# Accomplishments and Progress

## Project Goals

Cooling COP of 1.30

Heating COP of 1.50

80% reduction in water heating energy consumption

Reduce peak electrical power demand by 85%

## Achieved results

Cooling COP 1.26, combined Cooling/Water Heating COP 1.77

Heating COP 1.46

Over 80% achieved

Over 85% achieved

# Next Steps

- **Commercialize RGHP**
  - Working with manufacturing partner to reduce costs through mass production
    - One-off costs will be reduced from \$15000 to \$9000
- **Expand beyond existing territory**
  - Nevada, Arizona, California (Present)
  - Southern states (In discussions with gas utilities)
- **Investigating standalone micro-CHP unit for existing electric HVAC**
  - Provides up to 10kW
  - Ability to provide 80,000 btu/hr output to water heating (100% of demand in most cases)
  - Cost - \$4000