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High-Performance RTU Market Characterization

Center for Energy and Environment (CEE)

Developed For

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Executive Summary

In February 2023, Center for Energy and the Environment (CEE) contracted with Cadeo to conduct a baseline market characterization for commercial rooftop units (RTUs) to inform the development of a high-performance RTU initiative.

1.1 Goals and Approach

This research was designed to provide market intelligence and improve CEE's overall understanding of the commercial RTU market and supply chain dynamics, identify the barriers and opportunities for increased adoption of efficient equipment, and provide direction for CEE's program development efforts.

CEE is considering developing two sub-types of high-performance RTUs: Efficient Gas RTUs and Dual Fuel Heat Pump RTUs. CEE has identified five priority efficient components, which are likely candidates to be combined into the final Efficient Gas RTU and Dual Fuel Heat Pump RTU product definitions:

- **Dual fuel heat pumps.** Use an electric heat pump as the main heating component, but a gas furnace for backup or auxiliary heat. *This design option is applicable to dual fuel RTUs only.*
- **Energy recovery ventilators (ERVs).** Recover energy from the exhaust air stream and transfer it to the incoming fresh-air stream.
- **Variable speed supply air fans (variable speed fans).** Provide the ability to vary supply airflow by changing the speed of the fan.
- **Low-leakage dampers.** Include outside air dampers with seals to prevent conditioned air leakage when they are closed.
- **Increased enclosure insulation.** Provide insulation levels greater than standard practice; typically, this is double-wall foam construction.

This market characterization was designed to understand the perspectives of two groups of important market actors:

- **Supply-Side Market Actors**, including the manufacturers, distributors, and contractors responsible for producing, procuring, and installing RTUs. This group is collectively referred to as the supply chain.
- **Demand-Side Market Actors**, including the building owner, who is ultimately responsible for the purchase, as well as facility managers, third-party property managers, maintenance managers, superintendents, city sustainability coordinators, and building engineers who are involved in specifying the product and advising the building owner on the purchase.

The primary data collection effort for this project included in-depth interviews, which occurred between May 2023 and July 2023. Cadeo completed 34 interviews in total, with an even split (17 each) across the two main market influencer groups.

1.2 Findings and Recommendations

This section of the Executive Summary combines key findings from the research with the main recommendations included in the conclusion of this report. Our findings and recommendations are grouped in three main categories:

1 | Supply Chain Dynamics. How equipment flows through the marketplace from manufacturer to distributor.
2 | Product Components. The barriers and opportunities related to the incorporation of efficient features into RTU equipment.
3 | Program Activities. Recommendations for CEE to consider as they develop a market transformation program focused on high-performance RTU equipment.

Supply Chain Dynamics

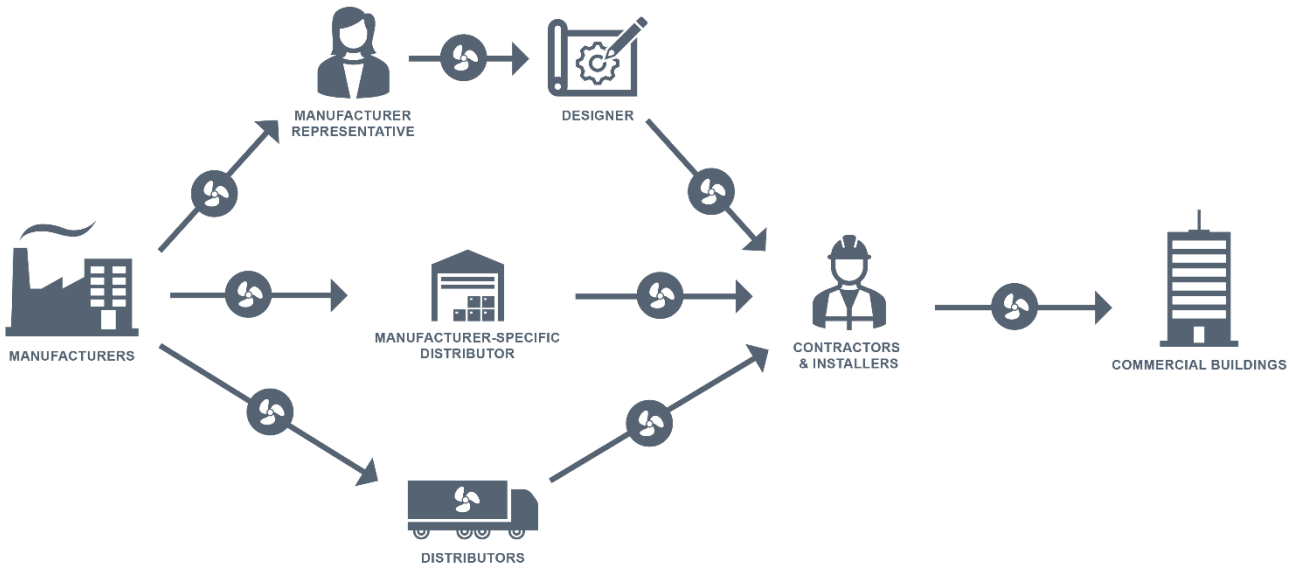
The flow of information, money, and physical equipment will vary from project to project; however, Figure 1 shows the primary connections between common market actors.

RTU manufacturers use a variety of strategies to deliver their products to end users:

- Manufacturer representatives and designers work together to provide a specialized piece of equipment. This path is less common for RTU replacements, covering less than 10% of the market.
- Distributors stock products purchased wholesale from various manufacturers and supply most of the standard efficiency commodity equipment.
- Manufacturer-specific distributors only represent a single brand per equipment type or across all products offered (e.g., Trane Twin Cities).

All of these players will influence contractors and installers who then recommend equipment to their customers—commercial building representatives.

Figure 1 Simplified RTU Market Map



Conclusion: Market actors report different barriers to promotion or adoption of Efficient Gas RTU and Dual Fuel Heat Pump RTU products.

Contractors state they "teach and preach" planned replacements, but building representatives do not always have the funding available so equipment is replaced only after it has failed. After a product has failed, it's an emergency, so contractors tend to only offer products with a quick turnaround. The different

objectives of these two parties can lead to friction in their interaction and decrease the likelihood that efficient options will be selected.

Recommendation: Develop strategies that address the needs of both groups in emergency replacement scenarios.

- Contractors need efficient equipment to be available right away in a form factor that will not require complicated building renovations.
- Building owners need help understanding and advocating for efficient equipment that will save them money over the lifetime of the equipment.

Product Components

CEE sought to understand the barriers, opportunities, and availability for five different product features associated with improved RTU energy performance. Table 1 summarizes the barriers and opportunities for each energy saving feature. Increased cost emerged as a barrier to every efficient feature and is generally believed to be the main barrier to increased adoption; however, other dynamics are also present.

Table 1: Summary of Barriers and Opportunities for Efficient Features

Feature	Barriers	Opportunities
Dual fuel heat pump	Market familiarity and acceptance Workforce training and development	Excitement around heat pumps Dual fuel is an excellent bridge technology to electrification
Energy recovery ventilator (ERV)	Perception that ERVs are only for 100% outside air Increases system complexity	Largest savings opportunity Bolt-on ERV may be a stocking intervention point
Variable speed fans	Additional training and technical support needed for contractors	Best market acceptance and awareness Helps with commissioning
Low-leakage outside air dampers	Not always in stock Associated with meeting code, not an energy savings opportunity[1]	Easiest ask—people are very used to them because of code requirement[2]
Increased enclosure insulation	Requires larger manufacturing change Lowest priority for manufacturers	Also provides desirable non-energy benefits Permanent change in manufacturing practice

[1] While the code requirement is certainly energy related, this perception barrier means it is less likely that someone would *voluntarily* add them to save energy or reduce their operating costs—they will only ever add them when triggered by code.
[2] 2020 MN Code C403.7.7 – 4 cfm/ft2 at 1 in w.g. (Ultra-low leak), automatic controls required.
https://codes.iccsafe.org/content/MNEC2020P1/chapter-4-ce-commercial-energy-efficiency#MNEC2020P1_CE_Ch04_SecC403.7.7

Table 2 summarizes the current market availability and sales for efficient features. All features had products available from one or more manufacturers, and supply chain contacts expect increased availability and sales. Insulation is the exception to this because manufacturers expected no change in availability or sales.

Table 2: Current Availability and Sales of Efficient Features

Feature	Product Availability	Sales
Dual fuel heat pump	Small availability, but expanding	Very low sales, but expected to increase quickly
Energy recovery ventilator (ERV)	Small availability, but expanding	Very low sales, some increase expected
Variable speed fans	Good availability	Moderate sales
Low-leakage dampers	100% availability	High sales
Increased enclosure insulation	Small availability, no change expected	Low sales, expected to stay the same

Informed by these results, the team developed the following conclusions and recommendations related to efficient product components:

Conclusion: The Efficient Gas RTU product definition will need to balance availability and long-term savings.

Findings indicate tradeoffs between incorporating components available today with those most likely to lead to long-term savings. Combining readily available features, such as fans and dampers, will mean the program has many units available today that can be incentivized, but this product definition will result in a smaller energy savings opportunity than a definition that incorporates all or most of the efficient features. Combining additional features into the Efficient Gas RTU product definition, like ERV and insulation, will result in more savings available from each unit, but will mean less product availability.

Recommendation: Consider developing a flexible approach that balances near-term availability and savings with long-term market transformation goals. For example, the program could include a near-term prescriptive option that is widely available in the market and could serve emergency replacement scenarios (e.g., efficient fans + low-leakage dampers *or* an ERV), and a second tier that defines a more comprehensive "high efficiency" product based either on a whole box metric or more comprehensive list of efficient features.

Conclusion: Dual Fuel Heat Pump RTUs are an emerging technology that could use a clear value proposition and definitional boundaries.

Supply chain interviews revealed that while dual fuel heat pump RTUs are available in the market, they are currently not widely deployed due to product cost and lack of market familiarity with equipment.

However, all manufacturers were invested in promoting this technology and projected that sales would increase significantly in the near future. Developing a clear definition and value proposition for dual fuel equipment will be important in developing strong demand for this equipment in the contractor and building owner community. Further research into the perceived and realized value of dual fuel equipment could be beneficial. We also observed a variety of different equipment types—all of which could fall under the dual fuel umbrella. We propose the following five options for CEE to consider for the product definition:

1 | "Standard" dual fuel with baseline controls
2 | Dual fuel with efficient controls[3]
3 | Dual fuel with simultaneous operation
4 | Dual fuel with Efficient Gas RTU features
5 | Dual fuel with ERV

The Efficient Gas RTU features and baseline and efficient controls are conceptual but not technical terms and do not have product definitions or requirements yet. CEE's next step is to further research these options (or others) to understand the savings potential, and an outcome of that research may be that there is not an incremental savings difference between options 1 and 2, or that option 5 has no product availability at this time.

Recommendation: CEE should further research the product availability, incremental cost, and (most importantly) the savings potential of Dual Fuel Heat Pump RTU product options before finalizing the Dual Fuel Heat Pump RTU product opportunity.

Program Activities

Cadeo identified five key programmatic conclusions and recommendations related to product definition, incremental costs, and supply chain engagement for CEE to consider as the organization finalizes the market intervention strategy.

Conclusion 1: The standard association with "efficient RTU" and efficient cooling undermines programmatic efforts to promote heating efficiency. Everyone across the supply chain, building representatives, and even the efficiency community associates an "efficient RTU" with a unit that has a high cooling rating. While cooling ratings certainly matter, it is an incomplete picture of the potential for energy savings in RTUs. This limited association reduces attention on any energy saving feature not well accounted for in the cooling metric. Similarly, "heating efficiency" is associated with furnace efficiency, which does not account for all features that reduce heating energy, specifically the five efficient features CEE is considering for their efficient product definition.

Recommendation 1: CEE should address this misconception in conversations about RTU efficiency and use the program as an opportunity to bring awareness of heating energy saving opportunities.

[3] In this report, "efficient controls" is not meant as a specific technical definition, but as the concept of RTU controls that offer energy savings over baseline controls. RTUs can have a range of control options, including but not limited to economizing, demand-controlled ventilation, fan control, temperature setbacks, and reset logic, but future program requirements would categorize these into either baseline or efficient controls. Some dual fuel HP manufacturers claim to have efficient control capability that maximizes the use of the heat pump and minimizes the use of the furnace, but the magnitude of these savings has not yet been confirmed.

CEE can develop a distributor training curriculum and deliver this message to distributors and their affiliated installers. Another opportunity is to help manufacturers market the heating efficiency benefits by marketing features associated with these savings.

Conclusion 2: Product-specific incremental cost data remains opaque and subject to diverse and variable market dynamics. RTU costs vary widely and many of the reasons for this variation remain unknown. CEE collected cost estimates for review in this project, but the quotes often contain insufficient information to explain the wide variation in costs. The key unknowns in pricing include:

- Contractor and distributor markups.
- Installation and labor costs.
- How specific product features drive cost differentials.
- Hedging related to supply chain disruptions.

Recommendation 2: As the vagaries of commercial HVAC pricing are likely to persist in the market, we recommend CEE focus future data collection efforts on upstream product- and feature-specific incremental costs. While reducing premium pricing for efficient equipment is an important focus for program interventions, specific data on current pricing practices is not necessary in order to affect these practices and may not be worth the significant resources necessary to collect robust data.

Conclusion 3: Transparency and trust between building owners and contractors is needed to bring high-performance RTU equipment options into the quoting and solicitation process. We heard from many building representatives that working with contractors is a challenge for them. We also heard from contractors that they feel constrained on what they can offer by the timeline and budget they're given by building representatives. This lack of transparency, trust, and understanding all lead to the same outcome: a cheaper, less-efficient RTU getting installed.

Recommendation 3: Provide support for both sides of the contractor/building representative conversation to make high-performance RTU options an expected part of the conversation. CEE could do this by implementing program interventions that:

- Support contractors by providing them with training and materials that help them explain the benefits of efficient components to their customers and encouraging or incentivizing them to quote efficient equipment options.
- Support building owners by providing example specifications, technical assistance in project and bid review, and even support in vetting or working with contractors to help them ensure that efficient options are part of their consideration set.

Conclusion 4: CEE will need to expand supply chain relationships and become a trusted partner in order to effectively implement midstream market interventions. Contractors and distributors in the Minnesota market were the hardest population to reach in this study. Building representatives also reported difficulties finding and working with contractors, indicating that these professionals are busy and not worried about expanding their work. Contractors and distributors are also key market actors in the procurement of high-performance RTU equipment. CEE will need to build relationships with key partners in this space to effectively implement a market transformation program.

Recommendation 4: CEE should build upon the outreach work completed through this research to identify key organizations and individuals in the distribution market that serve as market leaders.

CEE should then approach these potential partners with a value proposition that works for them to participate. CEE should also invest resources in relationship management throughout the engagement to build a taxonomy for the Minnesota RTU market that can be adapted as contacts change jobs or during mergers and acquisitions. Proactively managing these contacts will also be important, as turnover can affect program implementation.

Conclusion 5: Prepare to leverage research and development activities underway at manufacturers. Manufacturers, especially the manufacturers with the largest market share, often only make product development improvements when they are forced to by regulations and codes. Most recently, manufacturers were focused on meeting the increased 2023 cooling standards, and they are now focused on meeting the upcoming refrigerant phase out. This effort is taking up their limited time and money available for other product development, including development related to the efficient features CEE is interested in.

Recommendation 5: Look for opportunities to link efficient components with other manufacturer R&D priorities. CEE should look for opportunities to link desired product development with other required changes, organizational goals (e.g., GHG emissions reduction), or meeting stretch codes. This is probably best accomplished by working with others and approaching manufacturers with a single coordinated ask. CEE should also consider opportunities to align with other voluntary programs, utility programs, and efficiency organizations such as NEEA, Enbridge, Consortium for Energy Efficiency, and ENERGY STAR. Aligning with other high-performance RTU programs and specifications will increase the impact of CEE's program and increase the potential market for these efficient products.

