ASHRAE

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DAIKIN

BUILDING INTELLIGENCE GROUP LLC

COST OPTIMAL DECARBONIZATION:

A REGIONAL ANALYSIS OF ELECTRIC VERSUS GAS SUPPLEMENTAL HEATING FOR HEAT PUMPS

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OBJECTIVES

This study aims to:

- Quantify the **operational cost impacts** of electric versus gas supplemental heating for air source heat pumps (ASHPs) across **U.S. climate zones and commercial building types** using whole-building energy modeling.
- Incorporate **region-specific utility pricing** from the U.S. Energy Information Administration and link cost findings with prior **emissions analysis** to provide a holistic framework for cost-optimal decarbonization strategies.

METHODS

Simulation Approach:

- Developed hourly whole-building energy models using DOE's EnergyPlus v23.1
- Focuses on four common commercial building types:
  - Office (125k ft^2 / 11.6k m^2, 4 stories)
  - Multifamily (35k ft^2 / 3.3k m^2, 5 stories)
  - Hospital (240k ft^2 / 22.2k m^2, 5 stories)
  - School (210k ft^2 / 19.5k m^2, 3 stories)

Key Modeling Parameters:

- ASHRAE Standard 90.1 (2004) compliant models, reflecting HVAC replacement scenarios for existing buildings
- Simulations incorporate TMY3 hourly weather files for representative cities, covering all 18 U.S. electric grid regions

Modeled Representative Cities for Each Electric Grid Region Across the U.S.

Grid Region	Modeled State, City	Grid Region	Modeled State, City
NorthernGrid West	Washington, Seattle	SPP South	Kansas, Kansas City
CAISO	California, Los Angeles	ERCOT	Texas, Temple
NorthernGrid East	Montana, Helena	PJM West	Illinois, Chicago
NorthernGrid South	Nevada, Las Vegas	MISO Central	Indiana, Indianapolis
SPP North	South Dakota, Pierre	MISO South	Mississippi, Jackson
WestConnect North	Colorado, Denver	ISONE	Maine, Augusta
WestConnect South	New Mexico, Santa Fe	NYISO	New York, Queens
MISO North	Minnesota, International Falls	PJM East	Pennsylvania, Philadelphia
SERTP	North Carolina, Raleigh	FRCC	Florida, Tampa

Modeled Scenarios:

Scenario 1: Gas-Fueled Heating Baseline

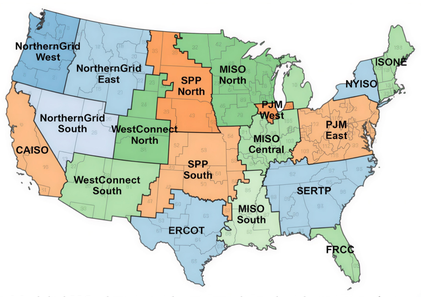
- Heating: Gas combustion
- Used as the baseline for cost and emissions comparisons

Scenario 2: Dual Fuel (ASHP + Gas Supplemental Heat)

- Heating: Electric heat pump with gas supplemental heating

Scenario 3: All Electric (ASHP + Electric Supplemental Heat)

- Heating: Electric heat pump with electric resistance supplemental heating

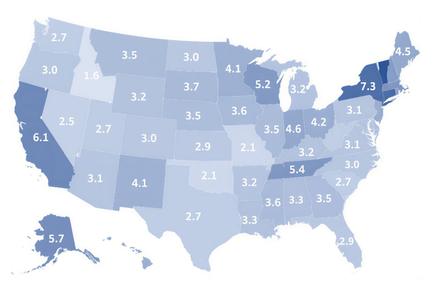


Modeled U.S. electric grid regions, aligned with emission factor datasets used in our previously published emissions focused study (Houssainy et al. 2025; NREL 2023).

System Specifications & Modeling Parameter:

- **Heat pump sizing:** Based on design cooling load for scenarios 2 & 3
- **DX cooling performance:** Identical across all three scenarios. Variable speed supply fans & compressors modeled for all systems
- **Efficiency assumptions:**
  - **Heat pump COP:** 3.5 at 47°F (8.33°C), 2.335 at 17°F (-8.33°C)
  - **Gas combustion efficiency:** 80%
  - **Electric supplemental heating efficiency:** 100%
- **Heat pump compressor shutoff temperature:** -10°F (-23.33°C)
- Defrost cycles not considered in analysis

216 simulations (18 regions × 4 building types × 3 scenarios)



State-level commercial electricity-to-gas price ratios (unitless), based on EIA's average reported prices as of February 2025, illustrating the relative regional variations in prices nationwide

Results of Interest:

