Decarbonizing Space Heating: Regional Insights on Supplemental Heat Electrification for Heat Pumps

New Study Challenges Conventional Assumptions on the Path to Decarbonized Buildings

Decarbonizing space heating in commercial buildings is essential in reducing greenhouse gas (GHG) emissions. Air-source heat pumps (ASHPs) have gained traction as a sustainable alternative to gas combustion heating, but their performance declines in colder climates, often requiring supplemental heat to maintain comfort levels. The widespread assumption is that electrifying supplemental heat is always beneficial, but this study provides a more nuanced, region-specific analysis to test that claim.

Methodology: A Whole-Building Energy Modeling Approach

To understand the emissions impact of different supplemental heating strategies, this study employed hourly whole-building energy modeling using the U.S. Department of Energy's EnergyPlus simulation engine. the assessment leveraged models aligned with ASHRAE Standard 90.1 and covered commercial building types across 18 U.S. electric grid regions, providing a comprehensive assessment of emissions impacts throughout the nation.

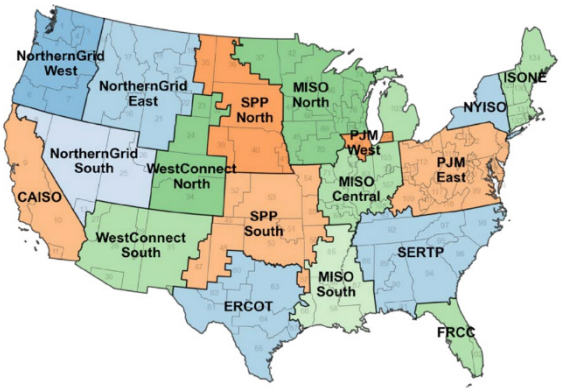


Figure 1: *U.S electrical grid regions (NREL 2023).*

The electric emissions were based on two key datasets:

- **EPA eGRID (2014-2022),** which reflects historical emissions based on actual power plant operational across the U.S.
- **NREL's Cambium dataset (2025-2050),** which forecasts electric grid emissions projections through 2050.

Three primary heating scenarios were modeled:

1. **Gas-Fueled Heating (Baseline)** – Rooftop systems with DX cooling and gas combustion heating.
2. **Dual-Fuel ASHPs** – Rooftop heat pumps supplemented by gas heating.
3. **All-Electric ASHPs** – Rooftop heat pumps supplemented by electric resistance heating.

Daikin's Rebel Rooftop units were used for this analysis, factoring in compressor cut-off temperatures, Cooling EER/IEER, and heating COPs. The heat pumps were sized based on their design cooling load, ensuring realistic performance assessments.

Findings: A Complex Regional Story

Current Grid Emissions (2022)

The analysis begins by looking at actual grid emissions data from 2022, revealing counterintuitive findings. While electrification of supplemental heat is often assumed to be the most sustainable option, results indicate that electrification actually leads to increased emissions in most U.S. regions—with two notable exceptions:

- **PJM West (Chicago, IL),** where a high nuclear energy share (22%) significantly lowers carbon emissions.
- **Northern Grid West (Washington State),** where hydropower comprises nearly 50% of the energy mix, mitigating emissions from supplemental heat electrification.

These regions see positive emissions reductions, but most of the country does not experience savings by shifting away from gas to electric resistance supplemental heat.

Looking Ahead to 2050

Projecting forward, future electric grid decarbonization trends suggest a more varied impact across different states. By 2050, supplemental heat electrification remains marginally effective, with the exception of MISO North, SPP North, and NYSIO (Wisconsin, Minnesota, New York) given their northern colder climates and high number of runtime heating hours.

However, not all northern states see equal benefits. Interestingly, regions such as Pennsylvania—which are geographically close to these higher-impact states—do not see significant emissions reductions. Likewise, some southern states, like Kansas, outperform their northern counterparts due to projected high wind energy penetration.