Section 1 Introduction

In July 2022, Minnesota Department of Commerce approved a market transformation portfolio as proposed by Center for Energy and the Environment (CEE) known as the Minnesota Efficient Technology Accelerator (ETA). This proposal included an initial portfolio of projects, including one focused on promoting high-performance rooftop units (RTUs).

CEE's portfolio of market transformation initiatives is designed to create lasting change in a variety of markets, including the market for high-performance RTUs. The High-Performance RTU initiative will be statewide, spanning multiple utility territories and covering both retrofit and new construction markets. CEE's efforts are expected to address both efficient gas-fired RTUs (Efficient Gas RTUs) and dual fuel heat pump RTUs (Dual Fuel Heat Pump RTUs). This report uses the term "high-performance RTU" when speaking about efficient equipment generally, and Efficient Gas RTU or Dual Fuel Heat Pump RTU when speaking about those unique products.

In February 2023, CEE contracted with Cadeo to conduct a baseline market characterization designed to understand the perspectives of two groups of important market influencers:

- **Supply Side-Market Actors**, including the manufacturers, distributors, and contractors responsible for producing, procuring, and installing high-performance RTUs. This group is collectively referred to as the supply chain in this report.
- **Demand-Side Market Actors**, including the building owner, who is ultimately responsible for the purchase, as well as facility managers, third-party property managers, maintenance managers, superintendents, city sustainability coordinators, and building engineers who are involved in specifying the product and advising the building owner on the purchase.

1.1 Research Goals

For this project, CEE established the following research objectives:

- Identify and confirm market barriers and drivers for installing high-performance RTUs, including costs, technical/infrastructure limitations, and product availability.
- Identify opportunities to accelerate the adoption of high-performance RTU products.
- Understand baseline awareness and market perceptions of high-performance RTU products.
- Identify and confirm market dynamics and paths to purchase for Efficient Gas RTUs and Dual Fuel RTUs.
- Document current project costs, current manufacturing costs, and projected manufacturing costs with increased market share over time.

Cadeo addressed these objectives through a combination of secondary data analysis (including existing documentation) and primary data collection (interviews).

1.2 High-Performance RTU Products

RTUs are responsible for heating and cooling 60% of US commercial building floor area and represent about a fifth of total commercial building energy use.[4] In Minnesota, there are 20,700 buildings with RTUs, which represents nearly 80% of commercial buildings or 730 million square feet.[5] There is significant variation in this market, ranging from mass-produced economic options to premium highly configurable pieces of equipment. The design of and features included in an RTU can have a significant impact on the amount of fuel it uses and the amount of heating and cooling capacity it provides.

Generally speaking, RTUs are composed of three major sections: a supply air fan, a cooling component (typically an integrated refrigeration system[6]), and a heating component (typically a gas furnace). These three components are also the three main energy consumers of the system—using either electricity or gas fuel.

Energy Saving Opportunities in RTUs

CEE is working to define a high-performance RTU that uses less energy while still meeting the heating/cooling demands of commercial buildings and maintaining or improving user experiences with the equipment. In addition to the three major sections of an RTU, there are many other auxiliary components and features that will impact how efficiently the equipment operates. There are three primary concepts underlying efficiency opportunities:

1. **Use less electricity and gas by increasing operational efficiency.** Operational efficiency is improved when a piece of equipment provides the same amount of output capacity with less energy input (i.e., fuel). Previous energy efficiency research and utility programs for RTUs have focused on ways to increase operational efficiency of the three key functional components.

- **Higher efficiency fans.** Include higher efficiency motors, improved fan blade design, and/or variable speed capability.
- **Higher efficiency cooling.** Characterized by high cooling ratings such as seasonal energy efficiency ratio (SEER2)[7] for residential and smaller capacity commercial units, and integrated energy efficiency ratio (IEER)[8] for larger capacity commercial units.
- **Higher efficiency gas furnace.** Designated by higher thermal efficiency (TE)[9] rating, such as a condensing furnace (>90% TE).
- **Change to electric heat pump.** Electric heating is much more efficient on a BTU basis and changes the fuel source from gas to electricity (i.e., electrification), which can help jurisdictions achieve carbon reduction goals.

[4] DOE Advanced Rooftop Unit Campaign https://www.energy.gov/eere/buildings/articles/retrofitting-commercial-rooftop-units-results-savings-56-million
[5] CEE 2017 CARD Final Report: Commercial Roof-top Units in Minnesota—Characteristics and Energy Performance
[6] The refrigeration system in a heat pump is also used for heating when in heat pump mode.
[7] SEER2 is the DOE regulated metric for residential central AC and small commercial packaged equipment. SEER2 ratings are developed using the Air Conditioning, Heating, and Refrigeration Institute (AHRI) test procedure AHRI 210/240-2020.
[8] IEER is currently the DOE-regulated metric for commercial unitary equipment. The test procedure for IEER is AHRI 340/360-2022.
[9] TE is the current warm-air furnace metric used for regulation by DOE. The test procedure for TE is CSA/ANSI Z21.47

2. **Identify ways to reduce the amount of heat loss from the RTU.** Reducing heat losses[10] can have a significant impact on seasonal energy consumption and *seasonal* efficiency. Strategies include:

- **Enclosure insulation** that reduces conduction and solar radiation.
- **Enclosure sealing** to reduce conditioned air leakage from the walls of the unit.
- **Damper sealing** that reduces air leakage from the outside air damper, decreasing heat loss during unoccupied hours or when economizers are off.
- **Exhaust air energy recovery**, which transfers energy from exhaust air to the incoming fresh-air stream using energy recovery ventilators (ERVs) or heat recovery ventilators (HRVs).
- **Isolation dampers** are added to the supply and return duct work and close when the unit is not operating at night.

3. **Design RTUs from a system perspective to ensure they provide the exact amount of energy (heating, cooling, and airflow) needed in the conditioned space.** A system perspective considers how the RTU is controlled as a part of a larger HVAC system and how it interacts with the building. A unit with very high operational efficiency will still have additional energy saving opportunity if it's set to provide more conditioning or airflow than is needed. Strategies associated with the RTU-as-a-system approach include:

- Economizers[11]
- Variable capacity heating/cooling
- Variable speed fans[12]
- Right sizing airflow and heating/cooling capacity
- Commissioning
- Ventilation right sizing (balance with indoor air quality)
- Efficient controls[13]

Energy saving opportunities related to whole system performance—equipment selection, commissioning, and operation—are more difficult (but not impossible) to influence at the manufacturing or distribution level because they relate to how components are used. However, efficiency advocates can work to ensure equipment has the *capability*, which is verifiable at the equipment level for variable speed fans, variable capacity cooling, and economizers. They can also ensure RTU systems are *commissioned* and *used* in a way that saves energy.

[10] Heat loss means the transfer of usable heat outside the system through conduction, convection, or radiation. For RTUs, this means either hot air or cold air that is lost to the outside air, which necessitates additional fuel being used to make up for the losses.
[11] Commercial buildings are commonly warmer than the outside air temperature because of occupant heat loads. Economizers let in cool outside air to provide cooling to the building rather than running the AC, which is known as "free cooling."
[12] Fan motors with electronically commutated motors (ECM) or variable frequency drive (VFD).
[13] In this report, "efficient controls" is not meant as a technical definition but as the concept of RTU controls that offer energy savings over baseline controls. Examples may include demand-control ventilation, economizing, fan control, temperature setbacks, reset logic, self-diagnostics, connectivity with building systems or manufacturer support, and dynamic control of variable speed fans and compressors based on load.

Priority Energy Saving Features

Table 3 includes the RTU features CEE flagged for potential inclusion in the Efficient Gas RTU and Dual Fuel Heat Pump RTU product definitions. We focused on researching these components in our supply chain and decision-maker interviews to understand the barriers and opportunities for each individually.

Table 3: High-Performance RTU Features

Feature	Description
Dual fuel heat pump	A dual fuel heat pump RTU uses an electric heat pump as the primary heating component and includes a gas furnace for auxiliary or back up heat on the coldest days.
Energy recovery ventilator (ERV)	In systems with ventilation air, this equipment recovers energy from exhaust air and transfers it to the incoming fresh-air stream. This can either be sensible only recovery (heat recovery ventilator or HRV) or latent and sensible recovery (energy recovery ventilator or ERV). This report uses the term ERVs because they are more common, but HRVs are not excluded.
Variable speed supply air fans (variable speed fans)	Variable speed fans provide the ability to vary supply airflow by changing the motor speed of the fan. Typically, this would be enabled by a variable frequency drive (VFD) or an electronically commutated motor (ECM), but any adjustable speed technology would qualify.
Low-leakage dampers	Outside air dampers prevent conditioned air leakage (convective heat loss) when they are closed. Low-leakage dampers are those that meet or exceed Minnesota 2020 energy code requirements (aligns with ASHRAE 90.1-2019 Table 6.4.3.4.3). For Minnesota, AMCA Class 1 or 1A (4 or 3 cfm/ft^2 at 1 in w.c.) meet the code requirement.
Increased enclosure insulation[14]	When the RTU enclosure has insulation levels greater than the current standard practice. Standard insulation for RTUs varies by manufacturer but is often ½-1" of fiberglass batting (R4-R7). A common level of high insulation is 2" double wall foam construction, which equates to a resistivity of R12.

CEE is considering two separate high-performance "products," one for Dual Fuel Heat Pump RTUs and another for Efficient Gas RTUs. Each product is likely to include one or more of the efficient features listed in Table 3, and there may be some overlap in the features included (e.g., both products could require low-leakage dampers and variable speed fans). While this project will not resolve the final product definition, one of our main research goals is to provide information on the barriers, opportunities, and market trends for these features so that CEE can make informed decisions on the characteristics of a final product(s).

[14] CEE staff indicate they may shift their focus from enclosure insulation to casing leakage. Casing leakage was not included in this research, but could be included in follow-up technical research along with other energy saving features listed in Section 1.2.

Section 2 Project Approach

Cadeo conducted primary data collection in the form of in-depth interviews with the RTU supply chain and key decision-makers for commercial buildings. CEE also collected RTU cost information during the project period. The approach to data collection is included in each subsection.

2.1 Supply Chain Interviews

Cadeo conducted in-depth interviews with representatives across the RTU supply chain, generally categorized into three groups: manufacturers, distributors, and contractors. The goals of this outreach included:

- Understand the RTU supply chain, decision-making, and points of influence.
- Characterize differences between target market segments (building types and Efficient Gas RTUs vs. Dual Fuel Heat Pump RTUs).
- Understand value propositions and opportunities for high-performance RTU adoption.
- Understand supply chain perceptions of high-performance RTUs, stocking practices, lead times, and sales trends.

Cadeo compiled supply chain contacts from multiple sources, including: existing contacts from CEE and Cadeo's previous work, The Blue Book[15], the Minnesota Mechanical Contractors Association[16], manufacturer websites, and DataAxle.[17] Cadeo also asked manufacturers and distributors who had completed interviews to provide contact information for distributors and contractors, respectively.

Cadeo completed 17 supply chain interviews from May 15 through July 7, 2023. Interviews with contractors and distributors lasted 30 minutes and participants were offered $100 e-gift cards as reimbursement for their time. Toward the end of the data collection period, Cadeo increased the incentive to $250 to obtain the final completes needed. Manufacturer interviews lasted up to an hour and generally included more than one representative from the manufacturer. The disposition of supply chain interviews is presented in Table 4.

Table 4: Supply Chain In-Depth Interviews Disposition

Disposition	Contractor	Distributor	Mfg. Rep	Manufacturer	Total
Complete	7	3	0	7	17
No-show	0	2	0	0	2
Refused	3	6	1	0	10
No response	234	37	5	1	277
List error	44	9	1	0	54

[15] Blue Book Construction Network. https://www.thebluebook.com/
[16] MN Mechanical Contractors Association Member Directory. https://members.minnesotamca.org/directory
[17] DataAxle is a third-party data provider firm that aggregates and sells business contacts (formerly called infogroup). https://www.data-axle.com/

Disposition	Contractor	Distributor	Mfg. Rep	Manufacturer	Total
Total	288	57	7	8	360

The detailed results of these interviews are included in Appendix A, and the summarized results are discussed in Section 3.

2.2 Key Decision-Maker Interviews

The outreach process for participant recruitment began on June 9, 2023, and data collection and recruitment ended on July 7, 2023. The research team emailed a total of 328 building representatives, primarily from lists provided by CEE, and supplemented with additional contacts suggested by other participants or identified through online sources by the research team staff. Participants in these interviews were offered $100 e-gift cards after completion of interviews. The roles of potential participants varied greatly and included building owners, third-party property managers, facility managers, maintenance managers, superintendents, city sustainability coordinators, and building engineers. Of the 328 contacts, 46 emails came back as undeliverable, and 4 responded that they were not interested in participating in the study. The research team sent a minimum of three emails to all nonresponsive contacts.

We completed 17 interviews with building representatives designed to:

- Understand the decision-making process for commercial HVAC customers.
- Determine the key influencers and decision-makers in purchasing an RTU.
- Document products and features that are most appealing to those decision-makers.
- Identify target market and customer segments for high-performance RTUs.
- Determine methods for engaging with target markets for demonstration projects, bulk sales, or purchase commitments.

The disposition of the building decision-maker in-depth interviews is included in Table 5.

Table 5: Key Decision-Maker In-Depth Interviews Disposition

Disposition	Count
Complete	17
No-Show	2
Refused	4
No response	259
List Error	46
Total	328

Recruitment efforts for these interviews were conducted together with another CEE study focused on Luminaire Level Lighting Controls (LLLCs), and all 17 interviewees participated in both sets of interviews

back-to-back. All interviews were conducted via video or phone call. Detailed call notes were taken during the interview, and calls were recorded to facilitate thorough analysis. The research team utilized qualitative analysis techniques to identify patterns, themes, and key findings from the collected data.

The detailed findings from these interviews are included in the Appendix B, and the synthesized results (combined with supply chain interviews) are discussed in Section 3.

2.3 Cost Data Collection

CEE collected cost data from six distributors representing five manufacturers for 20 units with varying features, including high efficiency cooling, dual fuel heat pumps, electric heat pumps, low-leakage economizers, and variable speed fans. CEE collected the estimates in 2018, 2022, and 2023. The costs sometimes included labor, sometimes only included equipment costs, and in some instances did not specify if the costs included labor.

Cadeo supported CEE's cost data collection by including sales and cost questions in the interviews and by reviewing CEE's RTU quotes. The findings related to costs and pricing practices are presented in Section 3.2.

Section 3 Cross-Cutting Results

This section presents cross-cutting results from our research. This synthesis reflects insights gleaned from literature review, previous market experience, interview findings, and analysis of RTU cost data.

