ET23SWG0002: Gas-Fired Heat Pump Water Heating & Combination System Pilot - Phase 2F – Site #1

Gas emerging technologies program (GET)

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Agenda

- Introduction
- Background
- Objectives
- M&V Plan
- Baseline Data Analysis
- Results
- Planned follow on Work
- Conclusions
- Recommendations

Introduction: Gas Absorption Heat Pump Water Heaters (GAHPs)

- Study Objectives:
  - Field testing of GAHP in a DHW-only application at a multifamily building in California.
  - Address knowledge gaps: performance, cost data, and market acceptance.
- Key Findings:
  - Energy Efficiency: Reduced natural gas consumption and operational costs.
  - Practical Benefits: No need for electric panel upgrades; ideal for retrofits.
  - Adoption Barriers: Limited field data, cost clarity, and contractor familiarity.
- Impact:
  - Supports decarbonization goals and utility measure packages.
  - Offers a scalable, sustainable, cost-effective solution for modern DHW needs.

Background and Evolution of Water Heating Technologies

- Previous Field Studies Highlighting GAHP Performance:
  - NEEA (Salem, Oregon)
    - 18% gas savings, COP of 1.06, ideal for mild climates.
  - TAF (Toronto, Canada)
    - 20-50% reduction in natural gas use; 10.1 tonnes CO_2 reduction annually.
  - CEC (California)
    - Up to 50% reduction in NOx and GHG emissions, with cost advantages for energy-intensive industries.

Gaps in GAHP Applications for DHW-Only Systems

- Research Limitations
  - Focus has been on combination systems (space and water heating).
    - Lack of data for moderate climates like California where space heating is minimal.
- Key Gaps Identified:

1. Performance Data: Limited insights into DHW-only efficiency and savings.
2. Sizing and Integration: Knowledge gaps in optimal sizing and system integration.
3. Maintenance Requirements: Unclear reliability and servicing needs.
4. Cost and Payback Periods: High initial cost with uncertain ROI.
5. Awareness and Utility Incentives: Limited promotion, incomplete measure packages.

Objective : Performance, Energy Savings, and Carbon Reduction Potential of a GAHP

- Key Objectives:

1. Energy Savings
2. Carbon Emissions
3. Performance Validation
4. Market Barrier Mitigation

- Approach:

1. Field technology assessment at a customer site with high DHW loads

Technology/Product Evaluation.

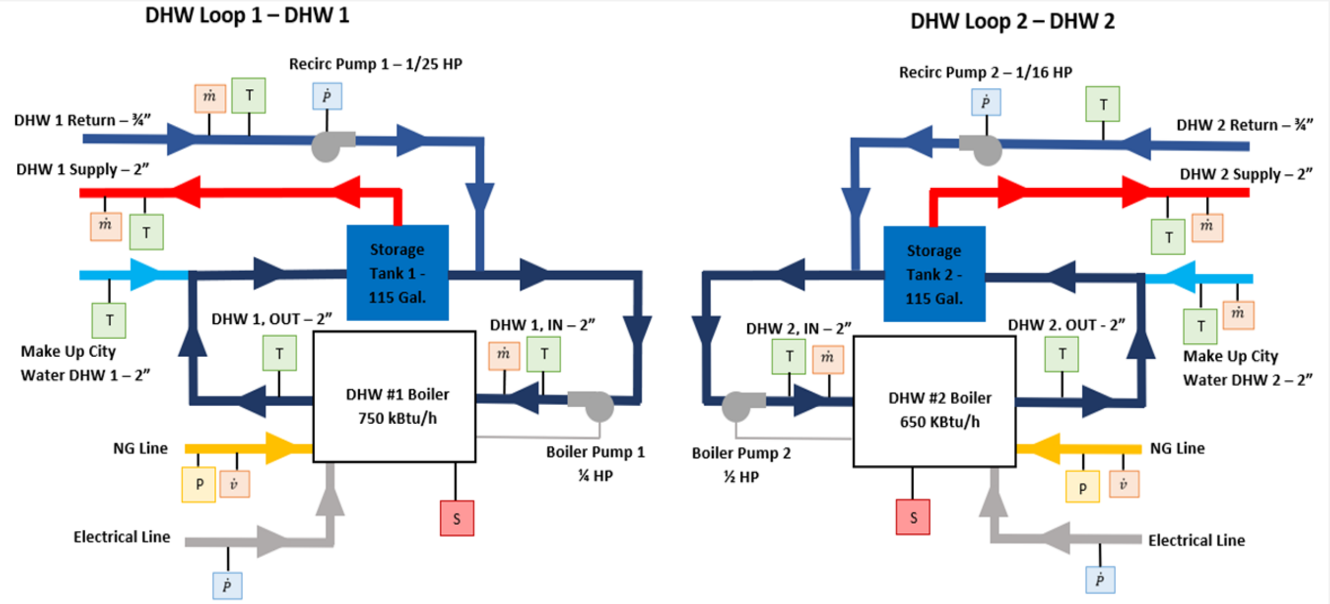
- Assessment Overview:
- Type: Field technology assessment at a customer site for realistic performance evaluation.