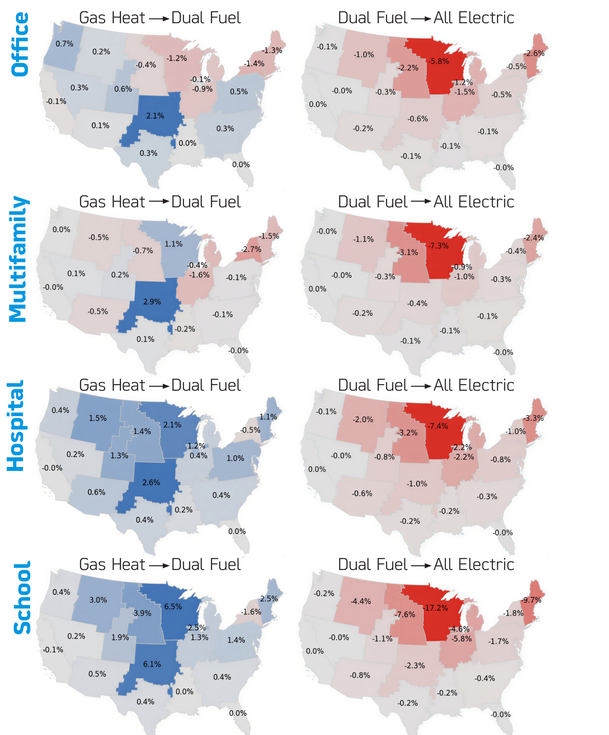
$$\%\ Cost\ Savings_{DualFuel} = \frac{Annual\ Cost_{All\ Gas} - Annual\ Cost_{DualFuel}}{Annual\ Cost_{All\ Gas}} \times 100$$

$$\%\ Incremental\ Cost\ Savings_{All\ Electric} = \frac{Annual\ Cost_{DualFuel} - Annual\ Cost_{All\ Electric}}{Annual\ Cost_{All\ Gas}} \times 100$$

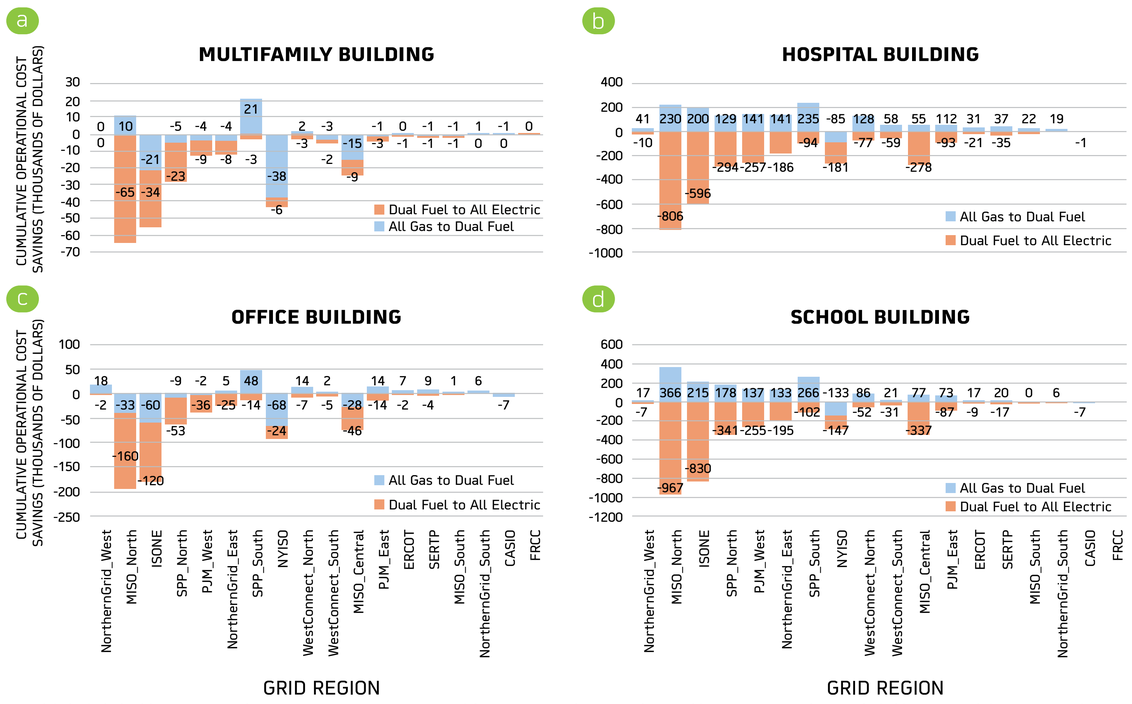
RESULTS

- **Electrifying supplemental heat never reduces costs.** Across all building types and regions, electric resistance supplemental heat increases operating costs compared to gas, with the steepest penalties in **MISO North, SPP North, and ISONE.**
- The **small efficiency gain** of electric resistance heating is outweighed by **higher electricity prices,** especially in colder climates with longer run hours.
- **Dual-fuel heat pumps** show more nuanced outcomes compared to all-gas heating.
  - **Ventilation-driven buildings** (schools, hospitals) consistently achieve cost savings, leveraging high COP performance during milder winter conditions.
  - **Envelope-driven buildings** (offices, multifamily) often see limited or negative savings, as reduced COP at cold temperatures and high electricity costs erode benefits.
- Regional price structures matter: in **California and New York,** high electricity-to-gas price ratios lead to higher costs for dual-fuel systems compared to all-gas heating across all building types.
- Overall, **building type and load profile** (ventilation vs. envelope) are key drivers of economic outcomes, explaining why dual-fuel systems favor high-ventilation facilities but not envelope-dominated ones.

