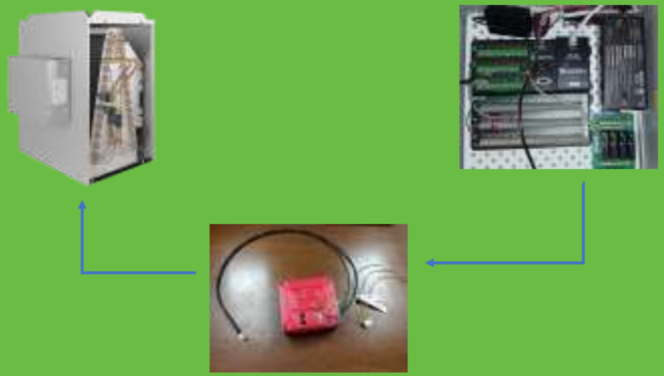
Demonstration of Optimized Controls for a Dual Fuel Heating System Retrofit



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Project Summary

Objective and outcome

The objective of this project is to develop optimized controls for a dual fuel heating system in a retrofit application and demonstrate the potential benefits in terms of efficiency, energy costs, and reduced GHG emissions. The expected outcome is acceleration in electrification of energy-efficient and affordable residential heating systems supporting reduced emissions and grid resiliency.

Team and Partners

Newport Partners is the prime contractor responsible for research design, control logic development, field demonstration, and reporting. **Oak Ridge National Lab** leads energy simulation analyses and supports datalogger programming for the field assessment. The project **Advisory Group** is comprised of manufacturers, utilities, and EE orgs.

Stats

Performance Period: 9/1/2020- 8/31/2024

DOE budget: $423,342 Cost Share: $158,800

Milestone 1: Simulations show 35% energy savings

Milestone 2: Calibrated model shows 35% savings

Problem

- Dual fuel heating system retrofits that integrate a new heat pump with an existing furnace system can serve as a critical bridge technology to a fully electrified future. However, controls for such “hybrid” systems have traditionally been very basic, such as a conservative switchover temperature set at 35F or 40F. This control scheme fails to leverage the enormous potential of this technology to optimize energy consumption, energy cost, emissions, and grid operations.

- The Northeast and Mid-Atlantic regions contain about 7.8 million single-family homes which use fossil-fired, central forced-air heating systems as their primary heat source, representing 40% of all homes in these regions (US EIA). Assuming an annual market penetration rate of 1% in this region, the regional impact over the life cycle of the control-optimized hybrid heating systems is 1.0 Quads. And beyond this region there are millions of additional homes that are good candidates for retrofits to control-optimized dual fuel heating systems.

Alignment and Impact

Meeting the project goals…

- Will facilitate increased integration of dual fuel heating with advanced controls into utility incentive programs and above code programs
- Will demonstrate to stakeholders the significant benefits of control-optimized dual fuel heating systems, especially in existing home retrofits.
  - GHG emission reductions of 33% (based on calibrated model) estimated for transitioning existing (high efficiency) furnace systems to control-optimized dual fuel systems.
  - Energy savings estimated at ≥ 35%
  - Furnace-only to dual fuel retrofits can avoid some costs of going to full electrification (i.e., no need for electric backup heat)
- These outcomes support DOE's goals for **GHG Emission Reductions** and **Energy Justice**, while leveraging DOE's goal for **Power System Decarbonization**
- What does success look like?
  - Increased market availability of heat pumps with advanced controls tailored for retrofits of existing forced-air furnace systems
  - Increased incentives / requirements for these technologies in utility programs, other EE programs, affordable housing programs, codes, and stretch codes

Approach…Industry Efforts

Industry Efforts Related to Optimized-Control Dual Fuel Heating Systems:

- Advanced controls for dual fuel retrofit systems were rare in the market (especially in retrofit applications) when this project commenced in 2020.
- Demonstrations and validation of the potential energy and emissions benefits of such technologies were lacking.
- But over the last year….
  – Some heat pump systems and associated advanced controls, tailored for retrofits, are starting to enter the marketplace (e.g., Mitsubishi IntelliHeat)
  – Some above-code programs like ENERGY STAR NextGen recognize dual fuel heating systems, a signal of the role of this technology as the industry moves towards electrification

Approach

How is the Project Approach Novel in Addressing the Problem:

- Research design of this project is not intended to validate one specific control scheme, but rather to demonstrate what is possible with current heat pump technologies when coupled with more advanced controls.
- The field assessment demonstrates technology implementation and illustrates the ability of advanced controls to maintain comfort while toggling between furnace and heat pump operation. The field site is carefully selected and extensively instrumented with monitors and sensors all linked to a datalogger sensing and control program.
- The field data provides in-situ data for calibration of an EnergyPlus model. A scaled-up modeling analysis (based on the calibrated model) then broadens the study to assess system benefits in different climate zones and with varying parameters (i.e., heat pump capacity, extent of home weatherization).
- There is stakeholder engagement throughout the project to engage utilities, manufacturers, and efficiency organizations to inform the research design and disseminate and leverage the project findings.

Major Project Phases

Complete

Rule Set
- Develop control logic

Initial Modeling
- Estimate performance impacts from control-optimized DF heating system

Fall 21 – Spring 23

Field Evaluation
- Winter 21-22 (furnace) – standard controls
- Winter 22-23 (DF) – optimized control logic

2022-2023

Model Calibration
- Integrate monitoring data into EnergyPlus model

2023

Broader Analysis
- Expand modeling analysis to multiple CZs (4-6) and vary other parameters

Barriers, Risks, & Mitigation Strategies

Potential Barrier or Risk	Mitigation Strategy
Lack of industry interest in dual fuel heating applications.	Demonstrate and validate the potential energy and emissions benefits of dual fuel heating with advanced controls retrofits. Thus far, industry interest appears strong and growing.
Poor energy or emissions results from control-optimized dual fuel heating systems.	Initial modeling validated significant energy and emissions potential benefits. Initial control of dual fuel system assumes TOU electric pricing which creates more dynamic pricing. The scaled-up modeling analysis will explore other pricing scenarios.

Stakeholder Engagement

Project Advisory Group

- Air-Conditioning, Heating, and Refrigeration Institute
- Consortium for Energy Efficiency
- Ecobee
- Eversource
- Google Nest
- Johnson Controls
- Massachusetts Clean Energy Center
- **Mitsubishi HVAC (IntelliHeat System)**
- National Grid
- Northeast Energy Efficiency Partnerships (NEEP)
- Northwest Energy Efficiency Alliance (NEEA)
- National Renewable Energy Lab
- Pacific Northwest National Lab
- Resideo Connected Homes
- Rheem
- Slipstream
- Southern Company

↔

- Inform research design
- Leverage & disseminate findings

Additional Outreach to Date:

- 2022 Building Performance Analysis Conference and SimBuild. Paper & presentation by ORNL.

Validation of Project Benefits:

- Demonstrated by field performance comparison of furnace-only and control-optimized dual fuel system
- Scaled-up modeling analysis across multiple climate zones and varying key parameters

Project Milestones & Accomplishments to Date

- Developed rule set for optimized control of dual fuel heating system
- Demonstrated savings for the control-optimized DF heating system (using model calibrated from Winter 1 data) ≥ 35% versus the furnace reference case
- Procured a suitable field assessment site, instrumented it with a full data acquisition system for energy use monitoring, environmental conditions, and active control of the dual fuel heating system