There are four main categories of synthesized results, which are covered in the following subsections:

- Commercial RTU Market Dynamics
- RTU Costs and Pricing Practices
- Availability of Efficient Features
- Barriers and Opportunities

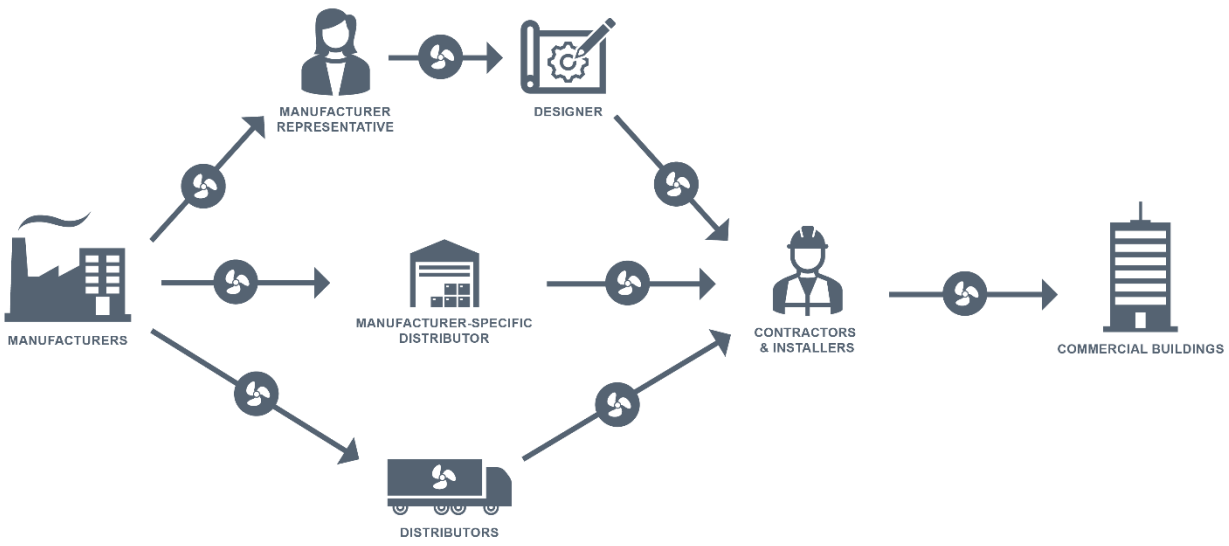
3.1 Commercial RTU Market Dynamics

CEE established research goals to understand the commercial RTU market to help support identification of target market actors and key partners for program implementation. The following subsections discuss the market mapping, supply side and demand side market actors, points of influence within the market, and the equipment replacement path.

Market Map

The team developed a market map based on review of existing literature and the results of interviews with manufacturers, distributors, and contractors. Figure 2 provides a basic depiction of the stakeholders involved in the common paths that RTUs take from manufacturer to installation in a building.

Figure 2. Simplified RTU Market Map



Reading the market map from left to right, the key roles are described as follows:

- **Manufacturer:** Develops product lines and sells their equipment through one of the three paths described below:

  - **Distributor:** Stocks products purchased wholesale from a manufacturer or manufacturer representative. They may source one type of equipment from multiple manufacturers. Typically, distributors stock standard efficiency products that are likely to sell quickly.
  - **Manufacturer-Specific Distributor:** These companies represent a single brand per piece of equipment or across all product lines. This includes local offices for a single manufacturer brand (e.g., Trane Twin Cities).
  - **Manufacturer Representative + Designer:** More commonly involved in projects that have custom RTUs rather than commodity products. This path usually serves more complicated projects or new construction where manufacturer representatives work with a designer to deliver a specialized piece of equipment. Typically, products are not kept in stock, but instead are shipped directly to the customer. This path was not the focus of this study as this is less common for RTU replacement, although this could be an opportunity for future research.
- **Contractor:** Sources equipment from one of the three paths described above and oversees the installation of the equipment in the building. They work with the building owner to determine building needs, initial costs vs. equipment life costs, and rebate opportunities.
- **Commercial Building Representative:** At the end of the market map is the building representative. For some buildings this may be the building owner, but for others, more than one person may be involved with the purchase of HVAC equipment, such as property managers or maintenance staff. The building representative works with a designer or contractor to get recommendations regarding equipment selection. Ultimately, the building representative is the final decision-maker on equipment selection.

The three major RTU manufacturers—Carrier, Lennox, and Trane—sell their equipment through manufacturer-specific distributors or wholesale distributors. These three (along with Bryant, which is also owned by Carrier) represent 89% of the market, as shown in Table 6. Typically, RTUs sold through this path are standard efficiency.

AAON and Daikin sell through manufacturer representatives. They have a smaller market share of 7% and represent more of the premium RTU market that more often includes efficient features as described in Section 1.2. Significantly more RTUs are sold through the distributor path than manufacturer representatives, although it is possible more dollars flow through manufacturer representatives because this customized equipment is more costly. This area could be worth confirming in future research.

Table 6: Market Share and Distribution Path by Manufacturer

Manufacturer	Portion of RTU Sales*	Distribution Path*	Market Share
Carrier	29.0%	Distributor and Manufacturer-specific distributor	89%
Lennox	23.8%		
Trane	22.1%		
Bryant (Carrier)	8.5%		
York	5.6%		

Manufacturer	Portion of RTU Sales*	Distribution Path*	Market Share
AAON	6.1%	Manufacturer Rep	7%
McQuay (Daikin)	1.2%		
Other	3.7%	Unknown	4%

** Market share by Portion of RTU Sales is based on CEE's 2017 RTU Market Characterization Study and Distribution Path and is consistent with Cadeo's previous experience.*

Points of Influence

Within and between each stakeholder in the supply chain there are opportunities to encourage the installation of high efficiency equipment in commercial buildings, including:

- **Product Development:** Manufacturers develop product lines with specific high efficiency features. Influencing product development will encourage them to include specific features, such as integrated ERV and dual fuel heat pumps.
- **Product Positioning:** Manufacturers have RTUs with heating efficiency features, but the industry is primarily focused on cooling efficiency metrics. There is an opportunity to work with manufacturers to increase their marketing of *heating efficiency* features that already exist.
- **Stocking:** Distributors stock equipment based on what is available from manufacturers and likely to sell quickly. Encouraging distributors to stock products with high efficiency features, such as variable speed fans and bolt-on ERVs, increases the likelihood those features will be installed.
- **Training and Education:** Contractors' primary source of product training and education is distributors. Partnering with distributors to deliver efficiency-focused technical information could encourage contractors to recommend products with efficient features.
- **Rebates:** Building owners rely on contractors to recommend the best options in the market. Incentives that reduce the cost associated with selecting high efficiency equipment can encourage them to select high efficiency RTUs.

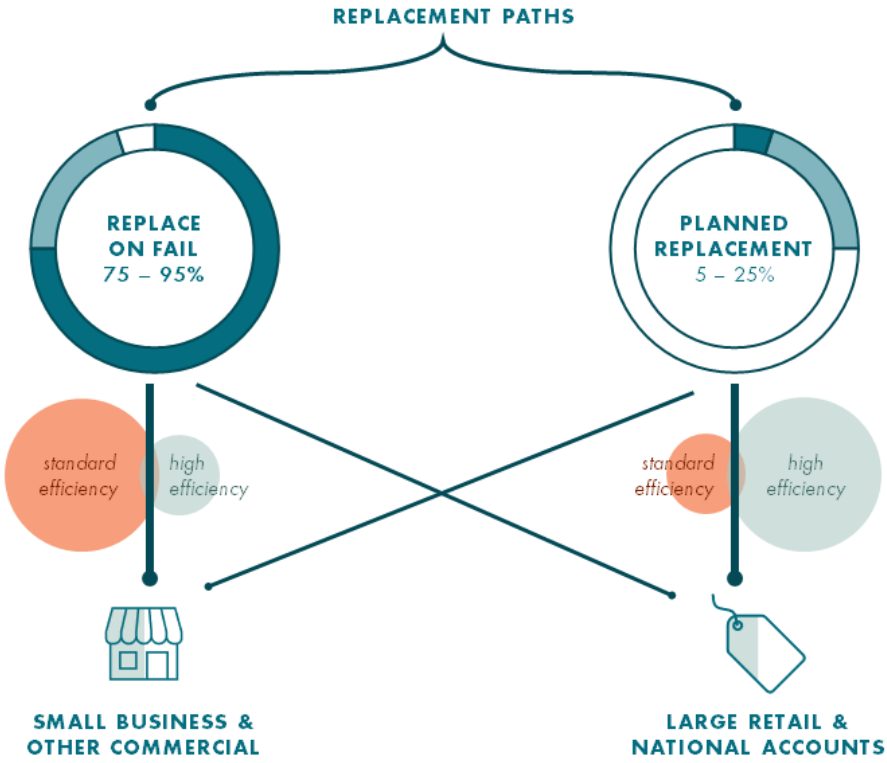
Replacement Market Paths

There are two common scenarios for RTU replacement:

- **Planned replacement:** Customer chooses to replace the system in advance of equipment failure. This may happen because they are anticipating failure, other remodeling is underway, there are roof issues, or they want to upgrade the existing equipment.
- **Replace-on-fail:** Complete failure forces an immediate replacement of existing equipment.

Figure 3 depicts the efficiency level of equipment typically installed in certain building types for a given replacement scenario.

Figure 3: RTU Replacement Scenarios and Efficiency Levels



The large majority (estimated between 75% and 95%) of RTU replacements happen in ***replace-on-fail*** scenarios. In these situations, the building owner calls their contractor, needing immediate replacement of equipment. The contractor then contacts the distributor to determine what they have in stock. These are typically standard or base-level efficiency RTUs.

When there are issues with equipment, building owners will often have in-house maintenance staff perform repairs, although contractors may also repair equipment. The preference to have maintenance personnel repair equipment means that contractors are not often aware of equipment being on the cusp of complete failure. If contractors are made aware, they may be able to make a plan for replacement with the building owner; however, in most cases, building owners do not have a plan for equipment replacement.

Replace-on-fail scenarios most commonly occur in small businesses and other standard commercial buildings. In many of these instances, energy efficiency is likely not prioritized because of time constraints, stocking availability, and split incentives that reduce the likelihood that high efficiency equipment will be selected for tenant-occupied space. When a building tenant pays the utility bill, the building owner is less incentivized to reduce energy costs and is more likely to select equipment with lower first costs.

The ***planned replacement*** path is more favorable to the selection of efficient equipment because the building representative had more time to budget for the upgrade and source equipment from the manufacturer. While this may be an easier market to target for high efficiency equipment, the majority of RTU replacements are not planned.

Planned replacement most regularly occurs for large retail and national accounts and in the public building sector, such as schools and government buildings. Building owners who plan for replacements tend to have:

- Maintenance and building staff who keep logs of equipment functioning, costs, and repairs.
- Large building stock where they can comprehensively consider equipment upgrades.
- The ability to overcome initial costs in favor of reduced energy costs over equipment life.
- Sustainability or environmentally focused procurement guidelines and goals.

3.2 RTU Costs and Pricing Practices

The following sections highlight Cadeo's key findings related to cost and pricing practices during the supply chain and decision-maker interviews and cost data analysis.

RTU costs vary widely with many unknowns.

RTU cost estimates ranged from $900 per ton to $6,600 per ton but quotes often contain insufficient information to understand why costs vary so widely. The market continues to face volatile pricing, which varies by manufacturer and distributor. Supply chain disruptions also continue to challenge the market, which creates further uncertainty in pricing practices. CEE's quotes also do not provide insights into distributor and contractor markup practices, which can be a large driver of product costs.

The cost data also did not include a clear "baseline" unit for comparison. Despite the wide range in costs for units defined as "efficient," the costs cannot tell us how much more expensive the units are than a traditional unit. Baseline units could see similar variation in costs across manufacturers and units.

"High Efficiency" RTUs can come with high cost but not necessarily due to the efficient features.

The RTU market faces information asymmetry where detailed cost structures are only known by the supply chain. Historically, most products marketed as "premium" come with additional costs, regardless of whether the features actually have high incremental manufacturing costs. The cost data indicate this may be true for RTUs as well, with units defined as "high efficiency" in the data only having limited high efficiency features. Several of the units in the cost data have high efficiency labels but only feature efficient cooling. The interviews confirmed the market defines a high-performance RTU in terms of its cooling, even in Minnesota's heating-driven climate.

Isolating incremental costs of efficient features can be difficult.

Due to the variation in units and the data collected in the bids CEE solicited, incremental costs could not be calculated for CEE's highest priority efficient features. The data includes dual fuel heat pump units but does not include the same unit with a standard gas furnace as a baseline comparison. The costs associated with other efficient features like dampers, fans, and insulation cannot be disaggregated from the total costs. Even with comparable units, other non-energy features can be hidden that mask the reasons for cost differences.

3.3 Availability of Efficient Features

Table 7 provides a summary of the current and future availability and sales of the five efficient features we specifically investigated in our supply chain research. These are qualitative results intended to show directional trends and high-level comparisons between features.

Table 7: Summary of Efficient Feature Availability

Efficient Feature	Current Availability	Current Sales	Future Availability and Sales
Dual fuel heat pump	Most mfrs. have a product with this option.	No number given, but low.	Most mfrs. working on increasing the number of products with this option. Expecting sales to increase quickly.
ERV	Usually an option for light commercial (mix of third party and in-house, bolt-on and integrated). Semi-custom and larger commercial have integrated ERV options.	<2% for standard RTU. Higher (up to 50%) for semi-custom and higher for 100% OA units (DOAS) where required by code.	More options being developed; four mfrs. planning or considering bringing ERV manufacturing in-house.
Variable speed fans	Most products have the option for this feature, sometimes standard above ~7 tons.	No number given, but they're common, especially in larger sizes or where required by code.	Expect increased availability and becoming standard on more products.
Low-leakage dampers	100% of products have option for low-leakage dampers.	Required by code in MN. Mfrs. estimated 30-40% of national sales are low-leakage.	Increased sales possible—depends on code changes.
Cabinet insulation	Mfrs. offer one level of RTU insulation—varies R4-R13. No options for upgraded level in the typical ordering process. DOAS units (across mfrs.) usually have R13 insulation.	Either 0 or 100% depending on mfr. No sales in three major mfrs.' light commercial RTU product lines.	Mfrs. do not have plans to increase their cabinet insulation. Lower priority for product development.

3.4 Barriers and Opportunities

A key research objective for this project included identifying barriers and opportunities for high-performance equipment. We present these findings from two perspectives:

1 | For each efficient feature and
2 | From the perspective of each market actor.

These findings were informed by the interviews and are intended to be *key* barriers and opportunities. A complete summary of interview responses is included in Appendix A and Appendix B for supply chain interviews and key decision-maker interviews, respectively.

Efficient Features

While this section includes insights from all interviews, the majority of the insights came from supply chain interviews as the building representative interviews were less focused on specific efficient features. Supply chain interviews identified a number of challenges and opportunities for each of the five technologies. Contractor and distributor responses often aligned with manufacturers.

Dual Fuel Heat Pumps

According to manufacturers, the dual fuel market is small but growing. Although this equipment is not seen commonly in the field yet, interviews revealed a high level of product awareness and expectations that this market will grow. Supply chain contacts identified several barriers and opportunities, which are listed in Table 8.

Table 8: Dual Fuel Heat Pump Barriers and Opportunities

Barriers	Opportunities
⊘ Market familiarity and acceptance. ⊘ Demonstrated demand. ⊘ Workforce training and development. ⊘ Cost (over baseline gas RTU).	✓ Excellent bridge technology—reducing natural gas consumption on all but the coldest days. ✓ Avoids grid strain and/or grid upgrades associated with full electrification. ✓ Reduced investment in site capacity (e.g., avoid electrical panel upgrades).

We note that the main barriers for dual fuel product adoption tend to be knowledge and information based (solvable through education/training/research) rather than technical (inherent to the technology and hard to change). Distributors and contractors both expect that the dual fuel market will grow significantly once there are more options and availability from manufacturers.

Energy Recovery Ventilators (ERV)

ERVs have the largest energy savings potential of the five priority features. How an ERV is incorporated into a unit will vary depending on manufacturer or product line, but the two main types are **integrated** (ERV is included within the enclosure of the RTU) and **bolt-on** (ERV is attached to the RTU's outside air opening on-site).

While most supply chain respondents had positive things to say about the technology, sales are currently very low (1–2%) for this feature. There is a low level of awareness and interest in ERV, both integrated and bolt-on, in the market. Table 9 lists the key barriers and opportunities for ERV.

Table 9: ERV Barriers and Opportunities

Barriers	Opportunities
⊘ Bolt-on ERVs are hard to source and have increased lead times. ⊘ Perception that ERVs are only for 100% outside air application.	✓ Work with distributors on how to increase stocking of bolt-on options in order to reduce lead times. ✓ Demonstrate lifetime savings opportunity and payback.

- ⊘ Knowledge of commissioning, operation, and maintenance.