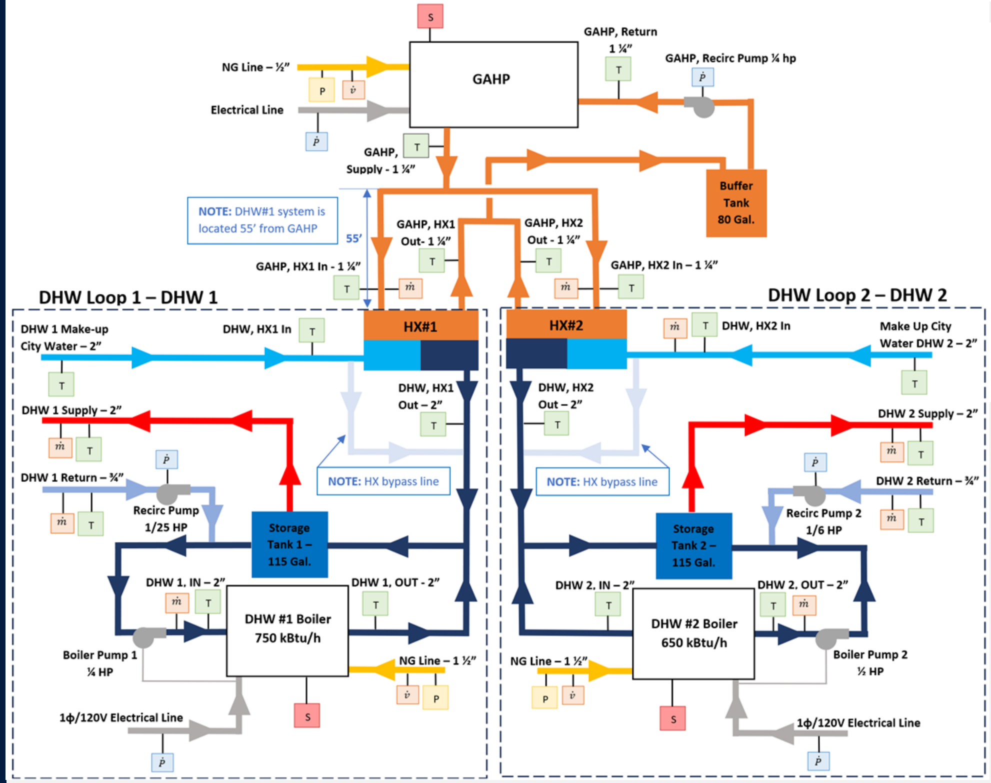
Assessment Activities:

1. Site Qualification.
2. Baseline Data Collection:
   - Installed M&V equipment to monitor existing system performance.
3. System Installation:
   - GAHP, controls, heat exchanger, circulation pump, and auxiliary equipment integrated into the DHW system.
4. Post-Installation Monitoring: Captured GAHP-specific data.
5. Performance Comparison: Evaluated post-installation data against baseline and EHPWH projections.