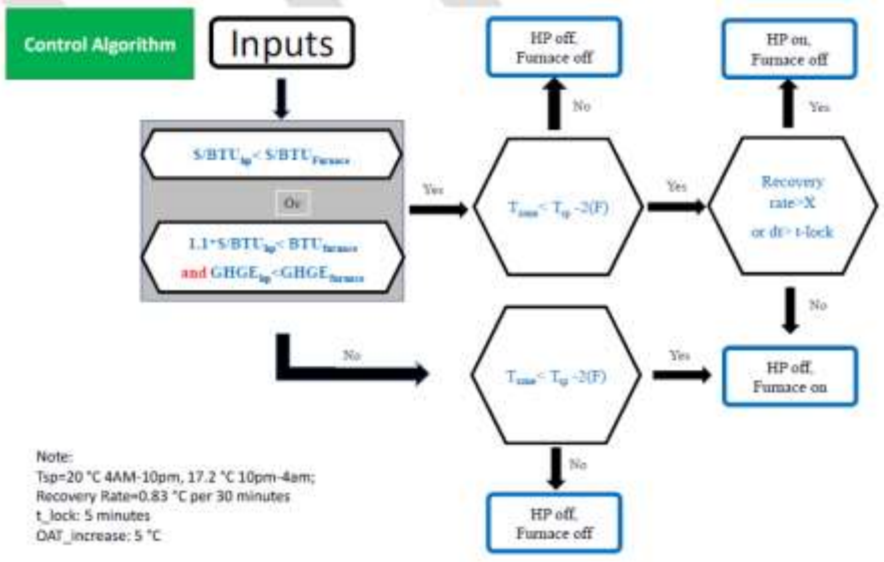
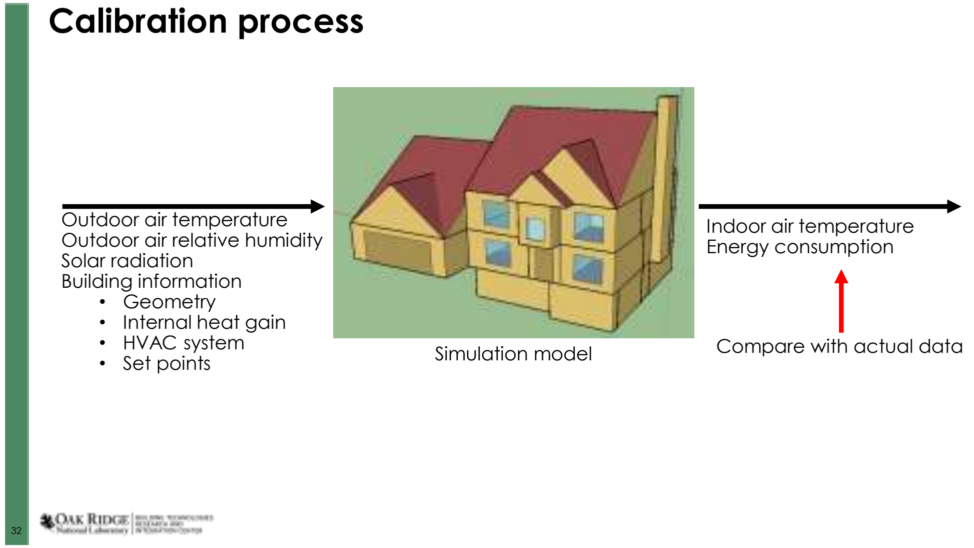


Figure 1 - Draft Rule Set for Dual Fuel Heating System

Project Milestones & Accomplishments to Date *(cont).*

- Successfully completed Winter #1 (2021-22) monitoring of furnace heating system
- Selected and procured heat pump addition (outdoor unit, indoor coil, controls) to add to existing furnace system. Mitsubishi IntelliHeat system, installed 10/2022.
- After initial testing of commercially controlled system, transitioned control of DF system to project rule set using datalogger to implement
- Calibrated EnergyPlus model based on field data



Challenges & Lessons Learned to Date

Equipment Procurement

- Some data acquisition equipment had long lead times

Heat Pump Equipment

- Single speed and two-speed HP options did not have suitable capacities to allow the unit to meet a substantial portion of heating demand without being oversized for cooling load