While a little over half of the key decision-makers interviewed (9 of 16) said they were familiar with ERVs, two said the technology was not worthwhile (more maintenance, no large savings) and only had them because they were required to. Manufacturers reported that higher costs are the main barrier to increased ERV sales. Manufacturers noted that while the payback on ERVs can be favorable it does not always overcome the higher first cost. For contractors and distributors, the three most discussed factors contributing to slow market adoption also included cost, lead times, and added complexity for specifying and installation.

Variable Speed Fans

Variable speed fans were the most well-known efficient feature we asked about. Commercial building key decision-makers all reported they had heard of them, many were currently using them, and several had positive things to say about them. Distributors and contractors were supportive of variable speed fans because they provide cost savings to the consumer, but they also help contractors adjust airflow to duct conditions during the commissioning process. The barriers and opportunities for variable speed fans are listed in Table 10.

Table 10: Variable Speed Fans Barriers and Opportunities

Barriers	Opportunities
⊘ Added cost. ⊘ Additional training and technical support needed for commissioning variable speed fans.	✓ Good product availability. ✓ More benefits than just energy savings—helps with commissioning units and helps meet cooling ratings.

From the manufacturers' perspective, the only barrier to increased adoption of variable speed fans is higher first cost, with one manufacturer estimating variable speed fans add 10–15% to RTU product cost. Contractors noted that the commissioning process for variable speed fans is more complex, which requires additional training. One contractor noted they didn't always have the technical support needed from manufacturers, particularly for overseas brands. For distributors, the biggest challenges (besides cost) are contractor education and training, which aligns with what contractors reported.

Low-Leakage Dampers

Low-leakage dampers are the most widely available efficient feature. All manufacturers stated that 100% of their products include low-leakage dampers as standard or an upgrade option. The barriers and opportunities highlighted during the supply chain interviews are listed in Table 11.

Table 11: Low-Leakage Dampers Barriers and Opportunities

Barriers	Opportunities

- ⊘ Added cost.
- ⊘ Not always in stock.
- ⊘ Contractors do not always understand benefits.
- ⊘ Often sold as a field-installed option—manufacturers do not have control over what damper is paired with their product.
- ✓ No product development needed.
- ✓ Required by code in Minnesota.[18]
- ✓ Expand message from code compliance to energy savings.

Even though low-leakage dampers are an accessible option and sometimes required by code, less than half of national RTU sales include them, though we expect this is higher in Minnesota based on contractor interviews. Most contractors reported that they are very familiar with installing low-leakage dampers because they are required by code. Interestingly, some contractors noted that they believe low-leakage dampers are not an energy saving opportunity because dampers are usually open. This is a potential opportunity for education to note *when* low-leakage dampers save energy (during unoccupied hours) and the magnitude of energy savings possible.

Enclosure Insulation

Increased insulation is a substantial barrier for some manufacturers because increasing insulation levels can require significant investment in manufacturing and product redesign. Products that include higher levels of insulation are typically double-wall foam panels. Changing to extruded foam paneling can require new machinery, raw materials, and processing steps in addition to redesigning the inside layout of units. However, insulation also has some intriguing benefits and manufacturers who had already made that change reported lower manufacturing costs over time, increased structural rigidity,[19] and decreased weight. The main barriers and opportunities for increased insulation are listed in Table 12.

Table 12: Enclosure Insulation Barriers and Opportunities

Barriers	Opportunities
⊘ Not simple to add on, requires change in the manufacturing process. ⊘ Manufacturers without enhanced insulation report no plans to increase insulation levels and see no reason to do so.	✓ Full integration of updated insulation led to lighter, cheaper, better performing products. ✓ Perception that Minnesota code is "creeping up" on this. Opportunity to leverage expectation from the market. ✓ Permanent change in manufacturing practice will expand benefits well beyond program intervention.

Another interesting insight from one contractor is that they expected an insulation requirement in code might happen in the future because code already has a requirement for duct insulation and recently added a new requirement for insulation on roof curbs. These existing code requirements could be used as justification for why a new code requirement for RTU insulation is reasonable and would ensure consistency.

[18] 2020 MN Commercial Energy Code. Section C403.7.7 – 4 cfm/ft^2 at 1 in w.g. (Ultra-low-leakage), automatic controls required.
[19] When units are lifted onto rooftops via crane, minimal deflection occurs with more structural rigidity due to double wall, insulated panels.

Market Roles

This section provides a second point of view on the barriers to high-performance RTU installations in general. Interviews across the supply chain identified a number of challenges specific to each group we interviewed. These concepts consider how the different supply chain actors interact with each other and how they do their job. It is a more people-focused view of the barriers and opportunities for efficient equipment. This will help CEE understand the point of view of market actors for future conversations and factors into the best opportunities for programmatic intervention.

Manufacturers

Barriers	Opportunities
⊘ Have to meet regulations first—other R&D is lower priority. • Their current focus is refrigerant phaseout and future cooling regulations—not heating efficiency. ⊘ Work in cycles—can't just make a change out of the blue. ⊘ They can't (or won't want to) make a change without proof it's a good business decision for them.	✓ Opportunity to work changes in when they're already redesigning product lines. ✓ Build relationships with key contacts developed during this research. • Develop a unique value proposition for future outreach, they won't keep answering questions without there being a benefit for them. ✓ Help them promote or market efficient products/features they're already offering.

Distributors

Barriers	Opportunities
⊘ We don't know how "stocking" works for this equipment (both RTUs themselves and optional components like dampers and ERV)—it's not physically on a shelf in a local warehouse. ⊘ They're limited in what they can sell by what the manufacturers are producing.	✓ Future research to fully characterize the Minnesota market. ✓ Distributor-offered trainings are the main source of information for contractors—good single point of influence. ✓ Possible opportunity to support more stocking of low-leakage dampers and bolt-on ERVs. ✓ Distributors can put pressure on mfrs. to offer different products.

Contractors

Barriers	Opportunities
⊘ They're busy people—up to 95% of their job is replacing equipment that's already failed which means they need to work on SHORT timelines. ⊘ Preference for distributors they like and equipment they are familiar with limits experimentation and learning. ⊘ Changing how they do things (quoting/installing efficient equipment) creates business risk. ⊘ Contractors may not see the value of efficient equipment, especially if it is harder to sell to their customers.	✓ Look for opportunities to reduce contractor risk. ✓ Offer training on efficient equipment through distributors. ✓ Help qualified contractors differentiate themselves from competitors. ✓ Align incentives with their workflow—be careful of added lift/paperwork for them.

Building Representatives

Barriers	Opportunities
⊘ They sometimes have to follow a long procurement process. ⊘ They struggle to work effectively with contractors. ⊘ They may not understand what comprises efficient equipment and how it can help them. ⊘ Capital project funding and annual budgets can prevent them from planning replacements or getting more energy-efficient features.	✓ Help building representatives manage contractor interactions. • Advocate for efficient equipment, help review bids. ✓ Develop a qualified contractor list and promote through appropriate channels. ✓ Use procurement process to target public buildings (e.g., schools) and promote a high-performance RTU product likely to meet their criteria and timeline.

Section 4 Conclusion

This research confirmed that RTUs are an excellent opportunity for efficiency programs. We heard from the supply chain that the RTU market is expected to be a steady or increasing market over the next five years. Because these products have historically been price-driven products with a lower focus on efficiency, there is substantial opportunity for energy savings.

We found varying levels of availability and often low sales for the features CEE is interested in. We expect more availability of products with these features in the future without CEE's intervention, but there are opportunities to expedite this with market intervention. Developing a specific product definition for Efficient Gas RTUs and Dual Fuel Heat Pump RTUs will be tricky, because the combining of more than one efficient feature could impact savings and availability, but multiple options exist to choose from based on CEE's program goals and timeline.

There are more than just product availability barriers to a future program—we found that the RTU market is multi-stepped, pricing is opaque, and supply chain actors are extremely busy. CEE will want to consider how this market works and align with different actors when looking for key intervention points.

While designing programs for RTUs will be tricky, CEE is not alone in this effort—many other organizations want to support RTU programs because they provide a unique opportunity for both gas and electric savings in a time that gas savings are hard to find. Collaborating with these organizations will provide an opportunity to share research and increase the reach and impact of the program.

Based on the cross-cutting results discussed in Section 3, this section identifies implications for CEE's **product definition** and **program development**. We provide specific recommendations, when possible, but if the "right" choice is not clear based on the available information or current status of CEE's program we instead provide options for consideration.

4.1 Product Definition

Our research looked at efficient features in isolation, but CEE will likely combine features into a final product definition for the program. The availability of combined options is a key consideration in feasibility for a future program.

RTUs are typically a price-driven product and we learned from interviews that the supply chain and consumers value simplicity when choosing products. As energy efficiency professionals we often want *minimum thresholds* and *specific ratings* for clarity and the maximum energy savings possible, but in this type of market those extra hurdles can hurt the uptake of the program. We recommend CEE weigh the value of simplicity vs. specificity when setting a final product definition. An example of this kind of simplicity is requiring a code-level damper rather than a specific leakage rating. Contractors and specifiers are used to meeting code requirements, so this requirement would fit into their workflow well. Another example would be requiring *any kind* of ERV rather than a *certain efficient threshold*[20]. While higher sensible and latent recovery ratios mean more savings, requiring additional documentation might be prohibitively burdensome for both participants and implementors of the program.

[20] Such as a specific sensible recovery effectiveness (SRE) according to a specific test procedure (e.g., AHRI 1060).

Efficient Gas RTU

This section provides options for an Efficient Gas RTU product definition but is not limited to only features that reduce gas consumption. The options are simplistic and focus on the required components rather than a technical product definition. Once this list of options is narrowed down, we recommend CEE spend time refining the technical requirements for each component. The pros, cons, and availability listed for each option in Table 13 are informed by all aspects of our research.

Table 13: Options for Efficient Gas RTU Product definition

Option	Pros	Cons	Availability
NEEA's Tier 1 Prescriptive Spec (insulation + dampers)	Consistent messaging to market, larger influence, best chance for information sharing. Good savings potential.	Because NEEA is focused on gas, this does not include variable speed fans.	Few qualifying units available today and insulation product development is a long-term effort (not easy to get more units).
Fans and dampers	No product development needed. Likely closest to a "like-for-like" replacement.	This combo has not been researched/marketed yet—risk that there is a savings trade off between gas and electric[21]. Risk that this is already a code-level unit—standard practice? It will be confusingly only *slightly* different than NEEA Tier 1.	Probably the best availability—we know both these features are common options.
ERV only	This is the component with the most energy savings potential—get most of the benefits with a single upgrade.	Might be just an ERV program. More research needed on applicability—is it all buildings or only certain applications.	Availability today is ok to low.
Align with NEEA's Tier 2 Prescriptive Spec (insulation, dampers, and ERV)	Same pros as NEEA Tier 1, more energy savings.	This combination likely only available in premium semi-custom units.	Less availability than ERV only.
ERV plus fans and dampers	More savings than ERV only.	It will be confusingly only *slightly* different than NEEA Tier 2.	Unknown—did not ask about this combination specifically. Expect better availability than NEEA Tier 2, but less than only ERV or "fans + dampers" options.
Require all features	Most energy savings. Consider for long-term goal even if not achievable in short term.	Only premium units available with these features—incremental cost for incremental savings create challenging economics.	Least product availability, basically just AAON units.

[21] More efficient fans reduce waste heat, which actually increases gas consumption while decreasing electricity consumption.

Option	Pros	Cons	Availability
Whole box RTU rating w/ minimum threshold[22]	Gives mfr. flexibility on combining features. One number for the market to use instead of having to verify individual features. Best long-term option. Opportunity to align with NEEA's performance spec for TCOP ratings.	Success of this option hinges on market acceptance of metric and/or methodology. No-one currently tests to CSA P.8-2022 (the basis of the TCOP rating),[23] and few people are familiar with it. Program design using calculators will be different—unclear if harder/more work.	Unknown. Expecting better availability than options requiring insulation.

Our recommendation for CEE on an Efficient Gas RTU product definition depends on the goals for the program. If the goal is to get a program into the market as soon as possible, we recommend options that align better with how the RTU market currently operates.

The easiest Efficient Gas RTU product definitions would be:

- Fans and dampers
- ERV only

These two paths would meet less resistance in the market because the product availability is already there (for fans and dampers) or is in the works (ERV). This does not mean that developing a program will not be challenging, but it would require less product development at the manufacturing level (which is needed for options including insulation) or in identifying and tracking qualifying units (for the TCOP metric path).

The best long-term Efficient Gas RTU product combines more features to offer additional savings:

- Options that include insulation
- Require all of the features
- Whole box rating approach

These options would mean lower product availability in the short term but have appealing benefits over the "easy" options listed previously. Insulation is appealing because it is an all-or-nothing change, and once the manufacturing process is changed it is a **standard** feature. The whole box rating approach is also a powerful long-term option because it gives manufacturers more flexibility in how they design a product to use less energy. They could design certain features and skip others and still meet the performance threshold. This is a great idea *in theory* but getting the industry to support and adopt a change to testing and ratings takes time.

If these longer-term interventions do not offer sufficient short-term opportunity, we recommend staging the program to focus on easier options in the next two to three years and then adapt the program to include more features as products that include them are more readily available. CEE could also promote

[22] An example of a whole box RTU test procedure is CSA P.8-2022, which is the basis of NEEA's $TCOP_{HS}$ rating. While this option is not limited to CSA P.8 specifically, the research team is not aware of other test procedures that combine furnace efficiency, enclosure losses, and ERV gains into a single seasonal rating.
[23] Note that NEEA has developed an Excel calculator that uses existing test data so that no additional testing is required to generate a TCOP rating. This helps with the testing barrier.

both the short-term and long-term products from the beginning but structure the program in a tiered approach.

CEE could also consider two products or two tiers that are tailored to align with the two replacement paths discussed in Section 3.1 Points of Influence.

Dual Fuel Heat Pump RTUs

While the supply chain interviews included questions about the benefits and barriers of dual fuel heat pumps, they did not go into detail on *different types* of dual fuel options. Table 14 is a summary of Cadeo's current thinking about the possible options for the Dual Fuel Heat Pump RTU product definition, but we note it is an area worth researching further. Only the availability of the first three options were directly informed by supply chain interviews.

Table 14: Options for Dual Fuel Heat Pump RTU Product Definition

Option	Pros	Cons	Availability
"Standard" dual fuel	Good step toward electrification. Easiest of the options—just a check box, no detailed verification needed.	Percent of the load covered by the gas furnace may still be significant—not as much electrification as we hoped.	Best availability—options available today from most mfrs. and more coming soon.
"Better" dual fuel w/ efficient controls[24]	More electrification savings than standard dual fuel. Potential to get most of the savings of simultaneous operation but lower cost/easier development?	Need to define what qualifies as efficient controls. Verification needed that efficient controls achieve savings over "Standard."	Unknown—probably between the "Standard" and simultaneous options. Mfrs. are advertising these—trying to differentiate products.
Dual fuel w/ simultaneous operation[25]	Maximize use of the electric heat pump. May be paired with efficient controls as a standard feature?	Incremental benefit over standard dual fuel *expected* but *magnitude unknown*. Not feasible for a small, compact, light commercial product?	Lower product availability but is available from two premium mfrs. today.
Dual fuel combined with Efficient Gas RTU	Expect that efficient features will help reduce the design load.	Interactive effects have not been researched yet?	Unknown. Likely that incrementally adding

[24] Efficient controls only switch to gas heat when the heat pump is not keeping up with demand, whereas baseline controls just switch to gas at a predetermined outside air temperature. One manufacturer stated they already offer this control capability and a second said they were working on offering this in the next two years.
[25] Simultaneous operation means that the gas furnace and electric heat pump can operate at the same time. There is no hard switchover temperature, and the heat pump can still cover part of the heating load at lower temperatures.

