Don’t Judge an RTU by Its Cooling Label

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ABSTRACT

Packaged rooftop units (RTUs) are a dominant heating, ventilation, and air-conditioning (HVAC) solution in the commercial sector, and newer high-efficiency models promise substantial energy savings over conventional gas RTUs. However, “efficiency” in this context is often narrowly defined—typically by cooling performance metrics—without a holistic evaluation of real-world energy impacts across climates, building types, and system configurations.

This paper presents an assessment of RTU energy-efficiency measures using the EnergyPlus-based modeling framework Modelkit Flannel (“Modelkit”). The research team developed and analyzed over 3,300 building energy models, covering seven commercial building types, 11 U.S. climate zones, four RTU system types, and 15 energy-efficiency measures, assessed both individually and in combination.

Findings reveal that the commonly emphasized “efficient cooling” measure produces the lowest average HVAC energy savings nationally, challenging long-held industry assumptions. Instead, significant savings were associated with bundled efficiency strategies, heat pump RTU replacements, and the integration of energy recovery ventilation (ERV) in gas RTUs. These results underscore the importance of evaluating whole-system performance, not just isolated components.

This research provides actionable insights for policymakers, program designers, and industry stakeholders seeking to improve HVAC efficiency standards, incentive structures, and market transformation strategies. By leveraging detailed energy modeling across diverse conditions, this study identifies which measures—and measure combinations—most effectively deliver energy, guiding efforts toward more impactful and data-driven HVAC upgrades.

Introduction

Efficient packaged rooftop unit products present significant energy savings over code-minimum gas and electric packaged RTU equipment common in the commercial sector. For several years, the Northwest Energy Efficiency Alliance (NEEA) has supported the research of efficient RTUs. NEEA’s efficient gas RTU market transformation program (NEEA 2026) leverages building energy modeling analyses to quantify potential energy savings to be gained by implementing efficient RTU measures. While NEEA’s efficient RTU research and initiatives historically focused on the Pacific Northwest, NEEA is presently also supporting revisions to standards and market transformation efforts at a national level.

This paper presents a comprehensive analysis of commercial HVAC efficiency measures for various types of commercial RTU equipment and the corresponding energy-savings potential across different climate zones.[1] This analysis was conducted to support the development of national RTU initiatives on behalf of NEEA and the Center for Energy and Environment (CEE), with consultation and input from Nicor Gas. The Resource Innovations and A2 Efficiency team,

[1] This analysis did not investigate energy pricing, cost savings, or carbon savings.

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or “research team,” utilized an EnergyPlus building energy modeling framework, Modelkit Flannel (“Modelkit”)[2], to develop over 3,300 models to quantify the energy-savings potential of RTU-related measures. The research assessed key measures individually and in combination, highlighting the implications for program development, market transformation, code enhancement, and federal standards improvement. The research also provides actionable insights to support future studies. By focusing on the combined impacts of the measures and addressing regulatory gaps, stakeholders can drive significant advancements in HVAC efficiency, leading to substantial energy and cost savings nationwide.

This paper contains the following five sections which describe the research team’s methodology, results, and recommendations: (1) Research Design, (2) Modeling Approach, (3) Model Results, (4) Recommendations, and (5) Conclusion. For more information on this research, see NEEA’s 2025 National Efficient Rooftop Unit Energy Modeling report (NEEA 2025).

Research Design

The research approach utilized detailed building energy modeling to estimate performance outcomes for different efficiency measures applied to RTUs. Critical dimensions of the simulations included: climate zones, building types, HVAC systems, and efficiency measures. The research team worked with NEEA, CEE, and Nicor Gas to select the following building simulation segments that were modeled for this research. In total, the research team simulated over 3,300 building energy models:

- Eleven locations representing climate diversity for most of the population in the United States (95%).
- Seven building types representing the most common applications of packaged RTUs (68% of RTU-conditioned commercial floorspace nationally).
- Four RTU HVAC types representing the most common gas and heat pump RTU technologies available.
- Fifteen different energy-efficiency measures or combinations of measures.

To best represent national climatic diversity, the research team assigned geographical climate zone regions in alignment with climate zones from ASHRAE Standard 90.1 (ASHRAE 2019). The research team sought to select the minimum number of regions required to (1) represent the national weather variability; and (2) account for most highly populated cities and regions in the United States. The locations used in this analysis, referred to as the “Reference City” for each region, are based on those used by ASHRAE for its simulation-based codes and standards impact analyses, with revisions representing climate zones 5A and 6A for Chicago, IL, and Minneapolis, MN, respectively. Table 1 details all climate zones, Reference Cities, and the heating degree days (HDD at 65˚F/18˚C) and cooling degree days (CDD at 74˚F/23˚C) for each location in this analysis (ASHRAE 2021). Figure 1 maps climate zones and Reference Cities.