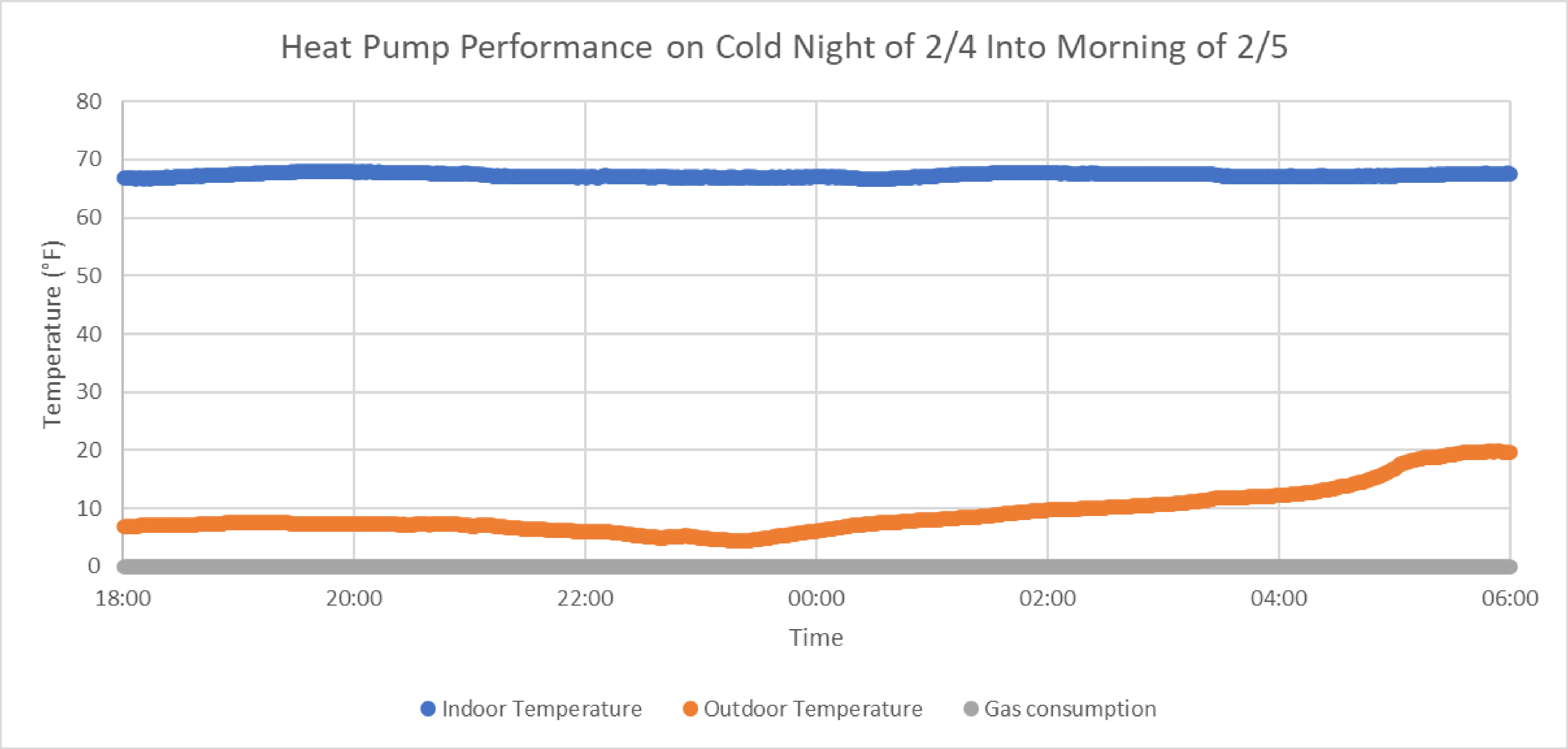
Thermostat Setback

- Native control functionality of the heat pump system at field site can have the effect of locking out HP operation during recovery after nighttime setback