Option	Pros	Cons	Availability
features (fans, dampers, insulation)	Align with Efficient Gas RTU program—consistent messaging.	Will increase cost over other dual fuel options.	features will negatively impact availability.
Dual fuel with ERV	Great idea, and ERV could help downsize the heat pump. Might increase the hours/temperature range you can use your heat pump because the ERV will temper incoming OA.	Might be prohibitively expensive. Interactive effects have not been researched yet? Lots of stuff to fit into a single box.	Unknown.

A final option for defining a Dual Fuel Heat Pump RTU is similar to the final option for an Efficient Gas RTU—using a whole box rating with a minimum threshold rather than prescriptive requirements of the other options. **This option was not included in the table because,** to our knowledge**, such a metric does not exist**. Theoretically, a metric like CSA P.8's TCOP could be redesigned or expanded to give a whole box rating for an electric heat pump or dual fuel heat pump in conjunction with other features. If this metric was well designed, the simultaneous dual fuel option would get a better rating than the standard dual fuel option because it uses less energy.

Right now, a heat pump is rated separately from a gas furnace even if they are included in the same packaged RTU. A packaged dual fuel heat pump is actually triple regulated[26] if you consider the cooling requirement separate from the heat pump. This is an issue because when a single product component is regulated separately it is likely that operational interactive effects of the entire unit are either not captured or not weighted appropriately. Two manufacturers spoke about efficient controls that maximize the use of the heat pump to save energy, but the regulatory framework is not set up to give them **any** credit for this feature and the test procedure does not provide any way to validate or refute these claims.

This does not directly impact how CEE chooses to define the Dual Fuel Heat Pump RTU product, but we provide this context because it's worth understanding how regulations support or undermine the development and definition of an efficient product.

Developing a clear definition and value proposition for dual fuel equipment will be important in developing strong demand for this equipment in the contractor and building owner community. CEE should further research the product availability, incremental cost, and (most importantly) the savings potential of Dual Fuel Heat Pump RTU product options before finalizing the Dual Fuel Heat Pump RTU product opportunity.

[26] Double or triple regulated means that a single piece of equipment must meet multiple standards—in the case of a dual fuel RTU, it must meet the cooling standard (SEER2 or IEER), the heat pump standard (COP), and the gas furnace standard (AFUE or TE).

4.2 Program Recommendations

This subsection provides five key concepts CEE should consider for program implementation. These concepts include options and/or recommendations for program design, potential pitfalls, and remaining information gaps that should be addressed.

1 | Address the misconception of RTU efficiency equating to cooling efficiency and use the program as an opportunity to bring awareness of heating energy saving opportunities.

A major finding from this research is that everyone across the supply chain, building representatives, and even the efficiency community associates an "efficient RTU" with a unit that has a high cooling rating (SEER2 or IEER ratings[27]). Manufacturers market their units as standard and high efficiency based on cooling ratings, and this terminology passes through to contractors and distributors. Organizations like ENERGY STAR set targets for air conditioners and heat pumps, and utilities offer rebates based on the cooling rating. Even the size of a unit is usually referred to in tonnage (e.g., a 5-ton unit), which refers to the nominal *cooling* capacity. Cooling capacity is not directly tied to heating capacity because units are often available with different options for furnace capacity for a given cooling capacity.

While cooling efficiency certainly matters, it is an incomplete picture of the potential for energy savings in RTUs. This is especially true for energy saving opportunities in the heating season, but it's also true for opportunities to reduce cooling energy like ERV and economizers.

We recommend CEE use this program to expand the conversation around RTU efficiency to include both heating and cooling savings. This includes telling the story about heating savings possible from efficient features.

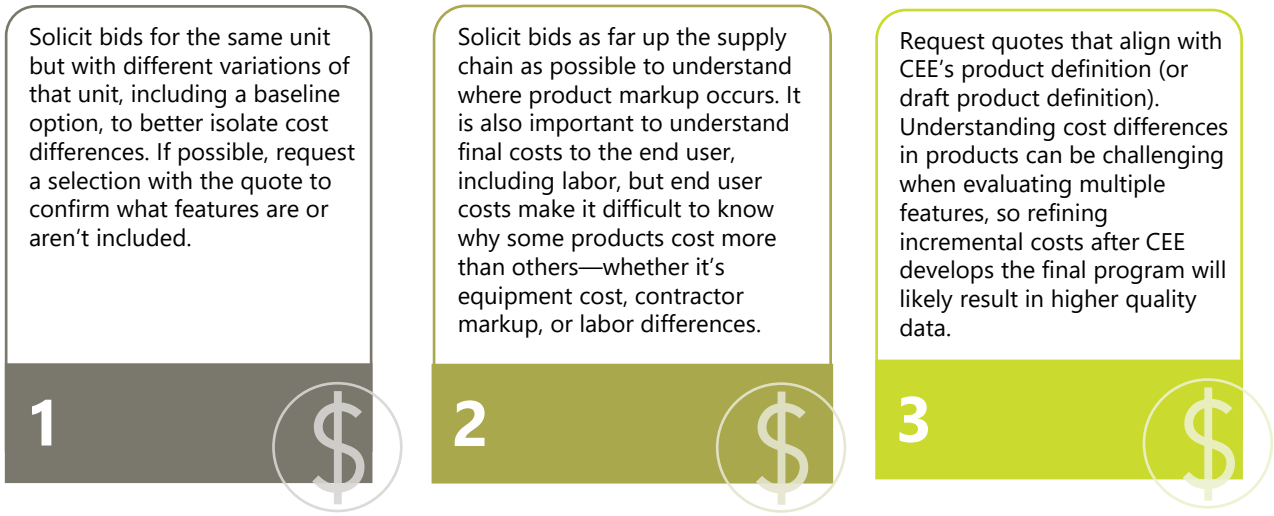
Two specific intervention points for changing the conversation would be **distributor training** and **manufacturer marketing**. CEE could work with local distributors to host training on products and features that can save energy and on how to talk to customers about those products. A second way to change the conversation is to talk with manufacturers about better marketing of efficient features. One option would be to change the spec sheet so that all efficient options are listed in one section or make it clear that adding these features will reduce energy consumption.

2 | Focus future data collection efforts on upstream product- and feature-specific incremental costs.

A key finding from our interviews and review of CEE's RTU quotes is that RTU costs vary widely and contain many unknown markups. Cost estimates ranged from $900/ton to $6,600/ton but did not include information on contractor and distributor markups, which can be a large driver of the final cost. Even though CEE was able to collect a variety of quotes for different types, sizes, and brands of units, incremental costs could not be calculated for CEE's highest priority features. If CEE continues to collect more unit quotes in the future, Cadeo recommends including the following considerations:

[27] Note that DOE has recently proposed adopting a new test procedure metric for commercial unitary AC, "IVEC," which is intended to better represent fan energy and economizer impacts. However, this metric still does not give credit to ERV and low-leakage dampers or correctly weight the impacts of enclosure insulation.

Figure 4: Recommendations for Future Quote Requests



Many of these barriers could also be overcome by focusing on differences in production cost gathered via teardown data. While these will need to be marked up, they may be a more transparent view of what efficient options really cost and less subject to the vagaries of market pricing, which will always be based on building-specific installation constraints, market supply and demand dynamics, and what the market will bear. While reducing premium pricing for efficient equipment is an important focus for program interventions, specific data on current pricing practices is not necessary in order to affect these practices and may not be worth the significant resources necessary to collect robust data.

3 | Provide support for both sides of the contractor/building representative conversation to make high-performance RTU options an expected part of the conversation.

We heard from many building representatives that working with contractors is a challenge for them. We also heard from contractors that they feel constrained on what they can offer given the timeline and budget from building representatives. This lack of transparency, lack of trust, and lack of understanding all lead to the same outcome: cheaper, less efficient equipment installed. This interaction is a key intervention point and opportunity to consider both points of view. Figure 5 includes ideas for supporting both parties before and after they interact.

Figure 5 Options for Supporting Contractor/Building Representative Conversations

4 | Build upon the outreach work completed through this research to identify key organizations and individuals in the distribution market that serve as market leaders.

Contractors and distributors in the Minnesota market were the hardest population to reach during this research. Even our building representatives reported that they struggle to get ahold of contractors. If CEE conducts additional outreach in the future, we recommend developing a value proposition that emphasizes the opportunity to help shape future programs or how the program may help them sell more equipment.

Additionally, more time spent characterizing the local market is needed. While we know the *type* of distribution each manufacturer goes through, we were not able to fully characterize the distributors/manufacturer representatives in Minnesota and the market share of each. Our research was unable to determine who the key players are in the market and where CEE should focus for future mid-stream outreach. Once the key players are identified, we also recommend developing key contacts and future partners at those organizations.

5 | Look for opportunities to link efficient components with other manufacturer R&D priorities.

We heard from manufacturers, contractors, and distributors that they expect the RTU market will see change from future cooling standards and refrigerant phaseout. Because manufacturers will have their hands full meeting these regulations, they have fewer resources (time, focus, money) for other product development. We did hear that product development is in the works for most product features CEE is interested in, but development of these efficient features will be in competition with other product development that manufacturers *have to* do to meet regulations.

CEE should look for opportunities to link desired product development with other required changes, organizational goals (e.g., GHG emissions reduction), or meeting stretch codes. There may be a chance to

nudge a manufacturer in a new direction rather than completely changing their course. For example, manufacturers may be more open to changes that require reconfiguring the unit if they're already overhauling a product line to change the refrigerant.

Finally, CEE should consider opportunities to align with other voluntary programs, such as NEEA, Enbridge, Consortium for Energy Efficiency, and ENERGY STAR. Manufacturers are more willing to consider making changes if they're getting consistent signals from the efficiency community, and because more organizations in alignment means more potential market for the products.

Appendix A Supply Chain Interviews

This appendix contains the qualitative findings from supply chain interviews. Since the number of completed interviews was small for each market actor group, the discussion below focuses on thematic findings rather than counts. Section A.1 covers findings from the seven completed manufacturer interviews, and Section A.2 covers findings from the ten interviews with contractors and distributors. We found contractor and distributor findings similar enough that they have been grouped into a single section, but we noted differences between the two market actors where appropriate.

A.1 Manufacturer Interviews

Cadeo developed an interview questionnaire specifically tailored to manufacturers with the following key sections:

- Awareness and perception of RTU efficiency
- High-performance product features
- Market trends

While Cadeo generally asked the same questions of each party, each conversation was unique and time spent discussing particular topics varied.

Awareness and Perception

We asked manufacturers a few questions about high efficiency RTUs before defining what it means to CEE. These questions were developed to understand their perception of efficient equipment. This information can inform CEE's product definition, use of terminology, and may highlight the need for additional education.

Manufacturers first associate "efficient RTU" with cooling efficiency and the metrics used to rate cooling efficiency. All seven manufacturers answered this question by describing equipment ratings associated with cooling metrics, such as AHRI efficiency tiers, products above DOE minimum, products with a high IEER/EER, IEER part load efficiency, or DOE's new IVEC metric.

While cooling efficiency (IEER rating) certainly matters, it is an incomplete picture of the potential for energy savings in RTUs. If manufacturers are only promoting "efficiency" as IEER ratings, the discussion is limited to the features well captured and represented by that metric (i.e., full- and part-load compressor efficiency, fan energy, and enclosure losses *during active cooling modes*). Other features that save energy (e.g., economizers, ERV, and low-leakage dampers) are not captured by IEER. Therefore, because of this association of RTU efficiency = high IEER, requesting an "efficient RTU" in today's market does not guarantee you're getting a unit that will use less energy.

Five manufacturers mentioned using different tiers for differentiating the cooling efficiency of their products. These were generally the terms "standard efficiency," "high efficiency," and "ultra-high efficiency." However, the kind of product manufacturers describe as "high efficiency" became the federal minimum in January 2023, so the equipment efficiency (IEER rating) associated with these terms is likely to shift over time.

When asked about "equipment that saves energy" (as opposed to "efficient equipment"), six manufacturers listed optional components and features. These components include:

- Variable speed fans (or multistage fans)
- Energy recovery ventilators (ERV)
- Variable capacity cooling
    - Also called inverter driven compressors or variable speed compressors
- Part-load efficiency
- Controls
    - Enables load matching to maximize the potential of variable speed fans and variable capacity cooling
- Economizers for free cooling
- Low-leakage dampers
- Cabinet sealing (prevents enclosure leakage)
- Modulating furnace

Several of the efficient features CEE is interested in were listed by manufacturers: low-leakage dampers, ERV, and variable speed fans. However, there were several other features manufacturers consider efficient that are not on the short list for CEE's RTU program. Some of these features may be difficult or not feasible to verify compliance (e.g., cabinet sealing and efficient controls) or their savings potential is not well documented (e.g., cabinet sealing and modulating furnace). These features are worth consideration by CEE, even if the result of that consideration is to be excluded from further research.

"Historically, efficiency is more focused on cooling, but [in the] last decade [there has been] more on energy efficiency and decarbonization. Rooftop's next frontier of decarbonization is moving to dual fuel heat pumps (or electric resistance back-up)"

[For us] there's not as much efficiency effort put into heating. Just meeting DOE minimum.

When asked about products that can reduce heating energy consumption, manufacturers described heat pumps and their efforts to expand/improve their heat pump products' capabilities. One manufacturer mentioned modulating furnaces and another mentioned condensing furnaces, but these were not a priority for any manufacturer. Even though the market is still dominated by gas heating (70–80% of sales), manufacturers are focusing their product development on electric systems (heat pumps) not gas. This could be because the *perception* of the savings opportunity for gas has historically been limited to condensing furnaces, even though research has shown that other features like ERV can also save gas.

Dual fuel heat pumps were not specifically considered as an *efficient* technology, but as a desirable option to *enable the use of a heat pump* for electrification in colder climates.

High-performance Product Features

The majority of the conversation with manufacturers was spent discussing the five high-performance product features CEE is most interested in for their High-Performance RTU initiative:

1 | Dual fuel heat pumps
2 | ERV
3 | Variable speed fans

4 | Low-leakage dampers
5 | Enclosure insulation

Dual Fuel Heat Pumps

Manufacturers' perception of dual fuel heat pumps was overall positive. They stated many benefits to dual fuel and thought that they were a good solution for increased heat pump adoption in cold climates.

Six of the seven manufacturers we spoke to either have dual fuel products available today or are actively developing them. Two of the three largest manufacturers had one or more dual fuel products available today, and the third was currently working to bring their first commercial dual fuel product to market. Two premium manufacturers (those with more expensive products and smaller market share) stated they already have dual fuel options for all products. These premium manufacturers were also the only ones with dual fuel systems capable of simultaneous operation and offered more sophisticated controls. Only one manufacturer was not actively developing dual fuel products, stating that they chose to focus their development on higher performance all-electric heat pumps.