M&V Plan

- M&V Plan – Option B: Retrofit Isolation: All Parameter Measurement
- Baseline M&V Duration: 10/14/23 – 12/15/23
- ReBaseline:
    - 07/26/24-8/14/24
    - 11/12/24–11/24/24
- Post-M&V Period: 08/16/24 - 11/11/24





Legend

- T Temperature
- P Natural Gas Pressure
- $\dot{P}$ Electric Energy
- $\dot{v}$ Natural Gas
- $\dot{m}$ Water/Glycol
- S Unit Status – No

Picture Above: Pre-Installation DHW System Schematic

Picture on Left: Post-Installation Combination Prototype System Schematic

Baseline Analysis

- System Overview
  - Two DHW boilers:
    i. System #1: 750 kBtuh, 80% efficient
    ii. System #2: 650 kBtuh, 83% efficient
- Key Components
  - Two 115-gallon storage tanks
  - Constant volume pumps for boiler operation and recirculation
  - Uninsulated piping and boiler controls
- Initial Baseline Results
  - System COPs (10/14/23 – 12/15/23):
  - System #1: 0.58 | System #2: 0.68
  - Total COP: 0.62

ReBaseline Analysis

What Changed?

- Boiler #2 was replaced in July 2024, improving overall system efficiency.
- New boiler of the same efficiency and capacity as the old boiler.

- Re-baseline periods:
  - Summer (July–Aug) : 07/26/24 – 8/14/24
  - Fall (Nov) : 11/12/24 – 11/24/24
- Re-Baseline Performance
  - System COPs:
  - System #1: 0.61 | System #2: 0.75 (new boiler)
  - Total COP: 0.67

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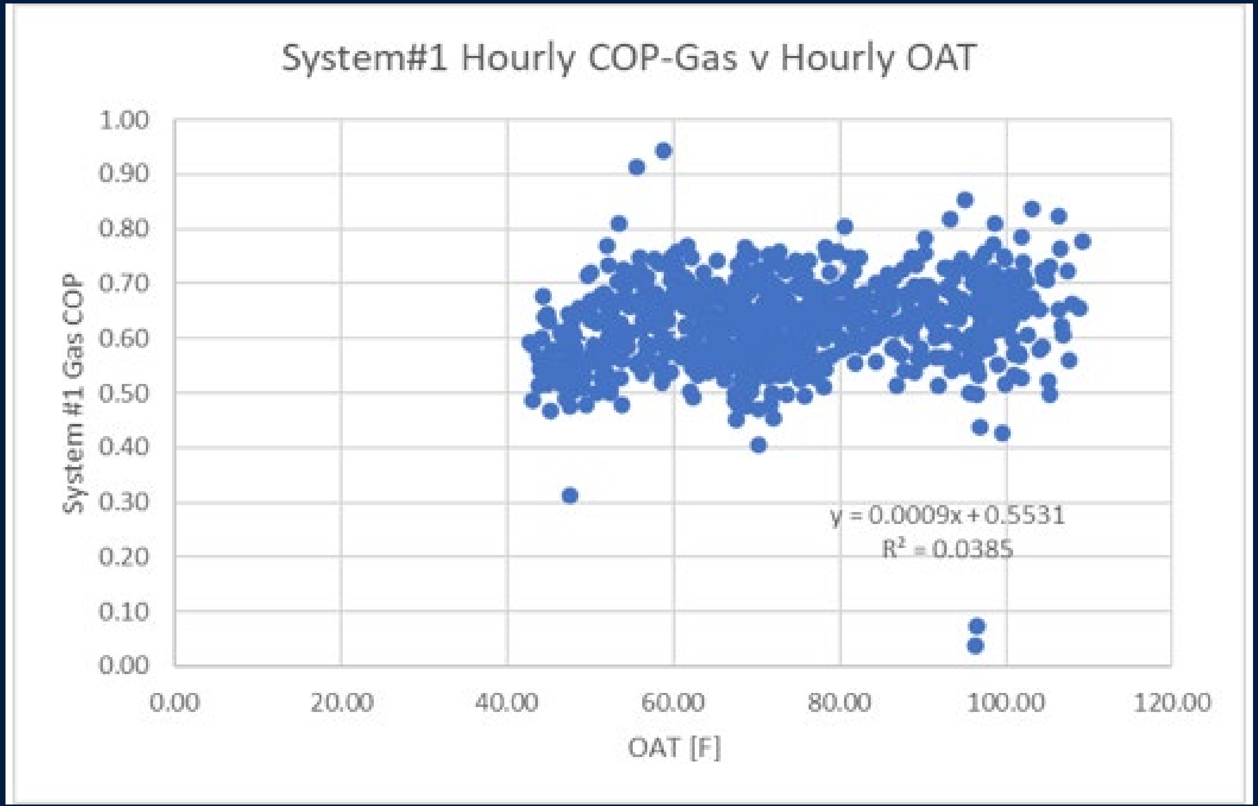
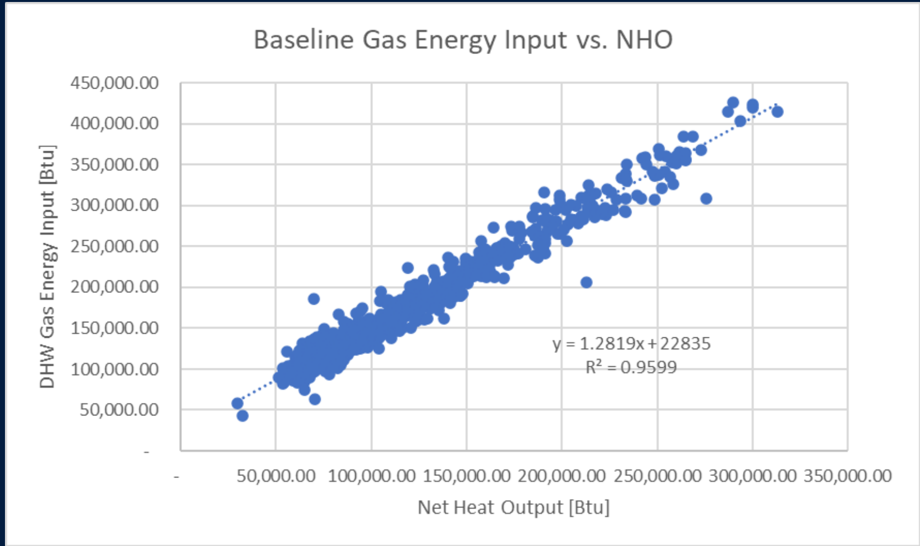
Correlation between COP and OAT