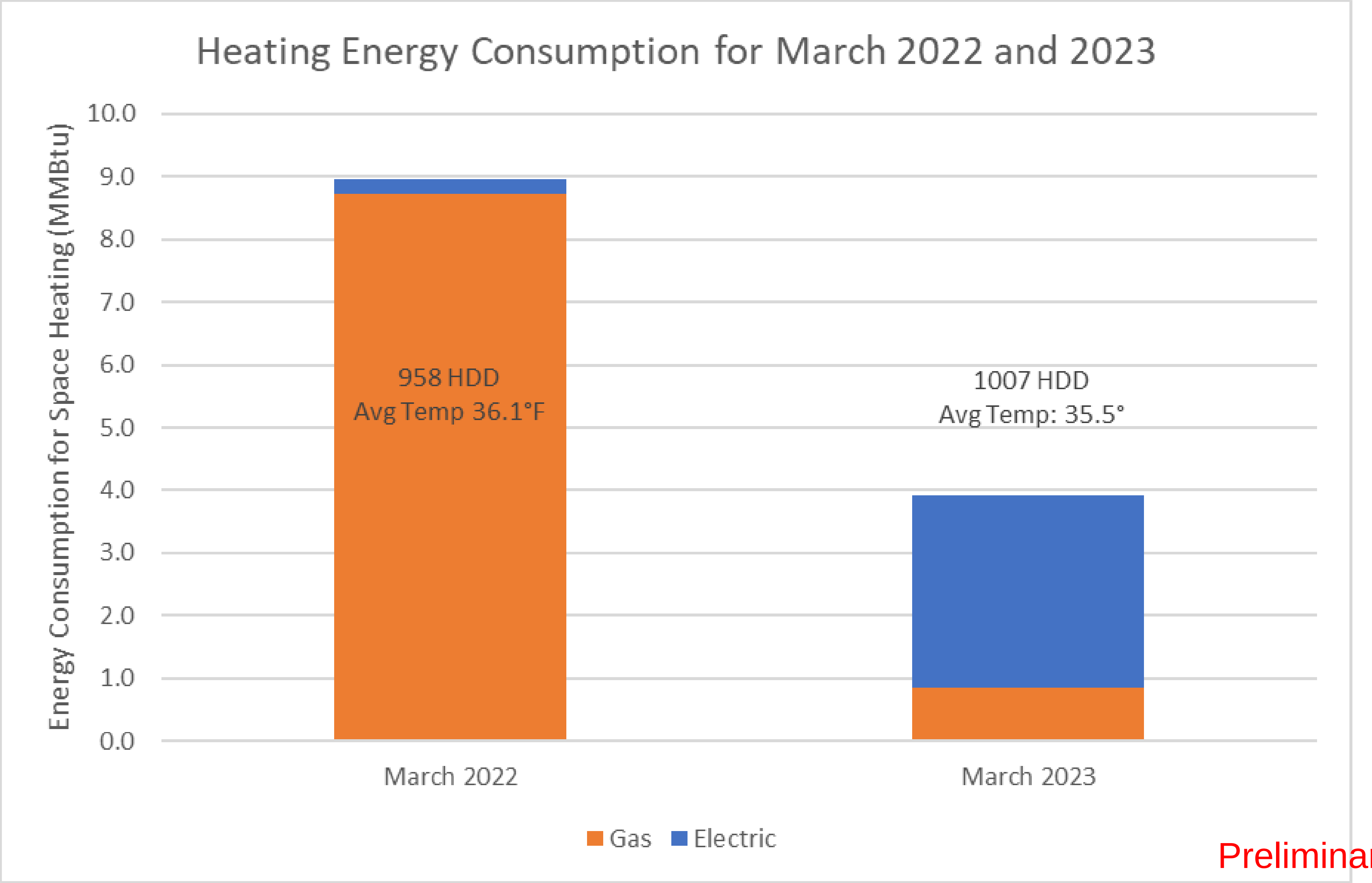
Heat Pump Operation at Cold Temps

- Heat pump has adequately maintained indoor setpoint during single digit outdoor temps

Interim Findings –
Heat Pump Maintaining Setpoint during Outdoor Temps Near Design Conditions