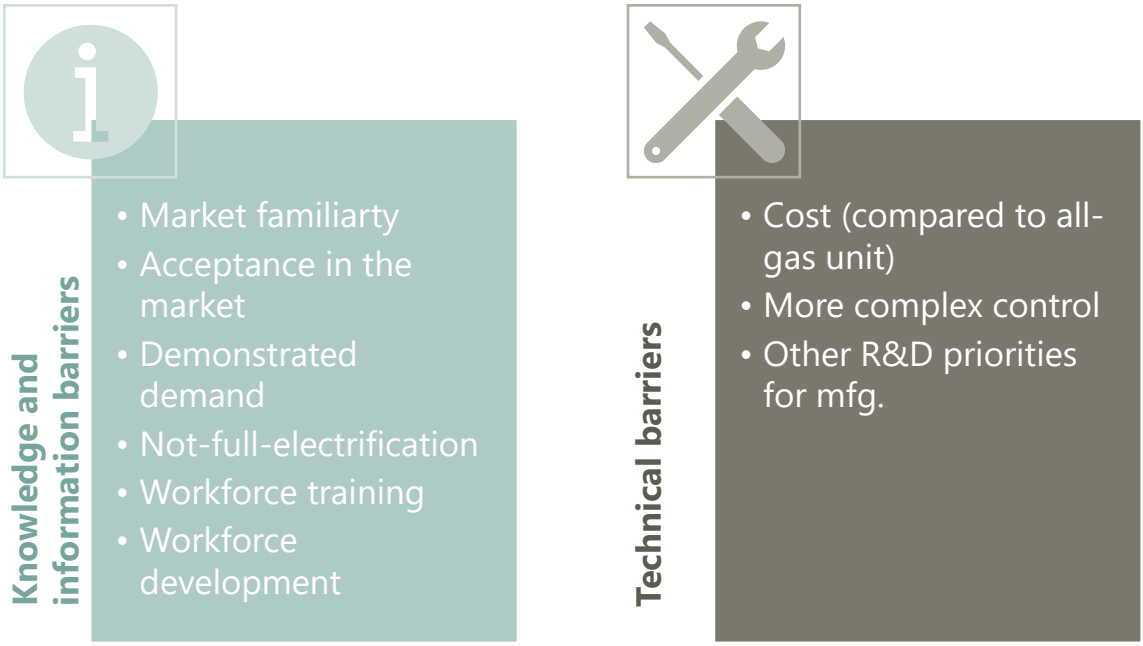
When asked if they saw more opportunity for all-electric cold climate heat pumps or dual fuel heat pumps, manufacturers stated they saw opportunity for both. Four of the five manufacturers we asked specifically said they were working on both solutions.

Manufacturers think dual fuel products are a good commercial HVAC solution, especially for Minnesota. They stated many benefits to the technology, including:

- A step toward electrification with less risk for the grid.
- Dual fuel is a *realistic* way to increase heat pump adoption in cold climates because it addresses some key barriers to electric heat pumps.
- Lower first cost than an all-electric heat pump.
- Resiliency for extreme weather events.
- Good option for retrofits (avoids electrical upgrades for building).
- Options to address comfort (quick warm up with gas, heat pump maintains).
- A way for manufacturers to keep up with their competitors.

Manufacturers also acknowledged there are some barriers to increased market adoption of dual fuel products. We noted that many of these barriers are more knowledge and information based (solvable through education/training/research) than technical (inherent to the technology and hard to change). **Figure 6** illustrates the differences between these barrier types.

Figure 6: Knowledge and Information Barriers vs. Technical Barriers for Dual Fuel Heat Pump RTUs



ERV

Everyone has options for ERV, but sales are still low. There are three general types of ERV that are offered by manufacturers:

- Integrated into unit
- Bolt-on sold as a factory option (through manufacturer)
- Bolt-on sold as a field installed option (through third party or distributor)

The two semi-custom/premium manufacturers had an integrated option for ERV on all products but did not offer bolt-on ERV. These manufacturers also offered different types of ERV, such as fixed plate or wheels and different types of heat transfer media. The five other manufacturers had a mix of ERV options, usually a third party add-on ERV. One of these manufacturers expected to offer an integrated option in the near future, another had longer-term plans (3–4 years) to develop integrated options, and two had plans to start manufacturing and selling an add-on ERV in house. **In general, there was a trend toward more options for ERV for all manufacturers.**

For the two manufacturers that already offered integrated ERV for all units, sales were significant—20–50% of the products they sell today. Three of the other manufacturers estimated very low sales—1–2%.

Benefits of ERV

- Energy savings.
- Meets code when required.
- Can extend the operating range (OA temperature range) of an air-source heat pump.
- Possible to downsize the unit's mechanical heating/cooling capacity.
- Helps keep demand charges down for end users.

- Better option for dehumidification (less energy intensive and no occupant comfort issues).
- Reduced emissions.

Five manufacturers stated a higher cost as the main barrier to increased ERV sales. Manufacturers noted that the payback on ERV works, but this does not always solve the first cost barrier. Two examples given were:

1 | A disconnect between who purchases the equipment and who pays the energy bill.
2 | RTU's are typically sold in the replacement market, which is particularly sensitive to price.

Other barriers mentioned:

- Product availability (two responses).
    - Whether options are in stock today (e.g., third party bolt-on) and their installation and shipping lead times.
- Product development.
    - Manufacturers are still working on providing additional options for ERV in their products (four responses).
    - The development of these options competes with other R&D priorities (one response specifically related to ERV, though multiple manufacturers mentioned competing R&D priorities throughout the interview).
- Perception that ERVs are for 100% OA units or DOAS (three responses that sales are 1–2% for light commercial RTU).
- People generally add them to meet code (two responses).
- Existing building conditions (two responses).
    - For example, roof curbs, weight limits, ductwork configuration.
- Increased maintenance requirements (cleaning the ERV) (one response).

Variable Speed Fans

Every manufacturer has products with variable speed fans, but they are not available on 100% of products. Some manufacturers only had variable speed fans on smaller products (3- to 5-ton range) and others only had them available in larger products (above 4 tons). Two manufacturers include variable speed fans standard in all their products—these were the two "premium" manufacturers we spoke with.

Manufacturers did not have plans to increase the number of products with variable speed fans unless pushed by codes or standards. Two manufacturers noted that variable speed fans increase their cooling ratings (IEER) and that was why they had included them in certain products to date and wouldn't add them to other products unless pushed to do so. Two other manufacturers noted they do not have plans to increase products with variable speed fans.

If CEE is interested in pursuing market transformation through a codes and standards play, there are a few pathways to consider:

- Increasing the minimum equipment rating (e.g., raise IEER requirements).

    - DOE standards and energy codes generally align on the equipment ratings. There are cases where either may go before the other, and DOE has provisions that it must align with ASHRAE 90.1.[28]
- Prescriptive requirement (e.g., "RTU fans above 5HP shall have variable speed control").
- Test procedure improvement or development.
    - Develop or revise the efficiency metric to give increased weight to fan energy use and efficiency so that having variable speed fans gives a big boost to the rating.
- ENERGY STAR as a pathway to future standards.
    - In the past, DOE has sometimes adopted voluntary standard levels as the DOE standard level, so these voluntary standards can be considered as a "foot in the door" or a "north star" for future regulation but are not a guarantee

The benefits of variable speed fans are not limited to just fan operating cost savings. Additional benefits of variable speed fans include:

- Give products higher cooling ratings (helps meet DOE standards).
- Are a good match for variable capacity heating and cooling (which multiple manufacturers are developing).
- Helps when commissioning units.
    - Right sizing airflow and adjusting for duct conditions on site.

From the manufacturer's perspective, the only barrier to increased adoption of variable speed fans was increased first cost. This is still an important barrier, but manufacturers did not say there were any acceptance, technical, or supply chain issues unique to variable speed fans. One manufacturer estimated the increased cost as 10–15% depending on tonnage of the unit.

Low-leakage Dampers

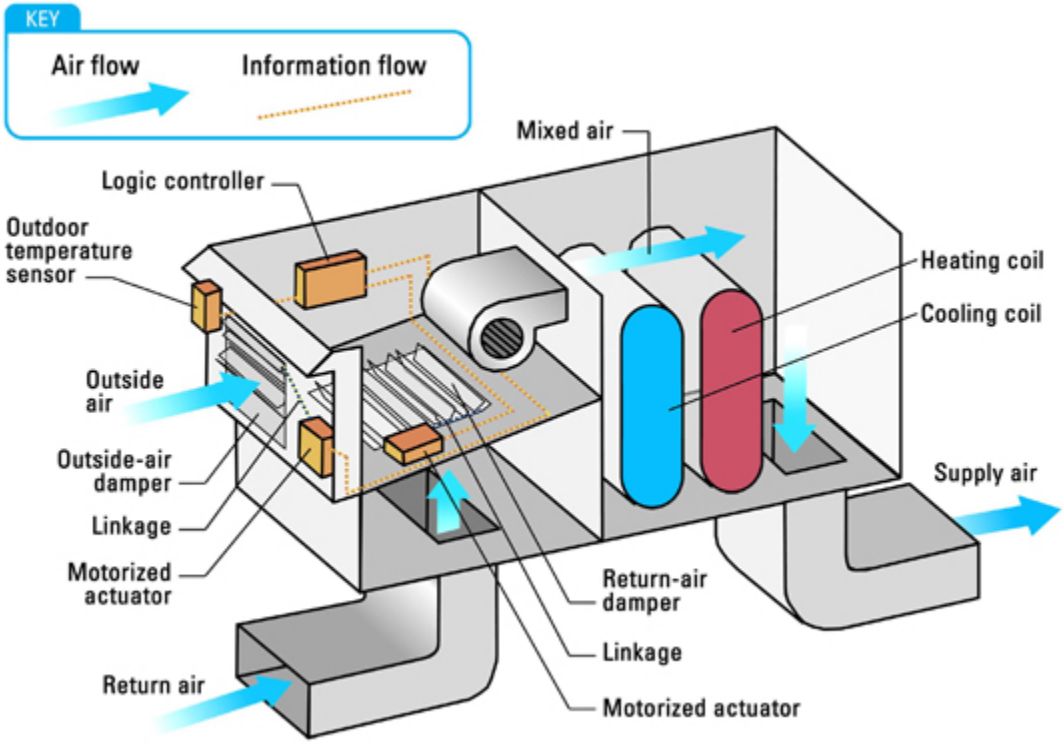
Outside air dampers are used to control the flow of outside air entering an RTU. Outside air may be used for ventilation purposes or to provide free cooling when the outside air temperature is lower than the inside air temperature.

Outside air dampers are commonly part of the economizer, which consists of an outside air damper, a return air damper (may also be called a control damper), motorized actuators, sensors, and controls. **Figure 7** is a simple diagram of an RTU economizer. Economizers are often sold as a field-installed or third-party option, but they may also be integrated into the unit at the manufacturer level. If the economizer components (dampers, controls, actuators) are fully integrated into the unit as a standard feature, the term "economizer" may not be used to describe them and instead they are just considered as components of the RTU.

Because physically an economizer is *mostly* dampers, the terms "dampers" and "economizer" are sometimes used interchangeably. However, we recommend using the term "outside air damper" if including a low-leakage damper provision in the product definition.

[28] Technically, DOE is only triggered to *review* a standard or test procedure if ASHRAE 90.1 changes theirs, but in practice they usually just adopt the same levels.

Figure 7: Diagram of an Air-side Economizer[29]



Low-leakage dampers are the most widely available efficient feature. All manufacturers stated that 100% of their products include low-leakage dampers standard or are available as an upgrade option.

Even though low-leakage dampers are an accessible option and sometimes required by code, less than half of RTU sales include them. Three manufacturers answered that they see sales between 30% and 40%, though we expect manufacturers were estimating their entire market and not exclusively Minnesota. Reponses from contractors and distributors estimated higher (and approaching 100%) sales in Minnesota because they are required by Minnesota energy code.[30]

"Dampers are not commonly thought of as an energy saving feature—[they're] an afterthought."

Code and product availability are the main drivers for selecting low-leakage dampers. Low-leakage dampers save energy during unoccupied hours, which is why they're included in code provisions, but the direct association with energy savings has been lost over time. Product availability will also have an impact on the dampers chosen. In a perfectly functioning supply chain, a customer is likely to choose the cheaper standard-leakage dampers unless they're required by code to upgrade to more expensive low-leakage dampers. However, **if standard dampers are not in stock, a consumer will take whatever is available on their timeline, even if the in-stock product is more expensive.**

[29] ENERGY STAR. Air Side Economizer
[30] 2020 MN Code C403.7.7 – 4 cfm/ft2 at 1 in w.g. (Ultra-low-leakage), automatic controls required. https://codes.iccsafe.org/content/MNEC2020P1/chapter-4-ce-commercial-energy-efficiency#MNEC2020P1_CE_Ch04_SecC403.7.7

Manufacturers do not always have control over the dampers that get installed on an RTU. If outside air dampers are integrated into the unit at the point of manufacture (either as a standard feature or a factory add-on), then a manufacturer has control over the type of damper installed and will know the sales percentage of products with dampers. If economizers are sold as an add-on and installed on the RTU on site, manufacturers have less control over the outside air dampers that are installed. In this scenario, they cannot guarantee low-leakage or even motorized dampers[31] are installed. Distributors have more power over what is installed based on what they stock, and we heard from contractors that they often install whatever is in stock.

Enclosure Insulation

Manufacturers typically offer one standard level of enclosure insulation across many products. One manufacturer we spoke to offered higher levels of insulation in larger capacity products, but the rest responded that they have a single level of insulation that they offer.[32] Additionally, no manufacturers had plans to increase the level of insulation offered in their products.

Making the change to increased insulation levels requires significant manufacturing redesign. Products that offer higher insulation (R12) are typically double-wall foam panels. Lower insulation levels (R4–R7) are typically built as sheet metal with fiberglass insulation. Changing to extruded foam paneling would require new machinery, raw materials, and processing steps in addition to redesigning the inside layout of units. However, one manufacturer who has made this transition found that they had lower manufacturing costs over time.

Increased insulation had the toughest barriers from the manufacturers' point of view.

- Requires significant manufacturing process redesign.
- Manufacturers don't get "credit" for this in the rating.
- There is no requirement for RTU insulation in energy codes.
- Manufacturers perceive that the energy savings opportunity is less than other options they're considering.
- They have other priorities for R&D (features that do not have the first four barriers).

Premium manufacturers have moved to double-wall foam construction but stated benefits other than energy savings. One manufacturer stated they have lower manufacturing costs, lighter unit weight, and increased stability—which are significant benefits. This manufacturer has fully transitioned to double-wall construction on all products. However, this manufacturer's manufacturing process is more customized than others', so these benefits may not be the same for everyone. The second manufacturer with high levels of insulation also stated they made the change for structural stability and that energy savings would not justify the upgrade.

[31] Motorized dampers can be opened and closed automatically by a control system. Non-motorized dampers are called manual dampers and must be physically opened and closed by maintenance personnel. Because of this added effort, manual dampers are unlikely to be opened and closed regularly and may be left completely open when they do not need to be—this is a worst-case scenario for damper energy loss.

[32] While our conversations did not specifically ask about DOAS units, we are aware of several major manufacturers (Trane, Carrier, Rheem, York) that include higher levels of insulation in their DOAS products than their "standard" RTU products.

Market Trends

Target Market

When asked about customers who are more likely to purchase efficient equipment, manufacturers listed three main types:

- Large national companies or accounts (Amazon, Walmart, Target).
- Schools or other government-funded buildings.
- People responsible for paying their own utility bill.

Manufacturers perceived that national accounts are more likely to have energy efficiency or GHG goals and the capital to purchase more expensive efficient units. They are also a good opportunity because they purchase significantly more units, so there is an economy of scale opportunity.

Schools were notable because they often have funding that they need to use or lose, and therefore are more likely to upgrade to take advantage of funding that would not get used otherwise.

Changing the Minnesota RTU Market

Manufacturers were also asked what they expected to change in the Minnesota RTU market in the next five years.

Manufacturers expect the market for RTUs will remain strong. They expect similar sales or even increased sales of RTUs. The reasons for increased sales include:

- Extra replacements that were delayed from supply chain shortages the last two years.
- Early replacement of units to get ahead of refrigerant change or increased standards.
- RTUs being applied to more building types.

Dual Fuel Heat Pump RTU market is expected to increase rapidly. One manufacturer expected their dual fuel sales to see 50% growth in the next three years. Because dual fuel heat pump RTUs are nascent today, their share of the total market may still be small three years from now, but it is an encouraging statement.

While most manufacturers are pursuing heat pump product development, it's worth stressing that the majority of the RTU market is still gas-fired. One manufacturer noted that 70–80% of their sales are for gas units (with the rest AC only or heat pumps). So, while electrification may be a *trend,* there is still a large market for efficient gas products.

Manufacturers noted that many factors will positively impact the trajectory of efficient equipment adoption. Manufacturers mentioned the following as ways CEE and market actors could increase the adoption of efficient equipment:

- Perception of the efficiency opportunity—people getting excited and investing.
    - Market knows about efficient products and is willing to pay for them (one response).
    - Efficiency community helps support research to demonstrate savings potential (one response).
    - Manufacturers invest time into product development they know will pay off (one response).
    - Contractors and distributors help promote and sell efficiency (one response).