Modeled Annual Whole-Building Operational Cost Savings

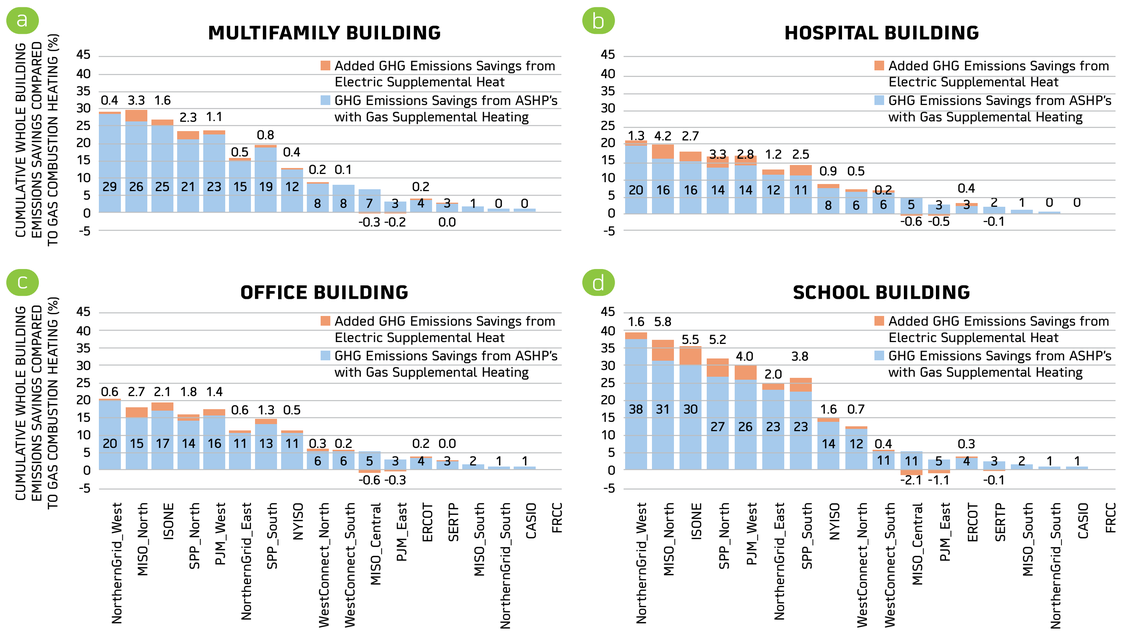


RESULTS



Modeled whole-building operational cost savings over a 15-year period from ASHPs with gas supplemental heating compared to gas-fueled heating, and the incremental savings from electrifying the supplemental heat for the (a) multifamily (b) hospital (c) office and (d) school building types.

- **15-year cumulative cost analysis** shows dual-fuel ASHPs with gas supplemental heat deliver consistent savings compared to all-gas systems, especially in **schools and hospitals.**
- **Electrifying supplemental heat** increases costs over the equipment lifespan in nearly all regions, with the **upper Midwest and Northeast** showing the steepest penalties.
- When paired with emissions outcomes, results reveal:
  - **Offices and multifamily buildings:** small incremental emissions savings from electrification are outweighed by higher operating costs nationwide.
  - **Schools and hospitals:** dual-fuel systems achieve both **cost and emissions savings,** reinforcing their advantage in ventilation-heavy applications.
- Full electrification often produces minimal or **negative emissions benefits** while raising costs, particularly in **MISO North, ISONE, SPP North, PJM West,** and **Northern Grid East**.
- Cost results are based on **EIA blended electricity rates,** which average TOU and demand charges. While this ensures broad applicability, site-specific costs may be underestimated in regions with significant TOU or peak demand pricing.



Prior published results of the modeled whole-building emissions savings over a 15-year period (2025-2040) from ASHPs with gas supplemental heating compared to gas-fueled heating, and the incremental increase in savings from electrifying the supplemental heat for the (a) multifamily (b) hospital (c) office and (d) school building types. (Houssainy et al. 2025)

CONCLUSIONS

- **Dual-fuel ASHPs** with gas supplemental heat often reduce operating costs and compared to all-gas systems, but outcomes vary by **building type and regional utility prices.**
- **Ventilation-driven buildings** (schools, hospitals) show the greatest cost and emissions benefits, while **envelope-dominated buildings** (offices, multifamily) see limited or negative cost savings in some regions.
- **Electrifying supplemental heat consistently raises costs nationwide,** with the steepest increases in the **upper Midwest and Northeast.**
- The small efficiency gain of electric resistance heating cannot offset higher electricity prices, especially in colder climates.
- When paired with limited emissions benefits, these results highlight the need for **precise, regionally tailored strategies** rather than blanket electrification assumptions.
- **Designers, policymakers, and building owners** must weigh both **cost and emissions outcomes** to ensure decarbonization pathways are truly sustainable and economically viable.

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