- Initial Baseline Analysis
  - Expectation: Hourly correlation between DHW System COP and OAT.
  - Finding: No correlation between COP and OAT



Correlation Between Gas Input Energy And Net Heat Output (NHO)

- Strong correlation between Gas Input Energy and Net Heat Output (NHO)
  - R^2 , CV(RSME) & NMBE meet goodness-of-fit criteria (Table Below).



Metric Name	Metric Number	Goodness of Fit Requirement
R^2	0.96	>0.70
CV(RMSE)	8.1%	<25%
NMBE	0.00%	-0.05%<NMBE<0.05%

- Gas Energy Input = (1.28*NHO + 22,835)
- This equation forms the basis for calculating annual baseline gas energy consumption, essential for savings comparisons.

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Installation Pictures

- Upper Left: Installed GAHP Unit
- Upper Right: Piping to and from HX (insulated per T24)
- Lower Left: GAHP DDC control
- Lower Right: New Concrete Pad

(L) Low water pressure DHW system #1
(R) Failed supply flow meter DHW system #1

Challenges

- Design:
  - No design support provided by mfg
  - Contractor struggled with HX size and buffer tank size
- Controls
  - Mfg has two controls
  - Contractor struggled to set up
- Site Specific Challenges
  - Water pressure regulator
  - Failed supply flow meter
  - Boiler #2 failure

Post-Installation GAHP COP Analysis

- Objective:
  - Determine the best-fitting model for GAHP COP.
- Key Findings
  - GAHP COP correlation with OAT or OAT^2 alone was insufficient.
  - Needed to use OAT AND NHO to get GAHP COP
  - Best-fit equation: GAHP COP = 0.000109 * NHO + 0.0046797 * OAT - 0.02489
  - Meets R2, CV(RSME) & NMBE Criteria