- External funding for efficient products.
    - Utility rebates (four responses).
    - Federal funding (one response).
- Advertising of programs to ensure customers and contractors are aware of funding (two responses).
- Workforce training—people qualified to work with efficient products (two responses).
- Workforce development—more people in the industry (one response).

"Typically, a contractor/developer wouldn't care about the equipment that goes in because their MO is to sell equipment ASAP. Building owners need to be educated on the equipment types that are going in so they can advocate for better systems/equipment that are efficient."

A.2 Distributor and Contractor Interviews

This section includes findings from interviews with contractors and distributors. While contractors and distributors were asked similar questions to manufacturers, these interviews contained more questions about sourcing equipment and the replacement market in Minnesota. The topics covered in the contractor and distributor interviews are grouped into the following sections:

- Awareness and Perception
- High-performance Product Features
- Product and Installation Training
- Market Trends

Awareness and Perception

In alignment with manufacturer perceptions, contractors and distributors first associate "efficient RTU" terminology with cooling efficiency metrics. "Standard" efficiency is considered code minimum while "high" efficiency is equipment that qualifies for rebates.

When asked about customers requesting products above code minimum, contractors said that they were the initiators of conversations about high efficiency equipment. Contractors felt that they were the primary source of both product and rebate/incentive information for customers. This information transfer point is an important **opportunity**—contractors need to be aware of high efficiency equipment and motivated to encourage these options when discussing possibilities with customers.

Rebates were discussed as being key to increasing efficient equipment installation. Contractors reported that customers are interested in high efficiency equipment until they see the cost difference. The common return-on-investment of ~10 years can be a hard sell. Contractors said they encouraged customers to get rebate-qualifying equipment and that in certain municipalities, such as Minneapolis, rebates can make installing high efficiency equipment even cheaper than code minimum equipment; however, in other locales they felt rebates are not keeping up. **Distributors and contractors across the board said they would like to see more rebates available.**

High-performance Product Features

Most conversations with distributors and contractors focused on discussing the first three of the following five high-performance product features:

1 | **Dual fuel heat pumps**
2 | **ERV**
3 | **Variable speed fans**
4 | Low-leakage dampers
5 | Enclosure Insulation

Dual Fuel Heat Pumps

Distributors and contractors feel that the current dual fuel market is small but growing. Although not seen commonly in the field, there was a lot of product awareness and enthusiasm. Both sectors felt that the dual fuel market will grow significantly once there are more options and availability from manufacturers.

> *"There's a big opportunity for dual fuel—**we're just waiting for the products to be available from manufacturers.**"*

Barrier: *Availability*—not currently stocked, lead time estimates of 24–30 weeks.

One distributor said that in previous years they had sold close to zero, but in the past year they sold 50+ because they are working with an engineer who works on heat pump sustainability initiatives. Although a significant increase for that distributor, it still only amounted to ~2% of RTU sales.

> *"I'm expecting [dual fuel] will make its way to commercial from the residential sector, but we're not seeing it yet."*

Opportunity: *Contractors* say that although not commonly seen in the field right now, they expect dual fuel to be hitting the market soon.

Load matching and "small sizing" equipment is seen as a strong benefit to dual fuel heat pumps. Distributors and contractors feel that the gas back-up allows for a realistic and cost-efficient approach to electrification in a cold climate market such as Minnesota. Rather than having oversized equipment to meet demand on the coldest days, the equipment can be sized more appropriately for meeting the cooling and mild weather heating load. Distributors and contractors said that the benefits of dual fuel heat pumps included:

- Smaller equipment is a less expensive up-front cost.
- Load matching means longer run cycles, which extends equipment life because there is less wear and tear on moving parts and heat exchanger from on/off cycling.
- Contractors appreciated the simplified HVAC approach, with one piece of equipment providing heating and cooling.
    - There was, however, the perception from some that the equipment would wear out faster than having a separate gas furnace and AC unit.

> *"I'm not 100% sold on them. Minnesota isn't the best state for electrical because electricity costs are so high. Not a lot of heat pumps are sold."*

Operational costs caused concern that dual fuel adoption may be difficult outside of municipalities that are focused on electrification efforts or in rural areas where current equipment runs off propane. Where electrification is incentivized, fuel switching off natural gas to electricity is feasible or may even be mandated; however, in cities where

people have the natural gas option, it is significantly cheaper than electricity. That reduces the pay back incentive.

Multiple contacts mentioned that they felt dual fuel was most appropriate for replacing propane equipment because propane is much more expensive than natural gas (more on par for cost with electricity). This may provide an **opportunity** to push for electrification and decarbonization in rural areas.

ERV

While respondents did have positive things to say about the technology, it is not currently very popular with either distributors or contractors. There is a lower level of awareness and interest in ERVs, both integrated and bolt-on. Most respondents said they see these less than 5% of the time, if at all.

Despite low popularity, contractors and distributors did see benefits to ERVs. The main benefits discussed included:

1 | Tempering outside air
2 | Energy savings
3 | Occupant comfort
4 | Humidity control

"In our climate you can downsize on the heating and cooling capacity if you've included ERV."

ERVs face numerous challenges to widespread market adoption. The three most discussed factors contributing to slow market adoption include:

1 | *Cost*—payback is a tough sell if the building owner is not very interested in energy or long-term cost savings. Payback does work out, but you have to have an owner who is invested in the long term and not scared away by the up-front cost.
2 | *Lead time*—ERVs are not standard or required so most significantly adds to lead time as they are not "off the shelf."
3 | *Complexity*—Adds complexity to design and installation. **Contractors do not love the bolt-on option.** It requires a second piece of equipment that connects to the unit, adding to the footprint which may require a **new curb**. ERVs require additional maintenance to clean the wheel.

"If there's something that makes an ERV integrated. That would be more appealing to sell and install."

Given the low uptake, there is a plethora of opportunity for increased market adoption across the supply chain. Potential intervention **opportunities** around ERVs could include:

- Codes implemented to require ERVs in more circumstances.
- Manufacturers incentivized/encouraged to develop integrated ERV options.
- Distributor stocking of bolt-on ERVs from manufacturer and/or third party.
- Contractor education on the technology and installation training.

Variable Speed Fans

Both distributors and contractors were enthusiastic about variable speed fans. They are commonly seen in the market. Respondents said they see variable speed fans on 60–90% of equipment sold/installed. This is particularly true with larger equipment and in new construction buildings. Contractors estimated that equipment 7.5 tons and above are required to include variable speed fans, though our review of Minnesota energy code is that the requirements are not that straightforward. It may

be that *functionally* this is the case, but *prescriptively* the code leaves room for staged or single-speed fans with high efficiency.[33] Contractors who worked primarily in the smaller equipment replacement market were less familiar with variable speed fans. Even contractors who said they saw variable speed fans more rarely felt favorably about them. Overall, respondents felt very positively about variable speed fans and listed the following benefits:

- Energy and cost savings.
- Slow ramp-up/down offers quieter operation and extends product life.
- Tighter temperature and humidity control.
- More flexibility and adjustability for field conditions.
- Right sizing and futureproofing.
- Noise reduction.

Not all of their experiences were positive, however. Two respondents noted issues with variable speed drives and the local grid's power quality.

> *"I will say we've found more "dirty grid" electrical grid challenges when we went to variable speed. They're more sensitive to voltage spikes/variable grid (power quality). The electronics systems in RTU (including fan control and variable speed motors) are advancing ahead of a steady clean grid. In areas around the Minneapolis/St. Paul metro area they have problems with the motors."*

Distributors find one of the biggest challenges in selling variable speed fans is contractor education and training. Another contractor called out issues with training, maintenance, and technical support from the distributor and manufacturer. This may be a potential **opportunity** for resources to be allocated to contractor training and education through distributors or opportunities to provide more on-call technical support.

> *"Lead times are a bigger driver in equipment selection over cost."*

There was also the sentiment that variable speed fans added lead time, thus reducing the likelihood of contractors to recommend equipment with them. As with other high efficiency product features, installation is likely to increase if the products are kept in stock and readily available off the shelf. This is an **opportunity** to increase distributor stocking of equipment with integrated variable speed fans.

The code requirement for fans is not straightforward. The Minnesota code requirement for fans was often mentioned by contractors and distributors, but respondents generally weren't sure what the cutoff was for requiring them (e.g., 5-ton, 7-ton, or 10-ton). We also reviewed the code requirement and reached the same conclusion: that it's tricky to say generally where the cutoff is for variable speed fans.

Minnesota's current energy code was revised in 2020[34] and is based on 2018 IECC and ASHRAE 90.1-2016 with certain revisions. We reviewed provisions relevant to RTU fans, specifically C403.8.[35] The code language related to fans is not straightforward, but our interpretation of the most relevant requirement is summarized below:

[33] More detail on the fans requirement in MN energy code is noted in the manufacturer section A.1 of this appendix.
[34] MN 2020 Energy Code. Section C403 Building Mechanical Systems. https://codes.iccsafe.org/content/MNEC2020P1/chapter-4-ce-commercial-energy-efficiency#MNEC2020P1_CE_Ch04_SecC403
[35] MN 2020 Energy Code. C403.8 Fans and Fan Controls. https://codes.iccsafe.org/content/MNEC2020P1/chapter-4-ce-commercial-energy-efficiency#MNEC2020P1_CE_Ch04_SecC403.8

- Fans on direct expansion (DX) cooling units above 65,000 btu/h (5.4 tons) "shall be designed to vary the indoor fan airflow as a function of load."
    - **Variable capacity units**—need **2 stages** or more and shall not exceed certain fan power thresholds (as a percentage of full load power) for low speeds.
    - **Variable air volume units**—need **modulating** control and shall not exceed certain fan power thresholds (as a percentage of full load power) for low speeds.
    - **Units with economizers**—need **2 speeds** or more.

While variable speed fans would likely meet or exceed these requirements, it does not *prescriptively require* variable speed fans, as multi-staged fans with high fan efficiency may also comply. Short answer: it depends, and it's not a straightforward cutoff by cooling capacity (tonnage). Revising this requirement to be easier to understand and requiring variable speed fans on more units is a possible codes opportunity. As a next step, CEE could complete a code review of all provisions related to the priority features (not just fans) and consider all code changes to advocate for in the next code update.

Low-leakage Dampers

Distributors and contractors overwhelmingly say that because low-leakage dampers have become code required, they are now installed on 99%+ of their projects. Many contractors felt they were installing these solely to meet code. A common sentiment was that because dampers are required to be open when occupied, they are not that beneficial. However, other respondents voiced that they saw the energy saving benefits from when the space is unoccupied, particularly overnight. Reducing the heating load also reduces the morning warm-up from both a time and energy perspective.

One contractor offered a unique perspective, that low-leakage dampers provide the ability to seal off outside air intake when air quality from wildfires is hazardous.

For the most part, contractors said they faced little issue in installing these because they are code required. However, others said that they are adding cost and that the high demand has been contributing to supply chain issues.

Enclosure Insulation and Roof Curbs

Because the RTU enclosure insulation is primarily dictated by the manufacturer, distributors and contractors had little to say on the matter. They said they discuss with customers insulating the roof curb and exterior ductwork but not the RTU enclosure. There was some anticipation of energy codes ratcheting up insulation levels to follow suit with the 2-inch insulation requirement for curb adapters.

> *"I think [an insulation requirement] is coming—in the future because of energy crunch. Because rooftops typically, if you buy them off the shelf, they typically only have ~1 inch insulation. That's not enough for Minnesota as far as I'm concerned. They just said that curb adapters have to have 2 inches or something. Seems like next step is going to be the RTU."*

Contractors say that roof curbs are an important consideration when replacing equipment. Roof curbs are expensive, upwards of $2,000 or more. They are so commonly required that while they may not necessarily be a major driver, contractors do prioritize like-for-like equipment when possible.

"Dual fuel can often fit on [the] same footprint, but this is a big driver"

Contractors would like to see more standardization around equipment size across manufacturers. Maintaining existing RTU footprints may be a consideration for manufacturers when developing dual fuel heat pumps or RTUs with high efficiency features.

Product and Installation Training

Product education and training was reported by respondents to happen in the same flow as the supply chain. Distributors say they are educated on product offerings by manufacturers or manufacturer representatives. Contractors overwhelmingly say they receive product information and training from distributors or sometimes from manufacturer representatives through:

- Training classes
- Product literature
- Newsletters
- Casual/working conversations

"Our vendors (distributors) are good about coming around and bringing in new literature. You're constantly learning and watching what's changing."

Market Trends

Replace-on-Fail vs. Planned Replacement

When asked if RTU replacement projects were typically "replace-on-fail" or "planned replacement," distributors and contractors unanimously agreed that the large majority are replace-on-fail. Respondents estimated that 75–95% of their projects were replace-on-fail.

"We teach and train and preach planned replacement, but the market has not shifted significantly."

Replace-on-fail scenarios require contractors to replace existing RTUs with equipment that is the most readily available. Contractors say that in these situations little to no care is paid to efficiency levels if they meet the code minimum.

Planned replacement is rare, but when it happens contractors say that building owners will often select higher efficiency equipment. Several contractors emphasized the importance of having relationships with building owners to help them plan equipment replacement in advance.

Distributors say they are selling high efficiency equipment, particularly dual fuel, to large corporations who have:

- Energy or climate goals and
- Purchase large amounts of equipment.

Contractors discuss the two scenarios more as owner- vs. renter-occupied buildings. In cases where the owner is not paying the energy bills, they are less likely to be invested in pre-planning for replacement and installing high efficiency equipment.

Sourcing Equipment

Distributors reported that they tend to work with one or possibly two manufacturers. Contractors on the other hand source equipment from multiple distributors/manufacturers, depending on **availability, cost, and working relationship.** Contractors reported prioritizing working with distributors who they have a good relationship with and who they can rely upon for post-installation technical support.

Changing Minnesota RTU Market

The consensus was that product efficiency standards will continue increasing and dual fuel will become more prominent as the region pushes toward decarbonization and electrification. There is the expectation that current add-on efficiency options will become standard. Distributors and contractors both voiced concerns over supply chain considerations. There is concern that availability of equipment will continue to be an issue.

Appendix B Key Decision-Maker Research

This appendix presents the results of the in-depth interviews with commercial building decision-makers conducted in June and July 2023. The 17 interview participants came from a range of backgrounds, with work ranging from one large building to hundreds of buildings within their portfolios. Five participants worked in the private sector, eleven in the public sector, and one worked for a large non-profit. Their building types included:

- Commercial office spaces
- Non-profit office and facilities
- Retail, including strip malls
- Medical, including hospitals
- Public school buildings (classrooms, administrative offices, garages, athletic facilities)
- City and county municipal buildings (fire, police, jails, office, libraries, parks and recreation facilities, animal control facilities)

The top findings from the interviews are:

- The factors rated most important when considering bids are lowering energy costs (16/17), working with a contractor they trust (15/17), and lowering maintenance costs (13/17).
- The main challenges that building representatives face when selecting new equipment are supply chain issues, a knowledge gap, budget constraints, the internal processes of their institution, and working with the contractors themselves.
- Processes for upgrading and replacing new equipment is very different for public vs. private sector buildings, with equipment replacement plans that can sometimes take years.
- Building owners are very familiar with RTU features like variable speed fans and low-leakage dampers, but very few had heard of dual fuel heat pumps or energy recovery ventilators.