[2] Big Ladder Software, “Modelkit/Params Framework,” https://bigladdersoftware.com/projects/modelkit/

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Table 1. Climate zones and reference cities

ASHRAE 90.1 climate zone	Reference city	HDD65/18	CDD74/23
4C	Seattle, WA	4,621	85
3C	San Diego, CA	1,101	101
5B	Denver, CO	5,874	421
6B	Great Falls, MT	7,593	241
2B	Tucson, AZ	1,328	1,969
3B	El Paso, TX	2,203	1,393
3A	Atlanta, GA	2,578	713
2A	Tampa, FL	481	1,421
5A	Chicago, IL	6,157	337
4A	New York City, NY	4,761	283
6A	Minneapolis, MN	7,396	295

This list of 11 Reference Cities accounted for about 95% of RTU shipments, as presented to Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) Working Group (WG) by industry (EERE 2022), and the United States' population based on state-level 2020 census data (Census Bureau 2021) and county-level 2024 census data (World Population Review 2024).

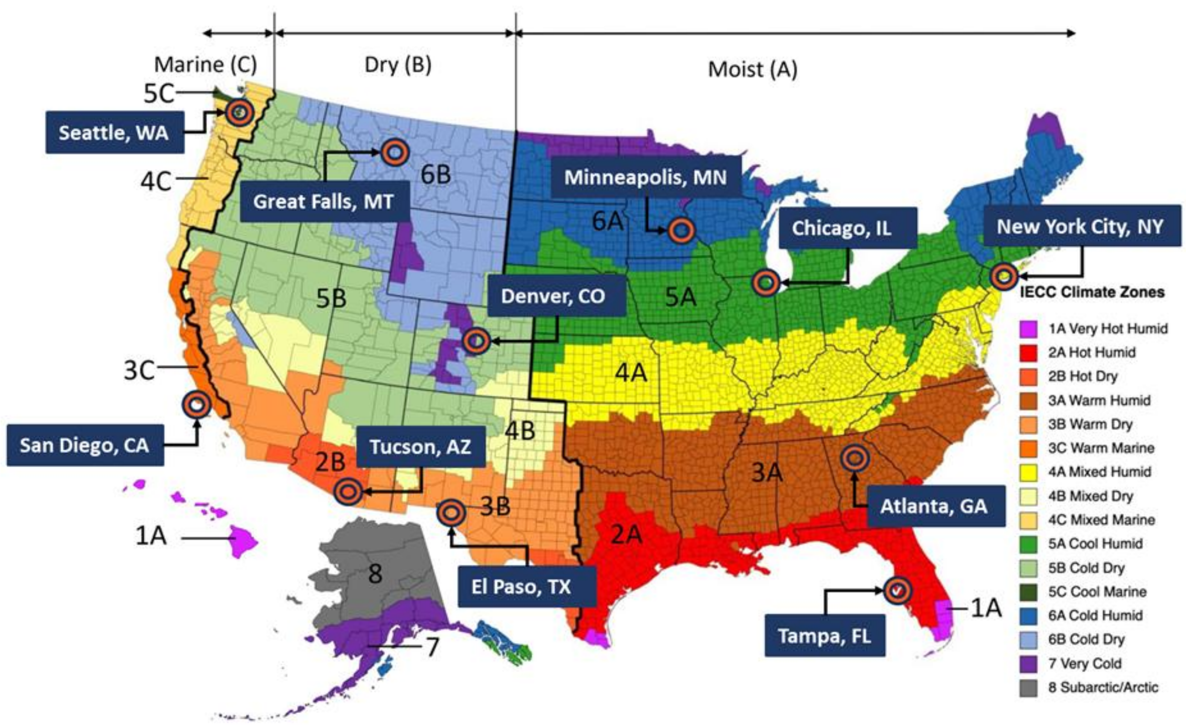

Figure 1. Mapped climate zones and reference cities. *Source: EERE 2022*

The research team carefully selected building types to reflect the majority of typical RTU installations. Using several key metrics, an analysis of the 2018 Commercial Building Energy Consumption Survey (EIA 2018) resulted in the following U.S. Department of Energy (DOE) Commercial Prototype Building Models (DOE 2004) simulated for this effort, which represents roughly 68% of commercial floorspace served by gas RTUs nationally: medium office, single-story medium office[3], stand-alone retail, strip-mall retail, grocery, primary school, and warehouse.

The research team included four packaged RTU system types in this project's scope, as listed and detailed in Table 2.

