Dual Fuel Heating System Retrofits with Advanced Controls

An energy, carbon, and cost-saving opportunity for gas-heated homes

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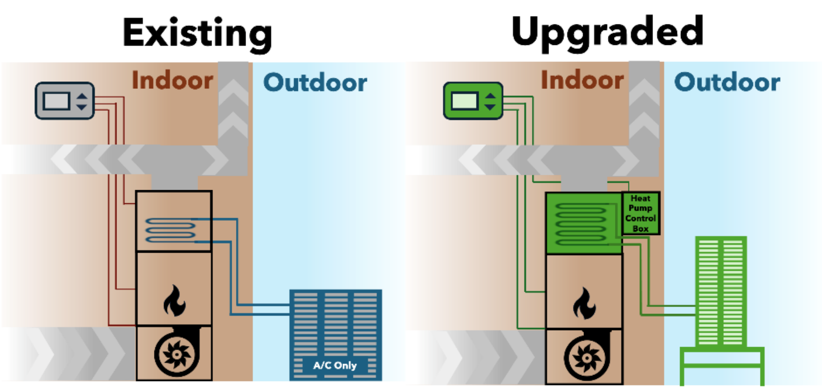
There are roughly 38.5 million homes in the mixed and cold climate regions of the U.S. (about 48% of the housing stock) with a gas based forced-air heating system. As utilities and energy efficiency programs seek to reduce energy use, GHG emissions, and costs, these homes are candidates for an **add-on heat pump with advanced controls**. This technology offers the potential for retrofits to reduce energy, costs, and carbon while keeping residents comfortable.

38.5 million
applicable housing units in IECC Climate Zones 4-6

Technology Overview

Dual Fuel Heating	Retrofit	Control-Optimized
Heating a home with both a **gas-fired** furnace and an **electric** heat pump with the capacity to provide adequate heating under most or all outdoor temperatures.	Replacing an existing air conditioner with a heat pump that cools in the summer and provides heating in the winter.	Using advanced controls that consider both **energy cost** and **system efficiency** to determine which system (furnace or heat pump) to use at different times.

This study investigated a home where an old A/C unit was replaced with a variable capacity heat pump system (indoor coil, outdoor unit, and controls). The heat pump system was added to an existing, relatively new forced-air furnace and utilized the furnace's blower and duct work. Additional hardware was used to implement customized advanced controls, which selected the furnace or heat pump based on the lower energy cost per BTU. The control logic also included rules to ensure that indoor temperature levels were maintained to support comfort. Field data monitoring was conducted to develop a calibrated EnergyPlus model to analyze the impact of key design variables on system performance in mixed and cold climate zones (CZs 4–6).



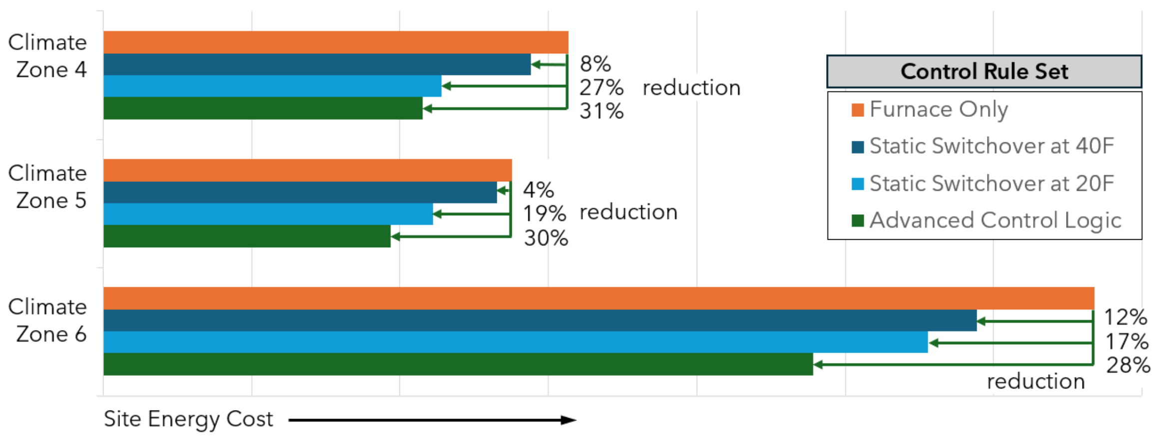
Key Factors Affecting Dual Fuel System Performance

Control Logic	Heat Pump Sizing	Building Tightness	Energy Rate Structure

Control Logic: What are the impacts of different control strategies?