Metric Name	Metric Number	Goodess of Fit Requirement
R^2	0.78	>0.70
CV(RMSE)	19%	<25%
NMBE	0.00%	–0.05%<NMBE<0.05%

Post-Installation Gas Energy Input

- Objective:
  - Analyze hourly gas energy input post-installation.
- Correlation Equation
  - Post-Installation Gas Energy Input = 1.0513 * NHO – 488.18 * OAT + 78,106.35
  - Meets R2, CV(RSME) & NMBE Criteria

Metric Name	Metric Number	Goodess of Fit Requirement
R^2	0.93	>0.70
CV(RMSE)	7.9%	<25%
NMBE	0.00%	-0.05%<NMBE<0.05%

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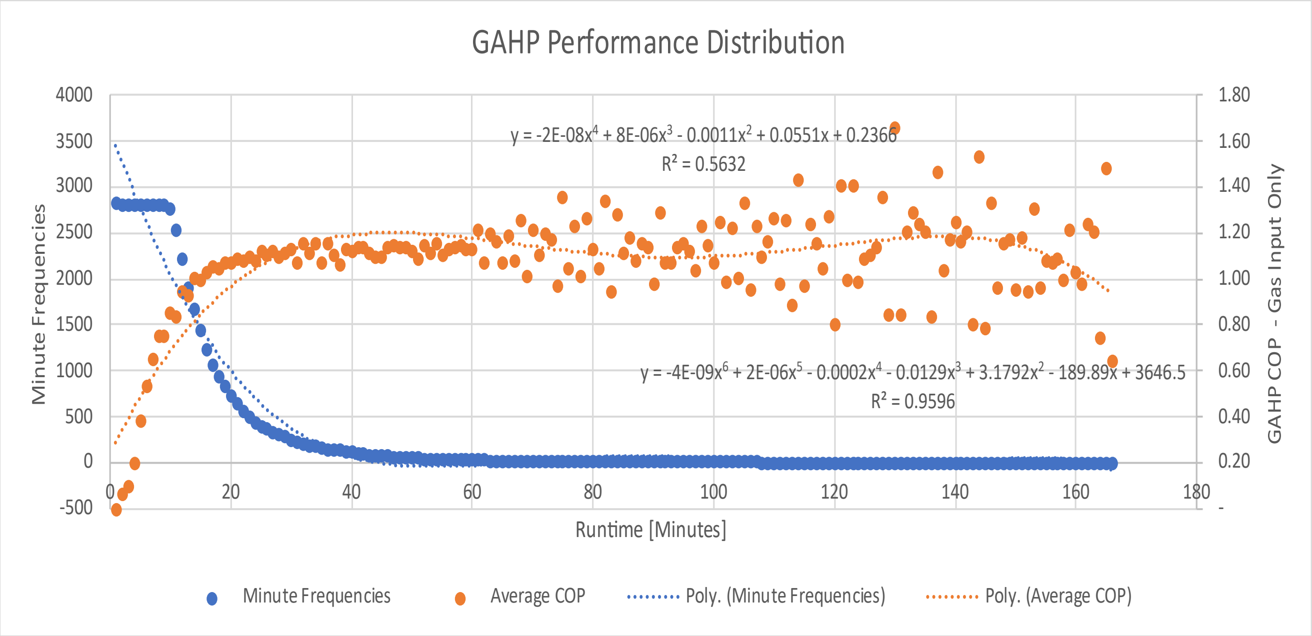
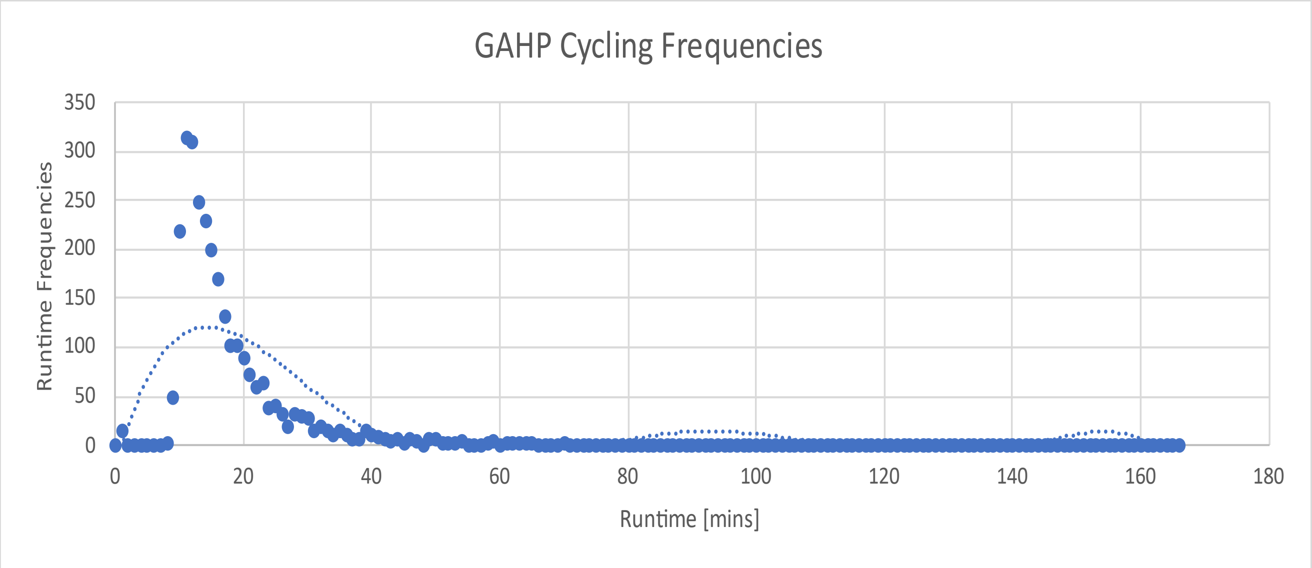
Post-Installation GAHP Performance Time Distribution