Table 2. HVAC system type

HVAC system type	System description
Gas Packaged RTU with AC	This system is the "typical" RTU[4]. Based on NEEA conversations with RTU manufacturers, the majority of RTUs sold nationally belong to this system type.
Gas Packaged RTU with Air Conditioner (AC) High-Ventilation	This system uses the same equipment as the gas-packaged RTU with an AC but uses ventilation rates higher than code minimums. Ventilation rates for other studied HVAC systems are set to ASHRAE 62.1-2004 levels (ASHRAE 2004). For this system type, the research team set ventilation rates equal to Leadership in Energy and Environment Design (LEED) v4.1 requirements (LEED 2025), equating to 30% higher outside air ventilation than ASHRAE 62.1-2016 requirements (ASHRAE 2016). The primary purpose of this HVAC type is to assess the potential energy savings increase ERV measure for ventilation rates higher than code minimum requirements.
Packaged Air-Source Heat Pump (ASHP) with Electric Resistance (ER) Backup ("All Electric Heat Pump")	This all-electric RTU system uses an electric heat pump as the main heating component and provides an electric resistance backup function for auxiliary heating.
Packaged ASHP with Gas Backup ("Dual-Fuel Heat Pump")	In this system, the electric heat pump serves as the main heating component, but the unit includes a gas furnace as a backup or auxiliary option. This system type is also called a "dual-fuel unit" or "hybrid unit".

[3] This altered version of the medium office prototype is one-story rather than three-story. Unlike the three-story medium office model, this version of the office building is more likely to be served by single zone packaged RTU systems.

[4] The project team assumed baseline energy models represent existing buildings where owners have replaced their original equipment with a current practice baseline. Therefore, the research team aligned the "typical" RTU with ASHRAE 90.1-2022. For additional details, see NEEA's 2025 National Efficient Rooftop Unit Energy Modeling report (NEEA 2025).

The research team developed the list of efficiency measures and baseline conditions shown in Table 3, which also provides a description of the technology or intervention. The only difference between baseline and measure systems are the descriptions below; all other system components are the same between baseline and measure system, so energy savings reflect only the measure definitions.

Table 3. Efficiency Measures & Baseline Conditions

Measure	Efficient description	Baseline description
Enclosure Insulation	This measure includes two scenarios: (1) R8 Insulation: A moderate amount of enclosure insulation; (2) R12 Insulation: A high amount of enclosure insulation.	Baseline enclosure insulation is R2.
Low-Leakage Dampers	This measure modeled outside air dampers with damper leakage rates equal to ASHRAE 90.1-2019, Table 6.4.3.4.3: Maximum Damper Leakage, which varied by climate zone (ASHRAE 2019).	The baseline damper leakage rate is equal to Air Movement and Control Association's (AMCA) Class 3 from AMCA Standard 500-D (AMCA 2018).
Enclosure Leakage	Reduced air leakage from an RTU enclosure meeting Class-Leakage 24 from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) 1350, Table 2: Casing Air Leakage Rating Class (AHRI 2014).	The baseline enclosure leakage rate is equal to Class-Leakage 100 from AHRI 1350, Table 2: Casing Air Leakage Rating Class.
Efficient Cooling	Cooling efficiencies (EER/IEER) that meet Advanced Tier specifications from the Consortium of Energy Efficiency Unitary AC Specs (CEE 2024).	The baseline cooling efficiency is equal to current federal minimum requirements (SEER2 and IEER ratings) converted to COP.
Energy Recovery Ventilation (ERV)	An additional heat exchanger component capable of recovering energy and moisture from the exhaust air stream and transferring it to the incoming outside air stream.	The baseline systems do not have this heat exchanger.
NEEA Tier 1	This measure, which aligns with NEEA's efficient gas RTU program specification, combines individual measures for R12 insulation and low-leak dampers.	The baseline system aligns with enclosure insulation, and low-leak dampers measure baselines.
NEEA Tier 2	This measure combines individual measures for NEEA Tier 1 (R12 enclosure insulation and low-leak dampers) and ERV.	The baseline system aligns with enclosure insulation, low-leak dampers, and ERV measure baselines.
Low Switchover Temperature	This measure includes two scenarios. (1) Compressor Lockout #1: A low compressor lockout of 15˚F/-9.4˚C; (2) Compressor Lockout #2: A very low compressor lockout of 5˚F/-15˚C.	For baseline systems, the heat pump compressor lockout is set to 30˚F/-1.1˚C based on heat pump program data and outreach to heat pump manufacturers and contractors.

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Cold Climate Heat Pump	This measure estimates the combined impacts of: (1) Removing the compressor lockout entirely, (2) allowing backup heating to turn on at lower temperatures (packaged ASHP with gas backup only), and (3) improving capacity and COP performance of heat pump units at lower temperatures.	The baseline heat pump performance curves are based on the DOE commercial building prototype models (DOE 2004).
Low Switchover Temperature with NEEA Tiers	This measure includes two scenarios: (1) Combine all criteria for Low Switchover Temperature with Compressor Lockout #1 and NEEA Tier 1; (2) Combine all criteria for Low Switchover Temperature with Compressor Lockout #1 and NEEA Tier 2.	The baseline system aligns with enclosure insulation, ERV, low-leak dampers and low switchover temperature measure baselines.
Cold Climate Heat Pump with NEEA Tiers	This measure includes two scenarios: (1) Combine all criteria for Cold Climate Heat Pump and NEEA Tier 1; (2) Combine all criteria for Cold Climate Heat Pump and NEEA Tier 2.	The baseline system aligns with enclosure insulation, low-leak dampers, ERV, and cold climate heat pump measure baselines.