3 control strategies for a dual fuel heating system were compared to a furnace-only scenario.
(1) Switchover temperature controls at 40° F (heat pump does not operate below 40° F).
(2) Switchover temperature controls at 20° F (heat pump does not operate below 20° F).
(3) Advanced control logic which selects the heating source (furnace or heat pump) based on the estimated $/Btu of heating, factoring in system efficiency (which depends on outdoor temperature) and energy prices. The logic was specifically developed for this project.

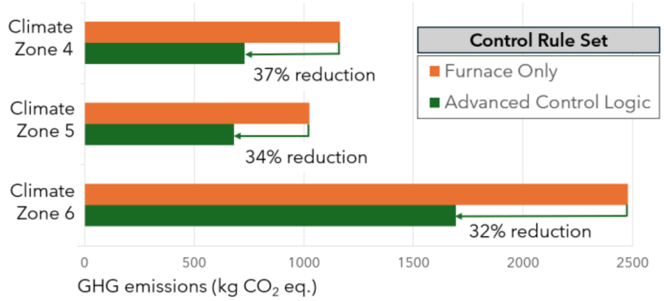
Control Rule Set Affects Site Energy Cost



Note: *Site Energy Costs in this fact sheet assume the use of time-of-use electric rates unless noted otherwise. See Key Assumptions section for more information on energy rates.*

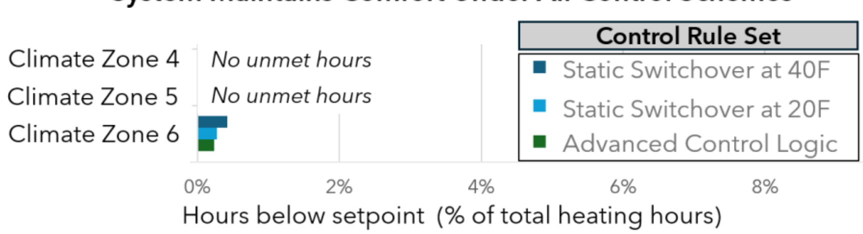
The data shows that advanced control logic yields the lowest energy cost in every climate zone, with increased performance gains in the coldest climate zone in the study (CZ 6). Additionally, the use of a 20° F switchover temperature allows more heat pump operation and results in greater cost savings compared to the 40° F switchover temperature. All three dual fuel control scenarios have lower energy costs compared to the furnace-only heating system scenario.

Dual Fuel Reduces GHG Emissions



Further, a dual fuel system with advanced control logic has the potential to significantly reduce GHG emissions compared to furnace-only systems. This data incorporates national average emissions rates for electricity from EPA's E-Grid data set.

System Maintains Comfort Under All Control Schemes



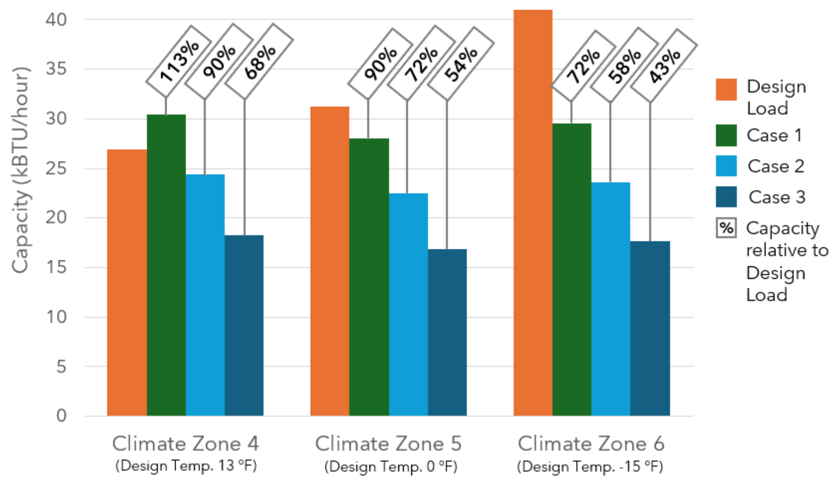
The dual fuel system is very effective at maintaining comfortable indoor conditions near the set point temperature under all three control strategies.