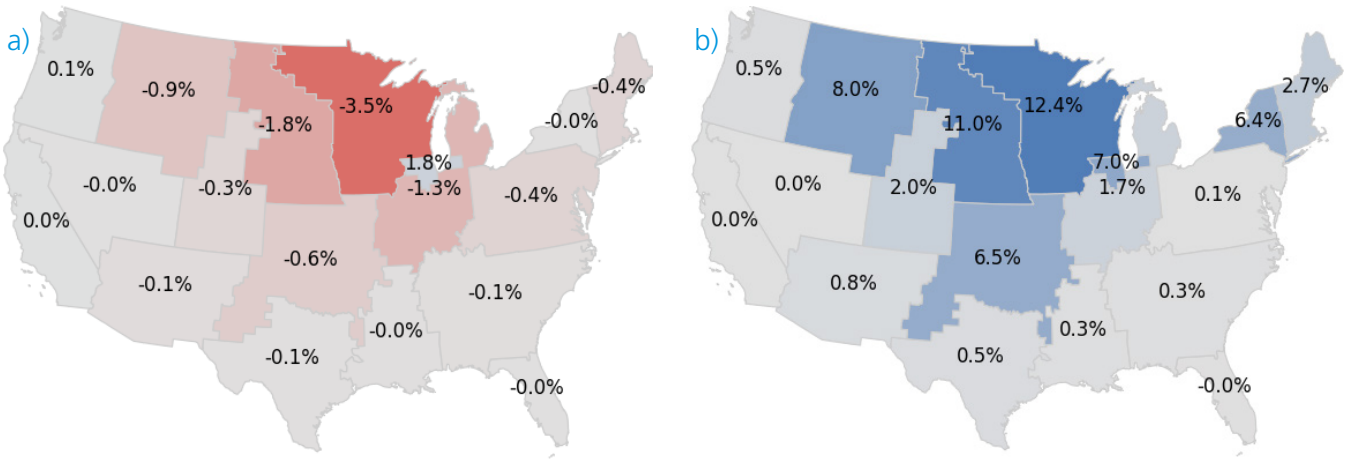


Figure 2: *Added annual whole-building emissions savings for the modeled office building from electrifying supplemental heat for* ***a)*** *the year 2022, corresponding to the most recent EPA eGrid Emissions Factors based on actual power plant operation data and* ***b)*** *the year 2050, based on NREL's projected grid emission factors.*

Lifetime Equipment Analysis (2025–2040)

A 15-year emissions assessment provides additional clarity on long-term impacts and a a practicle design assessment considering the cumulative impacts throughput an eequipment lifetime. Results indicate that:

- Dual-fuel ASHPs consistently provide emissions savings across all U.S. grid regions.
- Electrifying supplemental heat offers only modest improvements, with only a few regions seeing more than 2% emissions savings.
- In regions such as PJM East (Pennsylvania) and MISO Central (Indiana/Illinois), electrifying supplemental heat actually leads to increased emissions, while dual-fuel ASHPs remain beneficial.