To answer key research questions while balancing the modeling effort, the research team chose not to model every measure with every HVAC system type. Rather, the research team selected the measure set for each HVAC system type based on measure applicability and combinations best suited to answering the analysis' research questions. Table 4 shows the combinations of measures and HVAC system types.

Table 4. Measure segmentation by HVAC system type

HVAC system type	Measures
Gas Packaged RTU	Enclosure Insulation; Enclosure Leakage; Low-Leakage Dampers; Efficient Cooling; ERV; NEEA Tier 1; NEEA Tier 2.
Gas Packaged RTU with High-Ventilation	ERV.
Packaged ASHP with Electric Resistance (ER) Backup	Enclosure Insulation; Low-Leakage Dampers; Efficient Cooling; ERV; NEEA Tier 1; NEEA Tier 2; Low Switchover Temperature; Cold Climate Heat Pump; Low Switchover Temperature + NEEA Tiers; Cold Climate Heat Pump + NEEA Tiers.
Packaged ASHP with Gas Backup	Enclosure Insulation; Low-Leakage Dampers; Efficient Cooling; ERV; NEEA Tier 1; NEEA Tier 2; Low Switchover Temperature; Cold Climate Heat Pump; Low Switchover Temperature + NEEA Tiers; Cold Climate Heat Pump + NEEA Tiers.

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Modeling Approach

For developing the models, the research team adopted the following approach:

- Prepare simulation tool: The research team developed all models using the EnergyPlus modeling framework, Modelkit Flannel (Modelkit), using the simulation engine EnergyPlus version 22.1 as the program back-end. The research team customized the Modelkit script to simulate measures that are not inherent to EnergyPlus.
- Manufacturer specification sheet review: Several key inputs for baseline and measure models varied by RTU capacity and were determined through a review of manufacturer specification or cut sheets.
- Baseline and measure model development: The baseline energy models represent existing buildings where owners have replaced their original equipment with a current practice baseline RTU without applying any of the measures studied. For the measure energy models, the research team implemented measure specifications to applicable HVAC systems as described in Table 3 and Table 4.

Model Results

This section presents the results of the modeling research. First, we present baseline results followed by measure results. The research team used national RTU shipment data to weight results across climate zones. RTU shipments are dominated by large cities in cold climates, such as New York City, NY (4A), Chicago, IL (5A), and Minneapolis (6A), creating bias in the national savings results toward colder climates. Regardless of this bias, national results provide a helpful snapshot of RTU energy use and savings potential for informing national programs and standards. All HVAC energy savings presented in this report include gas and electric savings.

Baseline Model Results

For the simulated baseline systems, Figure 2 provides the average annual HVAC energy consumption results nationally by (1) end use as a percentage of HVAC energy use intensity (EUI) (left y-axis), and (2) total HVAC energy consumption as a percentage of whole building EUI (right y-axis). As shown, heating energy makes up a dominant portion of HVAC consumption — between 53% and 70%— nationally across all RTU types. Cooling energy consumption is much lower than heating consumption nationally, ranging from 18% to 28% of HVAC energy consumption. As performance standards— which focus primarily on cooling efficiency gains— continue to increase in stringency, there will be diminishing returns on energy savings from cooling. Meanwhile, opportunities are increasing to obtain energy savings from heating efficiency gains and heating-related energy consumption reductions.