Dual fuel programs can implement lower switchover temperatures or advanced control logic (as available) to reduce operating costs and emissions, while maintaining comfort.

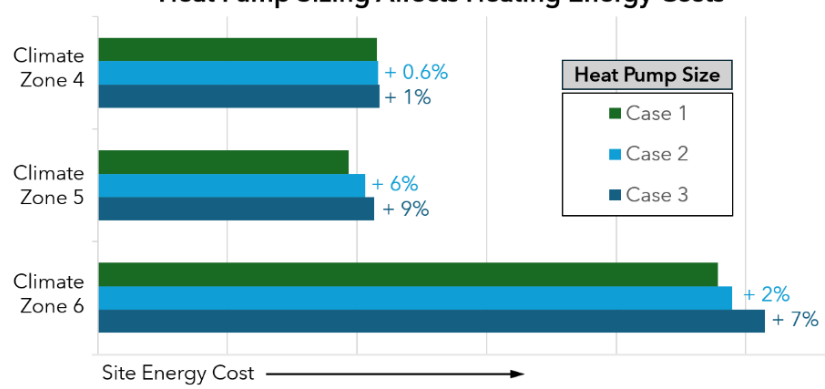
Heat Pump Sizing: What are the impacts of heat pump sizing?

This analysis examined the impact of using a heat pump with varying levels of heating capacity at design conditions relative to the home's design heating load. Case 1 (green) assumed the greatest amount of heating capacity (close to 100% in CZs 4 and 5), Case 2 (light blue) assumed a lower capacity, and Case 3 (dark blue) assumed the lowest capacity.

Heat Pump Capacities Used in Analysis



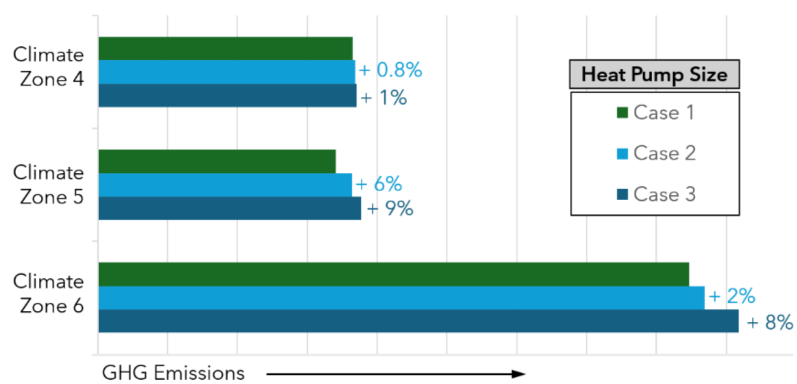
Heat Pump Sizing Affects Heating Energy Costs



Heating energy costs change very little in CZ 4 as heat pump capacity is reduced.

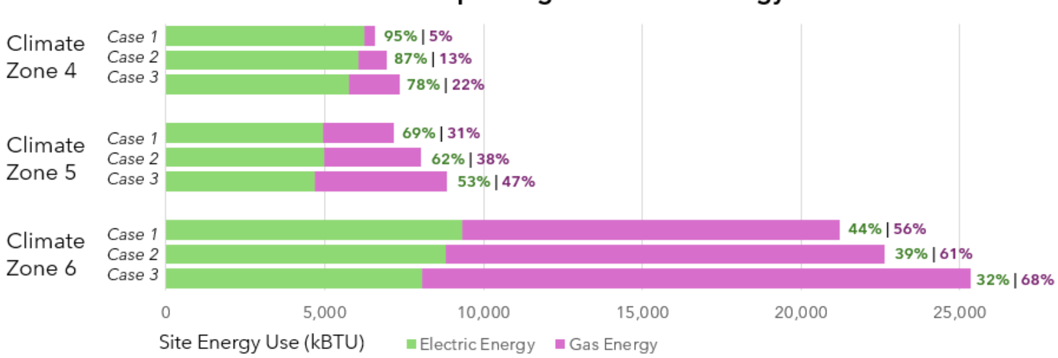
In colder zones, reduced heat pump capacity results in more significant heating energy cost increases. Case 3 is 9% higher than Case 1 in CZ 5, and 7% higher in CZ 6.

Heat Pump Sizing Affects GHG Emissions



Heat pump emissions increase with decreasing heat pump capacity, more significantly in the colder climate zones.