- Performance Insights
  - Warm-Up Period: GAHP COP reaches steady-state (~1.14) after 20 minutes of runtime.
  - Weighted Average COP: Only 0.75.
  - Average Runtime: 17.9 minutes during the post-installation period.
- Impact of Run Times
  - Shorter runtimes (<20 minutes) significantly reduce average COP.
  - Meter pulse data causes vacillations in minute-level COP values, particularly after 60 minutes.
  - Energy savings are highly sensitive to runtime duration.
- Conclusion:
  - Optimizing runtimes is critical for maximizing GAHP efficiency and achieving projected energy savings.





Post-Installation Energy Savings

Conclusion

While energy savings are below expectations, identified system adjustments and follow-on studies aim to enhance GAHP performance and energy efficiency.

- Energy Savings Overview
  - Post-Installation Net Heat Output: 233,218,011 Btu
  - Theoretical Baseline Gas Use: 347,102,703 Btu
  - Post-Installation Gas Use: 333,706,359 Btu
  - Savings: 13,396,345 Btu (134 therms, 4%)
- Key Observations
  - Savings Gap: Projected savings (30%) vs. actual (4%) due to system design and runtime limitations
- Challenges Identified:
  - Recirculation water reheating not integrated into GAHP load.
  - Site screening tools inadequately predict minimum DHW loads.
  - Short GAHP runtimes (avg. 17.9 min) hinder efficiency.
- Future Improvements
  - Incorporate recirculation DHW load into GAHP.
  - Add IST or additional hot water storage.
  - Optimize control settings to improve GAHP runtimes and efficiency.

Follow Up Work

- System Improvements:
  - Incorporate recirculation load into GAHP system.
  - Add IST or additional DHW storage.
  - Revise GAHP control settings.
- Goals:
  - Increase GAHP run-times for higher efficiency.
  - Validate lab data against field conditions.
- Future Studies:
  - Ongoing and planned field studies:
    - Hotel in Southern California. Multifamily site and additional hotel.
  - Insights from lab and field studies:
    - Optimize site selection for sufficient DHW loads. Enhance DHW system design for GAHP integration.