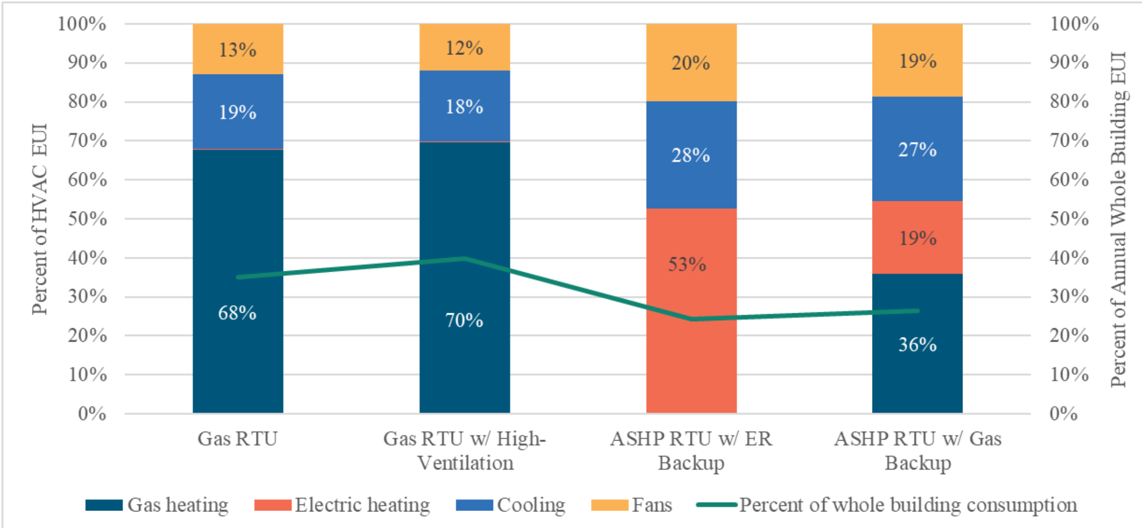

Figure 2. National Average Baseline Energy Consumption by HVAC System Type. Some bars may not exactly equal 100% due to rounding errors. *Source: NEEA 2025*

The baseline consumption results also illustrate how both all-electric and dual-fuel heat pump RTUs consume less energy, 24% and 26%, of whole building EUI respectively, than gas RTUs, which consume 35% of whole building energy. Heat pumps with gas backup offer an effective alternative to an all-electric heat pump for reducing gas consumption while balancing the increased cost of consuming electric heat.

Lastly, the baseline consumption results show how higher ventilation increases heating energy usage, as shown by the gas RTU with high-ventilation HVAC system type.

Measure Model Results

Measure energy savings results are shown in Table 5 for each HVAC system type. Results are presented in terms of the average annual percentage of HVAC energy savings nationally and in order of highest energy savings percentages for gas RTUs. Energy savings percentages differ across HVAC system types and, as shown in Table 5, heat pump RTUs were simulated with more measures than gas RTUs. As shown, bundled measures such as NEEA Tier 1, NEEA Tier 2, and combinations of these measures with the cold climate heat pump and low switchover temperature measures yielded the highest energy savings potential nationally. For gas RTUs, the addition of ERVs (and therefore the NEEA Tier 2 measure) offers significant energy savings potential, especially for gas RTUs with ventilation levels higher than code minimum requirements. Enclosure insulation and low leakage dampers measures individually offer moderate energy savings potential but combined as shown in NEEA Tier 1, these measures have substantial energy savings potential for all RTUs. Enclosure leakage – which is a measure that to our knowledge has never been simulated before – also yielded considerable energy savings potential on par with other enclosure measures. Efficient cooling is amongst the lowest energy savings opportunities nationally across all HVAC types.

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Table 5. HVAC measure national average energy savings percentage results

Measure	Gas RTU	Gas RTU with high ventilation	ASHP RTU with ER backup	ASHP RTU with gas backup
NEEA Tier 2	20%	-	12%	14%
ERV	11%	14%	3.4%	3.4%
NEEA Tier 1	9.4%	-	8.4%	8.7%
Enclosure Leakage	6.0%	-	4.8%	4.9%
Enclosure Insulation R12	5.2%	-	4.3%	4.5%
Enclosure Insulation R8	4.7%	-	3.9%	4.0%
Low Leakage Dampers	4.2%	-	4.0%	4.0%
Efficient Cooling	1.8%	-	3.5%	3.4%
Cold Climate Heat Pump + NEEA Tier 2	-	-	23%	27%
Low Switchover Temperature 1 + NEEA Tier 2	-	-	21%	24%
Cold Climate Heat Pump + NEEA Tier 1	-	-	20%	23%
Low Switchover Temperature + NEEA Tier 1	-	-	18%	20%
Cold Climate Heat Pump	-	-	13%	17%
Low Switchover Temperature 2	-	-	12%	16%
Low Switchover Temperature 1	-	-	11%	12%

Bundled measures result in the highest national average energy savings.

It should be noted that HVAC energy savings percentages vary widely by location. This paper presents national average energy savings, unless otherwise noted; however, national averages mask variations by climate zone. Therefore, it may be appropriate to consider impacts by climate regions. For example, efficient cooling produces considerable RTU energy savings opportunities in hot climates, but not in cold climates, as shown in Table 6. For more detailed results, including energy savings by end use and location, see the National Efficient Rooftop Unit Energy Modeling report (NEEA 2025).

Table 6. Efficient cooling measure percentage HVAC savings

Location	Gas RTU	ASHP RTU with ER Backup	ASHP RTU with Gas Backup
Seattle, WA (4C)	0.3%	1.1%	1.1%
Minneapolis, MN (6A)	0.4%	0.8%	0.6%
Tampa, FL (2A)	5.6%	9.0%	9.0%

Efficiency cooling measures can provide significant savings in hot and humid climates.