Heat Pump Sizing Affects Site Energy Use

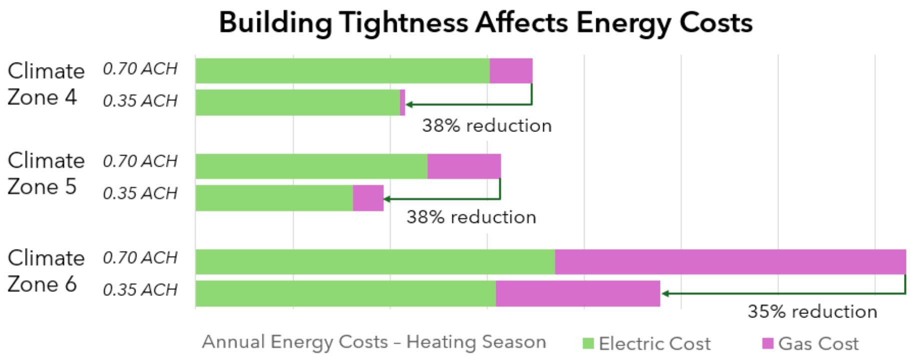


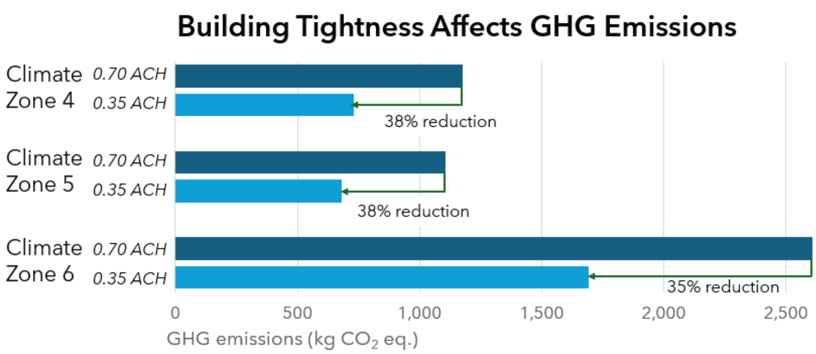
As heat pump capacity is reduced, there is less electricity use and greater gas energy consumption. Total site energy use increases.

Dual fuel incentive programs should encourage variable capacity heat pumps sized to meet most of the home's heating load at design conditions, to the extent possible. System capacity relative to the home's *cooling* load should also be within the heat pump's operation range.

Envelope Tightness: What are the impacts of a leaky building shell?

This analysis examined the impact of a leakier building envelope on the dual fuel heating system performance. The baseline infiltration rate used in this study was 0.35 air changes per hour (ACH), and was compared against a leakier envelope with a leakage rate of 0.70 ACH.





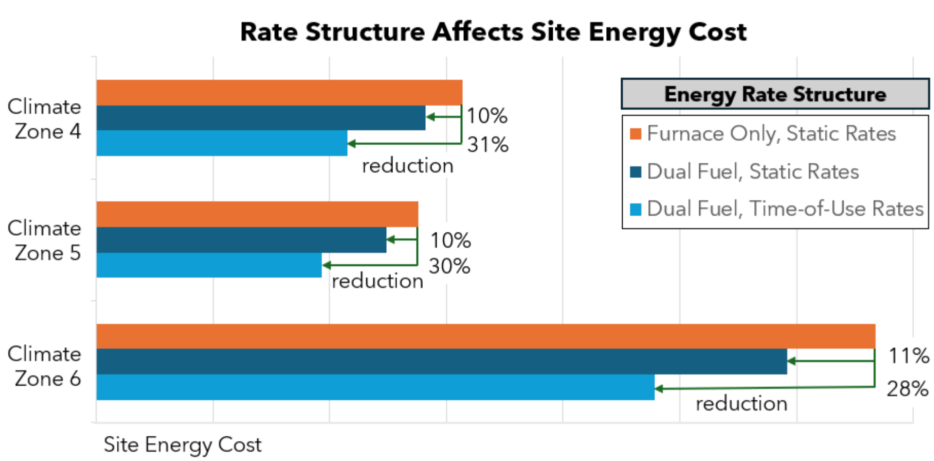
The data shows that a leakier envelope will increase electric costs, gas costs and GHG emissions.