Conclusion

- Key Findings:
  - Post-installation COP increased to 0.70 (from 0.67).
  - Gas consumption reduced by 134 therms (4% savings).
- Challenges:
  - Contractor expertise gaps in design and installation.
  - Insufficient manufacturer support for design.
  - Short run-times limiting steady-state efficiency.
- Next Steps:
  - Enhance DHW system design and controls.
  - Train contractors on GAHP installation and site selection.
  - Leverage findings to improve GAHP adoption in utility portfolios

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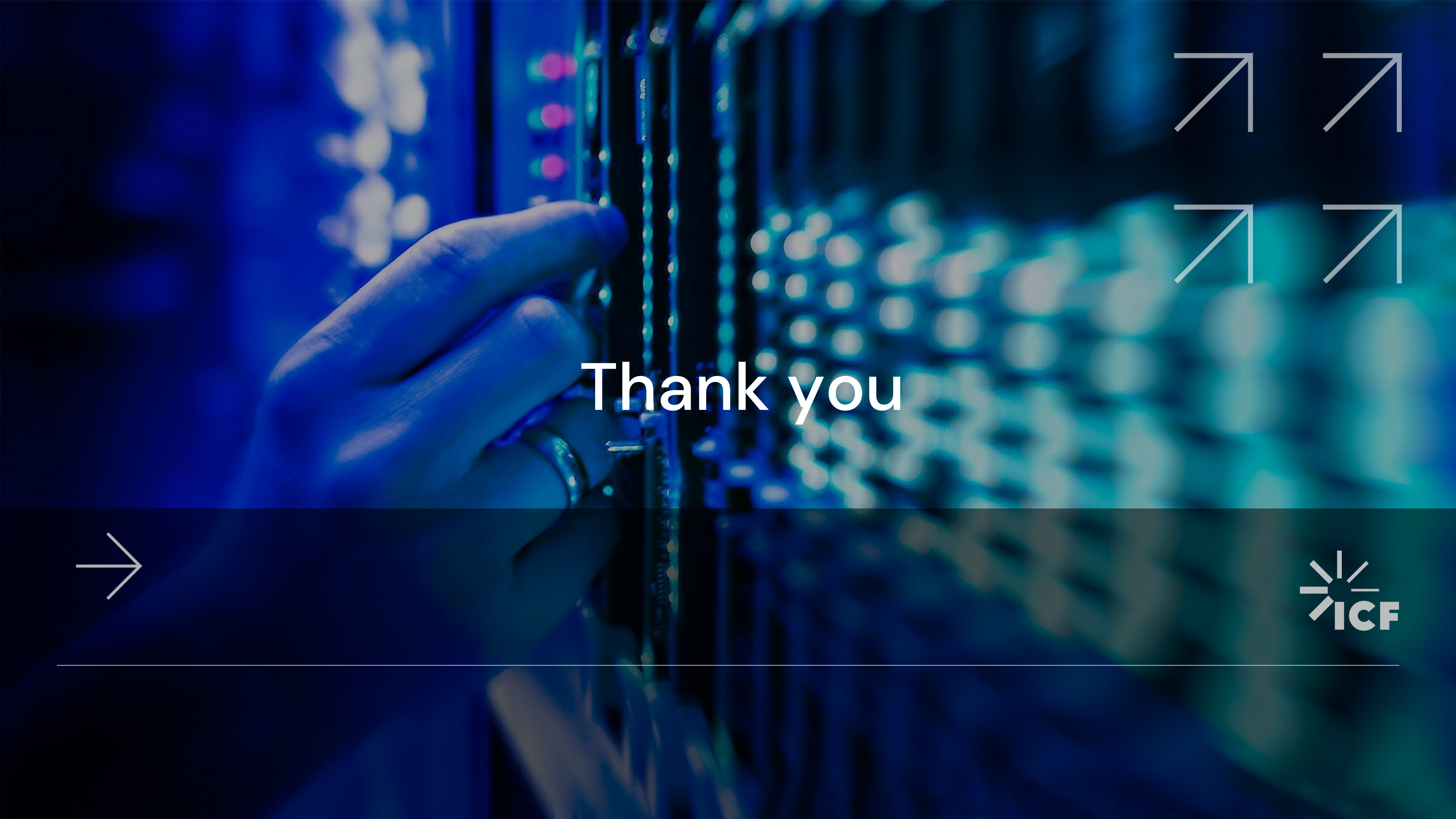

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