Measure Interactions. One goal of this research was to determine if bundling measures together would result in diminishing energy savings. As mentioned above, bundled measures, such as NEEA Tier 1 and Tier 2 result in some of the highest energy savings. The research team found that bundling measures resulted in minimal interactive effects ranging from -2.6% to +0.2%. In general, bundled measures resulted in nearly additive energy savings. Table 7, Table 8, and Table 9 compare NEEA Tier 1 and Tier 2 savings to the measures that make up each tier for gas RTUs, ASHP RTUs with electric resistance backup, and ASHP RTUs with gas backup respectively.

Table 7. Impacts by tier and constituent measures for gas RTUs

Measure	NEEA Tier 1	NEEA Tier 2
Enclosure Insulation R12	5.2%	5.2%
Low Leakage Dampers	4.2%	4.2%
ERV	-	10.8%
Measure Total	9.4%	20.2%
Tier Result	9.4%	20.0%

Gas RTUs see minimal interactive effects when bundling measures.

Table 8. Impacts by tier and constituent measures for ASHP RTUs with electric resistance backup

Measure	NEEA Tier 1	NEEA Tier 2	LST 1 + NEEA T1	LST 1 + NEEA T2	CCHP + NEEA T1	CCHP + NEEA T2
Enclosure Insulation R12	4.3%	4.3%	4.3%	4.3%	4.3%	4.3%
Low Leakage Dampers	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
ERV	-	3.4%	-	3.4%	-	3.4%
Low Switchover Temperature 1	-	-	10.9%	10.9%	-	-
Cold Climate Heat Pump	-	-	-	-	13.4%	13.4%
Measure Total	8.3%	11.7%	19.2%	22.6%	21.7%	25.1%
Tier Result	8.4%	11.9%	17.7%	21.1%	19.9%	23.3%

The research team found that summing savings from individual measures that make up NEEA T1 and NEEA T2 bundled measures for ASHP RTUs with gas backup (i.e., insulation R12, Low leakage dampers, and ERV) resulted in about 0.2% interactive effects. However, bundled measures that include Low switchover temperature 1 (i.e., LST 1 + NEEA T1 and LST 1 + NEEA T2) had about 1.5% interactive effects and bundled measures that include Cold climate heat pumps (i.e., CCHP + NEEA T1 and CCHP + NEEA T2) had about 2% interactive effects.

Table 9. Impacts by tier and constituent measures for ASHP RTUs with gas backup

Measure	NEEA T1	NEEA T2	LST 1 + NEEA T1	LST 1 + NEEA T2	CCHP + NEEA T1	CCHP + NEEA T2
Enclosure Insulation R12	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
Low Leakage Dampers	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%
ERV	-	3.4%	-	3.4%	-	3.4%

Low Switchover Temperature 1	-	-	13.7%	13.7%	-	-
Cold Climate Heat Pump	-	-	-	-	17.3%	17.3%
Measure Total	8.6%	12.0%	22.3%	25.7%	25.9%	29.3%
Tier Result	8.7%	12.2%	20.3%	23.6%	23.4%	26.7%

The research team found that summing savings from individual measures that make up NEEA T1 and NEEA T2 bundled measures for ASHP RTUs with gas backup (i.e., insulation R12, Low leakage dampers, and ERV) resulted about 0.2% interactive effects. However, bundled measures that include Low switchover temperature 1 or Cold climate heat pump (i.e., LST 1 + NEEA T1, LST 1 + NEEA T2, CCHP + NEEA T1, and CCHP + NEEA T2) had about 2% interactive effects. Gas RTU baseline vs. heat pump RTUs.

In addition to the impacts of energy-efficiency measures, the research team also investigated the results of replacing gas RTUs with various all-electric and dual-fuel heat pump RTUs. The results for converting to a code minimum ASHP, cold climate heat pump (CCHP), and a CCHP with the addition of the NEEA Tier 1 measure bundle are shown in Table 10; these are presented in terms of average annual HVAC energy savings percentage per location. For brevity, while demonstrating the differences of energy savings across climate zones, Table 10 includes results from mild [Seattle, WA (4C)], cold [Minneapolis, MN (6A)], and hot [Tampa, FL (2A)] climates. Overall, switching from a gas RTU to a heat pump RTU yielded higher energy savings potential nationally than any other measure or measure bundle. Notably, given the increase in electric energy consumption, energy bills may increase for consumers due to electric energy's higher cost than gas. Dual-fuel heat pump RTUs may provide a preferred option for consumers in very cold climates, where significant gas energy savings potential exists without the added consumption of more expensive electric backup heating when ambient temperatures drop below the switchover set point. Lastly, the addition of the NEEA Tier 1 measure bundle with a CCHP replacement demonstrates a significant step-up in energy savings in most climate zones. For more detailed results, including energy savings by all end uses, locations, and conversion scenarios (including the conversion to a CCHP with a NEEA Tier 2 measure bundle), see the National Efficient Rooftop Unit Energy Modeling report (NEEA 2025).