Additionally, the study concluded that hours where the indoor temperature drops below the setpoint increased significantly in the leakier home scenario. This effect was most significant in CZ 6. The leakier home scenario could result in comfort issues.

Dual fuel incentive programs can combine air sealing measures with add-on heat pump implementation to maximize the heat pump's effectiveness and improve comfort.

Energy Rates: How does the rate structure affect site energy cost?

This analysis examined the impact of time-of-use (TOU) electric rates as compared to static gas ($1.42/therm) and electric rates (15.12 cents/kWh) based on national average residential rates. The TOU rates are a 3-tier structure based on rate structures offered by some utilities in mixed/cold climates.

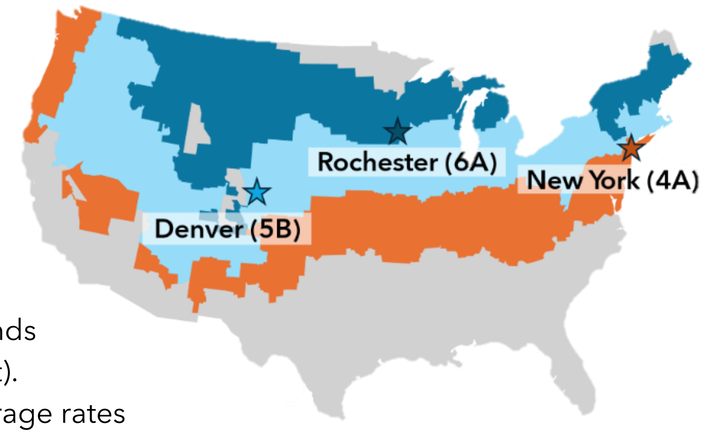


TOU electric rates combined with the control logic that selects the lower $/BTU heating source provides significant cost savings over a dual fuel system operating under static energy rates. A dual fuel system with static gas and electric rates delivers cost savings over furnace-only operation with the same gas rate.

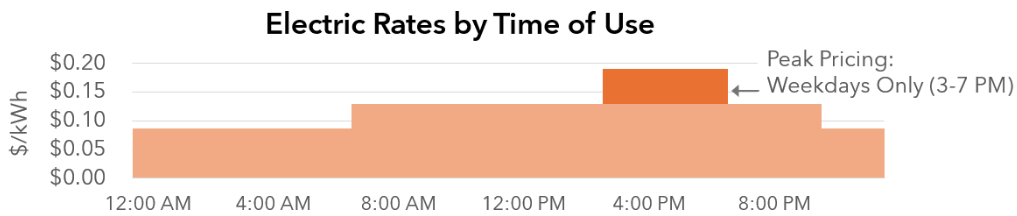
Dual fuel systems with advanced controls can increase cost savings for consumers by taking advantage of electric time-of-use rates, where available.

Key Assumptions

Conducting this analysis required numerous inputs and assumptions, several of which are highlighted below. Stakeholders should review these assumptions relative to their specific circumstances when applying the study findings and conduct additional analysis as necessary.



1. Each ***climate zone*** discussed above corresponds to data from representative cities (see map, right).
2. ***Emissions rates*** for electricity are national average rates sourced from EPA's E-Grid database.
3. ***Gas prices*** in the analysis are based on the 2022 national average residential price, $1.42/therm, sourced from the U.S. Energy Information Administration (EIA).
4. ***Electric rates*** are based on a time-of-use (TOU) schedule to demonstrate the ability of the dual fuel system and its innovative control system used in this study to select the heating source based on varying energy costs. The TOU schedule is based on a composite of 3-tier utility rates in several mixed/cold climate markets, the magnitude of differences between these tiers, and the 2022 national average electric price (15.12 ¢/kWh) from the EIA.



5. All findings are based on ***EnergyPlus modeling***, using a model calibrated by field site monitoring data. Heat pump performance within the model is based on a cold climate heat pump performance curve. The gas furnace in the model has an efficiency of 80 AFUE.

Market Integration

There are currently "add-on" heat pumps which are variable capacity and can integrate with existing furnaces and blowers to create dual fuel heating systems. Controls which allow dual fuel systems to select the heating source based on estimated costs are in development with manufacturers and expected within a few years, while controls offering the ability to set different switchover temperatures are currently available. Based on this research, dual fuel heating systems (especially those offering advanced controls) can offer a retrofit opportunity for gas-heated homes to deliver significant energy, cost, and emissions benefits while maintaining comfort.

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