Interim Findings – Heating Energy Savings

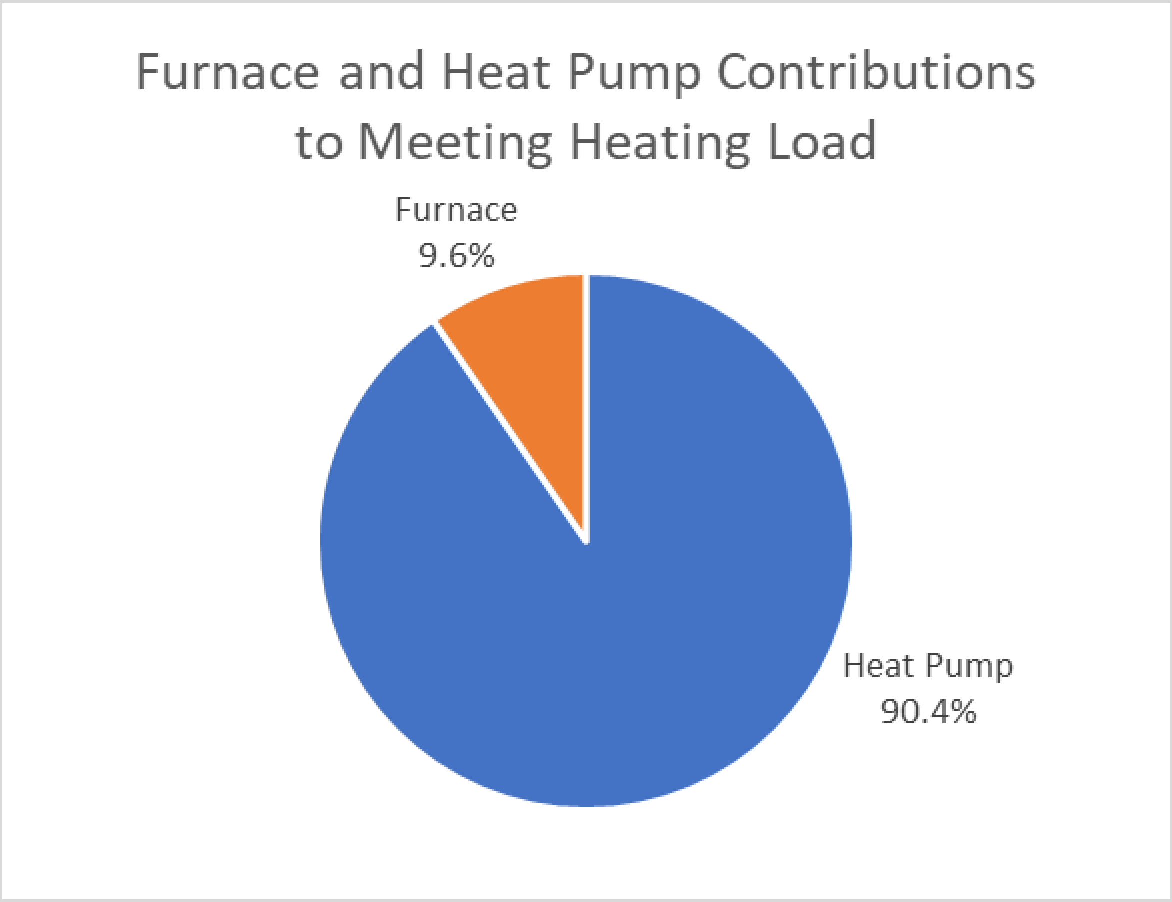


Heating Energy Savings (Normalized) from Control-Optimized DF Heating System:

- **58**%

Preliminary Analysis – Do Not Reference

Interim Findings –
System Operations & Estimated Heat Energy Cost Savings



Heating Energy Cost Savings (Normalized) from Control-Optimized DF Heating System:

- **13%**

Preliminary Analysis – Do Not Reference

Looking Forward

- Complete Winter #2 (2022-23) field data analysis
- Complete model calibration
- Conduct scaled-up modeling analysis to leverage and build upon findings
- Disseminate findings:
  - Advisory Group
  - Conference papers / presentations

Beyond the Project

- Identifying related needs to support broader implementation of control-optimized dual fuel heating systems (i.e., sizing guidance)
- Supporting broader implementation and recognition of this technology

Thank You

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REFERENCE SLIDES

Project Execution

					MONTHS FROM PROJECT START												
	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48
Task																	
1. Form Advisory Group		1.1															
2. Develop Optimized HHP Control (OHC)			2.1	2.2			2.3										
3. Validate & Analyze HHP w/ OHC					3.1			3.2	3.3			3.4					
4. Conduct Modeling to Leverage Test Results													4.0		4.1		
5. Manage Project & Disseminate Results														5.1		5.2	
GO / NO-GO Points					X				X								X

- Go/no-go points #1 and #2 have been completed and accepted
- No slipped milestones
- 1-year no-cost project extension added; primary reason was the need to monitor 2 winters of data at the field site and not being able to commence with this work until 2021-2022

Team

Newport Partners is the prime contractor responsible for research design, control logic development, field demonstration and energy analysis, and reporting.

Oak Ridge National Lab leads energy simulation analyses for the project (including scaled-up analysis) and supports datalogger programming for the field assessment.

The project **Advisory Group** is comprised of manufacturers, utilities, and EE organizations. The earlier Stakeholder Engagement slide lists all AG member organizations. **Mitsubishi HVAC** is an AG member and has also provided the IntelliHeat 36 kBTU heat pump system for the field assessment.

EERE/BTO goals

(Not a template slide – for informational purposes only)

The nation’s ambitious climate mitigation goals

Greenhouse gas emissions reductions

50-52% reduction by 2030 vs. 2005 levels

Net-zero emissions economy by 2050

Power system decarbonization

100% carbon pollution-free electricity by 2035

Energy justice

40% of benefits from federal climate and clean energy investments flow to disadvantaged communities

EERE/BTO’s vision for a net-zero U.S. building sector by 2050