Table 10. Gas RTU replacement HVAC energy savings percentage results by location

Location	ASHP RTU w/ ER backup	ASHP RTU w/ gas backup	CCHP w/ ER backup	CCHP w/ gas backup	CCHP w/ ER backup + NEEA Tier 1	CCHP w/ gas backup + NEEA Tier 1
Seattle, WA (4C)	58%	58%	59%	59%	63%	63%
Minneapolis, MN (6A)	26%	14%	45%	42%	52%	50%
Tampa, FL (2A)	13%	13%	14%	14%	15%	15%

Recommendations

The findings from the model results provide valuable insights that policymakers, program designers, and industry stakeholders could leverage to improve HVAC efficiency. This section will discuss opportunities for improving federal standards and test procedures as well as regional

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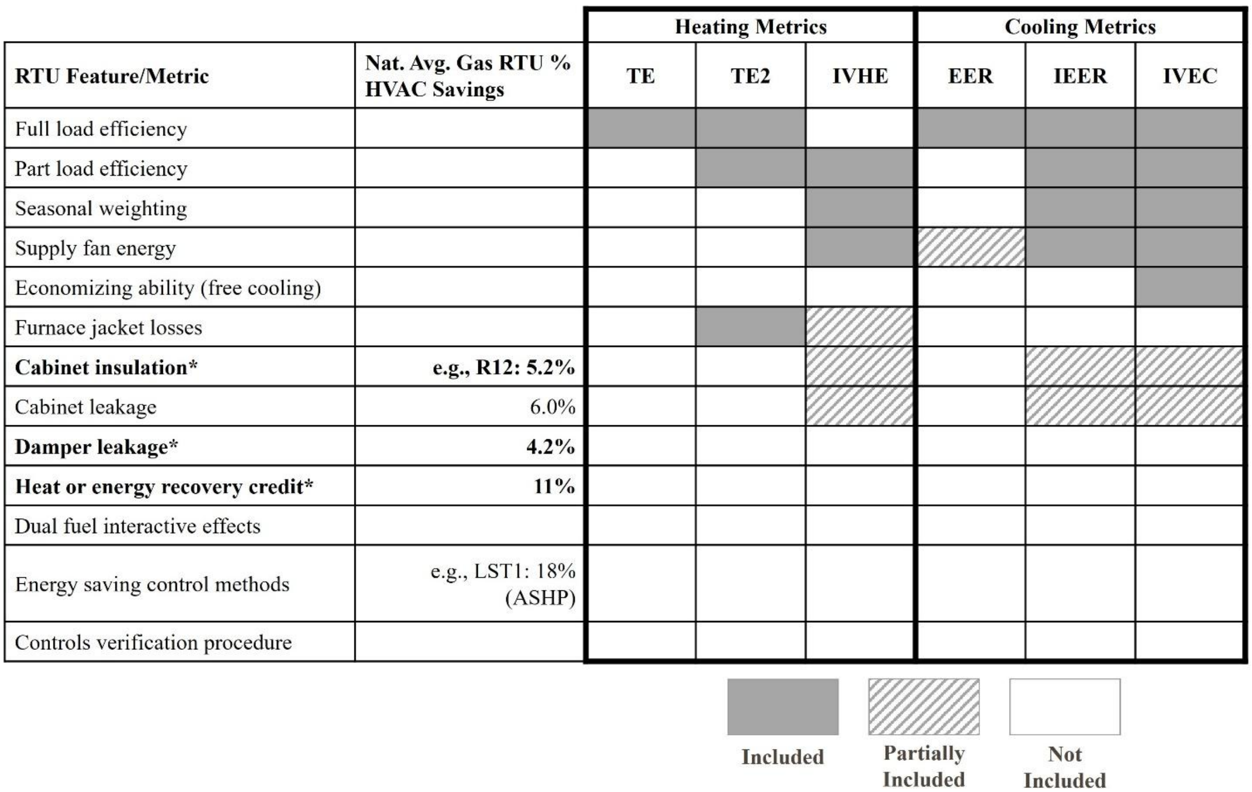
codes based on HVAC energy savings identified in this research. The following recommendations will require additional research focused on regional and national energy costs, and incremental costs associated with these measures.

Federal Standards and Test Procedures

As highlighted in Figure 3, some measures demonstrating significant energy savings through this research are not currently valued in RTU test procedures and federal regulations, such as ERVs, damper leakage, and switchover temperature setpoints.