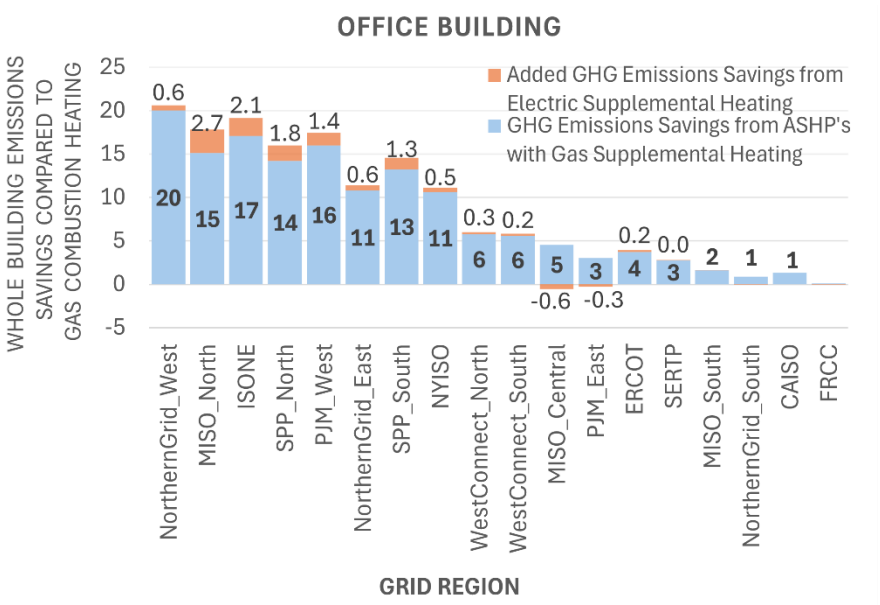


Figure 3: *Modeled whole-building emissions savings over a 15-year period (2025-2040) from ASHPs with gas supplemental heating compared to gas-fueled heating, and the added increase in savings from electrifying the supplemental heat*

Key Takeaways: The Case for Region-Specific Strategies

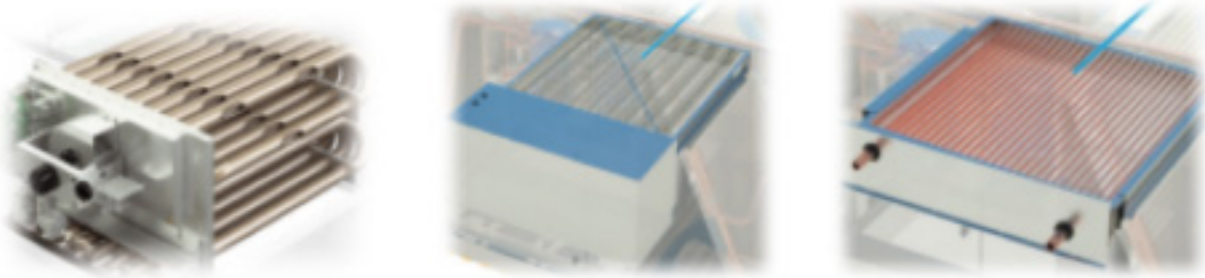
- Dual-fuel ASHPs reduce emissions nationwide, making them a strong option across all regions.
- Electrifying supplemental heat provides limited benefits and can result in increased emissions in some locations.
- States such as Minnesota, Wisconsin, and Maine benefit most from electrification, whereas Pennsylvania, Indiana, and Illinois see net-negative impacts.
- Strategic electrification must be tailored regionally rather than following a one-size-fits-all approach.

This study challenges the blanket assumption that electric resistance heat is always the best supplemental heating option, emphasizing the importance of precise emissions modeling and HVAC equipment selection in building decarbonization efforts.

Daikin's Versatile Heating Solutions

Understanding the regional variations in emissions performance is key to selecting the right heating solutions for any given project. Daikin's Rebel and Rebel Applied product lines offer flexibility to address the diverse needs identified in this study:

- **Multiple supplemental heating options for different climate and grid scenarios:**
  - **Natural Gas/Propane –** capable of simultaneous dual-fuel operations, staged/modulating controls, 12:1 turndown, and 100°F temp rise.
  - **Electric –** Staged or SCR controls, up to 80°F temp rise, dedicated power and kW limiting options to reduce electrical infrastructure costs.
  - **Hot Water –** Available in 1-, 2-, or 3-row coil options, with freeze-stat and valve package options.
- **High-Capacity Heating Performance:** Rebel Applied high heat output pump maintains 93% of nominal heating at 0°F with a COP of ~2, through additional dedicated compressors and increased outdoor coil surface area.



Natural Gas/Propane | Electric | Hot Water

Figure 4: Supplemental Rebel Heat Pump Heating Option
Energy modeling is critical in guiding building design, policy decisions, and HVAC technology development. Precision in equipment selection—rather than broad electrification mandates—will define the next phase of sustainable heating strategies.