RTU Feature/Metric	Nat. Avg. Gas RTU % HVAC Savings	Heating Metrics: TE	Heating Metrics: TE2	Heating Metrics: IVHE	Cooling Metrics: EER	Cooling Metrics: IEER	Cooling Metrics: IVEC
Full load efficiency							
Part load efficiency							
Seasonal weighting							
Supply fan energy							
Economizing ability (free cooling)							
Furnace jacket losses							
Cabinet insulation*	**e.g., R12: 5.2%**						
Cabinet leakage	6.0%						
Damper leakage*	**4.2%**						
Heat or energy recovery credit*	**11%**						
Dual fuel interactive effects							
Energy saving control methods	e.g., LST1: 18% (ASHP)						
Controls verification procedure							

Figure 3. Energy saving RTU features included, partially included, or not included in current test procedures. NEEA's program focuses on features denoted with an asterisk. *Source: NEEA*

While test procedures partially account for the value of the enclosure insulation and enclosure leakage measures, the impacts of the ratings from these measures are not proportional to their energy savings potential. This research can be used to support efforts to improve RTU regulations through the adoption of whole-box test procedures and performance metrics by quantifying the value of the measures in climates across the United States.

Regional Codes

In addition to federal standards, this research can support efforts to require efficient RTU features in energy codes. For some installations, energy codes already require low leakage dampers and ERVs. These requirements could be increased or expanded to include other measures, such as enclosure insulation or advanced heat pump controls. As energy savings for some measures vary significantly by climate zones, energy codes present an opportunity to account for regional variability in a way that federal standards typically cannot. An example of measure savings variation by climate zone is outlined in Table 11. A regional code in Tampa, FL may want to focus on efficient cooling and enclosure insulation, while codes in Minneapolis, MN and Seattle, WA may prioritize low-leakage dampers and enclosure insulation.

Table 11. Percent HVAC savings for locations representing hot, cold, and mild climates

Location	Efficient cooling	Enclosure insulation R12	Low-leakage dampers
Seattle, WA (4C)	0.3%	6.1%	3.7%
Minneapolis, MN (6A)	0.4%	6.1%	7.1%
Tampa, FL (2A)	5.6%	2.1%	0.5%

Conclusion

This study provides a comprehensive analysis of commercial HVAC efficiency measures for various commercial RTU equipment, including the corresponding energy savings potential, broader implications for market transformation, and influence on energy codes and standards. The findings highlight the significant energy savings potential for various RTU-related measures and measure combinations and inspire future research to understand cost-effectiveness of these measures in support of code and standard development.

Across all climate zones and HVAC system types, the highest energy savings potential that the study identified resulted from combining multiple measures, as shown for NEEA Tier 1, NEEA Tier 2, and combinations of these measures with cold climate heat pump and low switchover temperature measures (8.4% to 24% of total HVAC energy usage on average). The research team recommends pursuing bundled measures or whole-box approaches in efficiency programs rather than focusing solely on individual upgrades. Among individual efficiency measure performance nationally, gas RTUs can benefit the most from the ERV measure (11% of total HVAC energy usage on average). The cold climate heat pump measure had the highest potential energy savings for heat pump RTUs (13% to 17% of total HVAC energy usage on average). Reducing enclosure leakage also yielded considerable energy savings potential across all HVAC types (4.8% to 6.0% of total HVAC energy usage on average). One critical insight from this research is that cooling efficiency improvements face diminishing returns nationally; this study suggests a need for a shift in regulatory focus from cooling efficiency towards incorporating features such as ERVs, heat pump controls, and combinations of enclosure measures, which provide more substantial heating-related energy savings.

Depending on the climate zone and backup fuel type, converting a gas RTU to a standard-practice heat pump RTU can save 13% to 58% of total HVAC energy usage on average. Total HVAC energy savings can be even higher, up to 63% when incorporating the NEEA Tier 1 measure bundle. Although this study did not examine carbon savings, these measures could have a drastic (or even complete) reduction in emissions, depending on the electricity source. Dual-fuel heat pumps can save a similar amount of energy with a less expensive backup source and without requiring electrical upgrades. The additional energy savings captured between code minimum ASHPs and CCHPs vary widely, with very cold locations experiencing the greatest increases in additional energy savings.

Lastly, many measures studied, such as ERVs, low-leakage dampers, and cabinet insulation, are not fully considered in current RTU test procedures and federal standards. While current test procedures partially account for the value of the enclosure insulation, and enclosure leakage measures, impacts on the ratings from these measures are not proportional to their energy savings potential. The industry needs to move away from component-based test procedures and work toward testing and rating RTUs with a whole-box metric that captures all features that consume or save energy. The research presented in this paper can be used to support the adoption of whole-box test procedures and performance metrics by quantifying the value of the measures nationally and in individual climates across the U.S.

In addition to federal standards, this research can support efforts to require efficient RTU features in energy codes. Energy codes present an opportunity to account for regional variability in a way that federal standards typically cannot. Code already requires low-leak dampers and ERVs in some scenarios; however, these requirements could be expanded to include other measures, such as enclosure insulation or advanced heat pump controls.

Overall, this study contributes valuable insights to inform efficiency programs, policy development, and market transformation efforts. Using data from this effort, programs can drive meaningful advancements in HVAC efficiency, leading to substantial energy savings nationwide.

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