B.1 Building Representative Interviews

Findings from the building representative interviews are grouped into the following subsections:

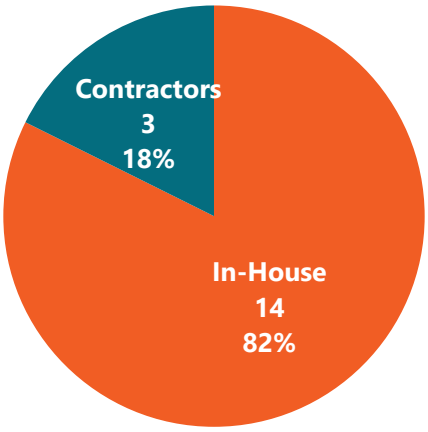
- Decision-Making Process
- Selecting HVAC Equipment for Replacements
- The Bid Review Process
- Important Considerations for New HVAC Equipment
- Efficient HVAC Equipment
- Information Sources on RTU Features

Decision-Making Process

Respondents described a wide variety of processes for HVAC equipment upgrades and replacements. In this subsection, the individuals involved in the decision-making process, important considerations when selecting new equipment, and their biggest challenges will be discussed.

To better understand the equipment upgrade or replacement process, the research team wanted to better understand who was responsible for equipment maintenance in the interviewees' buildings. Figure 8 depicts their responses.

Figure 8: Who Maintains the HVAC Equipment? (n=17)



Only three key decision makers, all of whom worked in the private sector, said that all their HVAC equipment maintenance is handled by third party contractors. *"For our commercial buildings, we have a third party contractor that is on-call for any issues."*

The majority of respondents, 14 out of 17, reported having an in-house team that typically handles their HVAC maintenance. However, almost all supplement with contractors for large issues. *"Predominantly, our building staff [handles all maintenance]. If we do get into a situation that's a long commitment with repair timeline, we'd bring in a contractor."*

Additionally, almost all participants, 16 out of 17, have a preventative maintenance program. Only one said that there was no preventative maintenance at all.

Selecting HVAC Equipment for Replacements

Building representatives reported many different considerations and limitations that were weighed when it came to upgrading and replacing their HVAC equipment. **In general, all of their responses fell into one of two separate approaches:**

- **Proactive:** those who are able to be proactive and are able to fully weigh factors including costs of repairs, age of equipment, and benefits of a new system.
- **Reactive:** those who lack funding and have to limp equipment along until it outright dies or the funding becomes available, regardless of the circumstances.

Proactive: Twelve out of 17 key decision-makers described a proactive approach to HVAC equipment replacement. In these circumstances the main concerns they will weigh are:

- **Age of the equipment:** "Typically, replacements happen when there is a failure of equipment between 12–16 years old. It needs to be a major component to justify the cost, like a heat exchanger, or something, that will make it more cost effective to get a new one over repairing."

> *"We tend to do things proactively. When we see a significant reason and opportunity to upgrade, we will, especially with those critical facilities."*

- **History of repairs:** "We keep an inventory on life cycles: when we installed it, if we go do a work order, we look at how old it is, etc. Anecdotally, how often have we had services. That's one point where we check in on whether to repair or replace."
- **Cumulative cost of repair over time:** "We look at the cost of repairs for our equipment over the year. How much have we sunk into it? If every year we've sunk thousands into a piece of equipment, then we will look into replacing it."

With this approach, it is common for key decision makers to say that they kept maintenance logs to be able to weigh those factors: *"In an ideal situation, we keep a close log of age and condition to avoid surprises as much as possible and try to plan for paying for repairs. Initially, as we buy properties, we continue keeping a log."* Participants also commonly described the process in the proactive approach as *"collective group discussions."*

The reactive approach does not always have the ability to weigh those factors, though they may still track the same information.

Reactive: Five out of 17 key decision-makers described processes that were entirely reactive. All five of these participants worked in the public sector and frequently listed issues with funding and competing priorities that prevented them from taking a more proactive approach to their HVAC maintenance.

> *"We've put together replacement plans for some of this stuff, but, with gas prices so high we are operating at a loss on utilities. But we don't have the funds to replace [equipment] unless it fails. I wish we could be proactive instead of reactive, but that's where we are."*

- **Essential Equipment Dies:** "We definitely have systems that are flagged as more urgent for replacement, but despite that we wait for something to die to get replaced. Just the nature of having that large of a portfolio and not being able to get ahead."
- **Available Funding:** "A lot of it has to do with external funding, can we find funds to do the improvement or upgrading?"

In these cases, older equipment that may be costing money in repairs and that has been regularly breaking down gets repaired and rebuilt to keep it "limping along" until the next funding cycle or until they are no longer able to do so.

Once key decision-makers know that they need to replace equipment, they next need to decide what new equipment they need. Interviewers asked participants if they typically replaced old equipment with an upgraded or redesigned system, or if they typically did a direct replacement with the same or similar equipment. Their answers are listed below in Table 15.

Table 15: Upgrades vs. Like-for-Like

Replacement Type	Count	Quote
Upgrade or Redesign	5	*"I always push for upgrades or redesign. I like to ask what high efficiency systems would cost and what the benefits would be so I can talk to the owner and be knowledgeable."*

Replacement Type	Count	Quote
Like-for-Like	4	*"Most HVAC replacements are like-for-like. They're so big and we have so many guidelines to follow for residential buildings that it is easier to stick with what we know."*
Depends	8	*"Some building owners have more of an appetite for improving the system and enhancing while others have different goals."*

Only 5 out of 17 key decision-makers said they prefer to redesign or upgrade the system anytime they do a replacement, saying that while they try and stick with similar types of equipment, they always hope to upgrade to the more energy efficient options whenever possible. Redesign projects are more associated with big remodel or rehab projects.

Four of the 17 key decision-makers said that their standard approach was to stick with as similar a system as possible under the assumption that they *"have a good unit in place already."* Other reasons for staying with similar equipment included the customized systems that were in place. One ice rink manager commented that they had had the current system specially designed to fit the area it served and that they did not want to deviate from what was working.

But most commonly, they said they did not have a standard approach. Eight participants said that it really depends on the kind of project, the equipment being replaced, and what new tech is even available. Additionally, building representatives noted that rebates were often an important driving factor for upgrades to their HVAC equipment, saying it was important *"to weigh whether there's a rebate available just to see what the incentives are to invest in a higher quality piece of equipment."*

Additionally, the decision-makers that we spoke to rarely, if ever, make these decisions on their own.

Public sector buildings require a lot more approval than their private or non-profit counterparts. As many as five different groups can be involved in procurement decisions, starting with maintenance crews and building or city engineers and then going to either the school district or to city officials for approval.

> *"Internally, besides [HVAC contractors], the buildings and grounds director and maintenance crew, myself [the superintendent], and the school district itself."*

Private sector decision-making tends to be more streamlined, typically involving the property manager, a contractor or consultant, and the building owner.

> *"I speak with a third party HVAC contractor, discuss with our building engineer, and then to the... owner or tenant after I have all the info."*

These differences between public vs. private procedures also impact the length of time that the process takes. For public institutions, as long as three years was reported. *"It's a three-year process. October 2021 the assessment was done on complete facilities, then August 2022 board approved moving forward with recommendations for improvements. Started the process in August 2022, with the plan that projects will be completed summer 2024. Bids go out July 2023."*

However, a few said they had completed the process in only a few months depending on installation and lead times. *"Things move pretty quick, we're a small city. Three months I'd say. Maybe six. Sometimes less*

than three." The size of the local government and the amount of oversight that they have to deal with determines the length of the process for public buildings as well as the number of pending projects vying for attention for approval and funding.

Key decision-makers who worked in the private sector uniformly reported a quick process, typically lasting two to six months. *"It's 30–60 days for approval on anything, and then the HVAC contractor needs to follow up once. All in all, it takes a few months start to finish."*

The Bid Review Process

All participants must get multiple bids in at least some scenarios.

Five out of 17 key decision-makers require bids only if the project meets a cost threshold, and these five respondents were a mix of public and private. Thresholds varied across participants, with some requiring relatively large costs that need multiple bids: "*District policy is that if expenses are over $25k you need at least three bids.*" Others had comparatively small cost requirements: "*Any large project over $5k requires multiple bids."*

Some public entities use master or state contracts and do not have to get bids on certain things if there is a standing contract in place. *"Being government, we can use existing contracts that have been bid out in the right way up to a certain dollar amount.*"

Only 2 out of 17 participants said they did not have a trusted contractor or vendor relationship that they could lean on during the bid review process.

Fifteen building representatives said they lean on a trusted contractor to guide them through the process. Participants stated that the more history they had with a contractor, the easier the process became because they were more familiar with the building and their needs.

"It's beneficial for us when they have a history with the building and are knowledgeable vs calling in someone new because it takes them longer to understand what is and has been going on."

For many, their maintenance crew and contractor were the only sources of information or advice that they sought out.

However, contractors were not the only resources that participants relied on during the bid review process. Participants listed other advisers, including:

- The city or county sustainability coordinator
- Peers
- Outside consultants (including CEE)
- Trusted vendors
- The internet

"We lean on our engineers and the mechanical guys. They give us advice based on what their experience is. So, we lean on the trades because they have to repair it."

Participants listed many different challenges, and often listed multiple challenges, that they faced during the bid review process. Across all answers, however, there were five main categories of response. They include supply chain issues, a knowledge gap, budget constraints, the internal processes of their institution, and working with the contractors themselves. Table 16 details these different categories and provides examples of each.

Table 16: Challenges Faced During the Bid Review Process

Challenge	Description	Quote
Supply Chain	Availability of the equipment that they need and problems with lead times.	*"Since covid, there have been new issues like availability of product and labor…Last year we had to wait months for RTU to be delivered, [they are] in short supply."*
Knowledge Gap	Common amongst property managers who may not have sustainability guidelines they are required to follow. Convincing building owners to invest in new technologies can be a challenge.	*"I would say the biggest challenge now is convincing owners and tenants why we should go to high efficiency instead of status quo and standard all the time. Educational factor: they don't know it's an option and…they don't always see the benefits."*
Budget & Cost	Often key decision-makers know what they need but cannot go with the best option due to a lack of available funds.	*"Funding! We try to get equipment that's not using natural gas, whether it's ground source heat pump or air source heat pump, those are a big focus for us. Those require additional funding though."*
Internal Process	Common amongst public sector employees who work for large school districts, municipalities, or counties. Navigating the process can take a long time and cause frustration.	*"Just getting to the point of going out to bid. Once it's out to bid that's faster. Everything that comes before is harder. I think a lot of it is city processes and procurement. We do bid out design separately from install work so there are two phases of project which draws our timeline out…The internal processes are long."*
Contractors	Typically, these challenges related to issues with contractor relationships and contractor knowledge.	*"Getting contractors to follow directions. Getting contractors to not try to upsell, getting them to compare apples to apples; at least with regard to getting comparable bids."*

Challenges with HVAC contractors came up multiple times throughout these interviews. Quotes like the one above in Table 16 and to the right highlight the frustration some building representatives have with contractors when going out to bid.

However, these complaints did not come up solely in the HVAC interviews. Two separate participants made a point to say that working with lighting

> *"Often the biggest barrier is contractor knowledge or engagement or lack thereof….There is a built-in bias from a lot of contractors where they want to replace x with x, we can't replace with y 'we don't know how to install it, it's more work for us, yada yada yada' it's just unfortunate."*

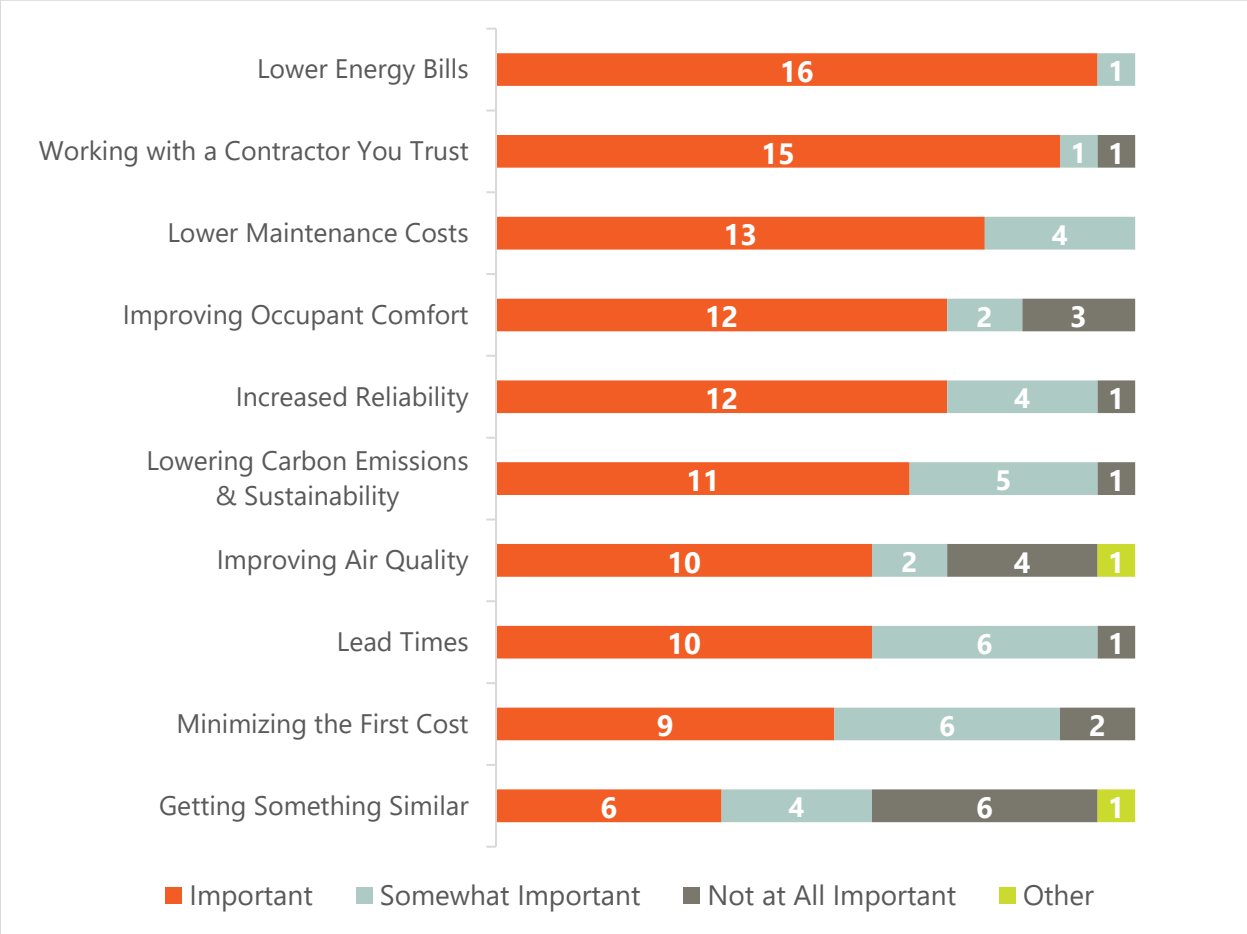
contractors and electricians was easier than working with HVAC contractors during the lighting controls interviews that took place directly after the HVAC interviews.

> *"The challenges are similar to what we experience with HVAC, but with lighting, the contractors are more helpful with applying for rebates. Which they don't do for HVAC. And generally, they are much easier to work with for lighting than with HVAC. Maybe it's because they know us better? So maybe it's really about relationships."*

Important Considerations for New HVAC Equipment

When selecting new HVAC equipment, key decision-makers have many different considerations to weigh. Researchers asked the participants to rate common considerations as either important, somewhat important, or not at all important. Their responses to these questions are shown in Figure 9.

Figure 9: Important Considerations for Key Decision-Makers (n=17)



Improving air quality and improving occupant comfort both yielded conflicting comments. For both those responding important and not at all important, there were comments that this particular factor is just assumed. For some, that led them to rank it as important, while others said unimportant because it would never factor into their decision-making process: *"This is a given. The equipment is designed to do this."*

When asked about air quality, one participant responded that it depended on any ordinances they might need to follow, but ultimately, *"not important, the side effect is improved air quality, but not the goal."*

The category that most respondents deemed important was lowered energy bills. Sixteen out of 17 said that this was important, only one participant considered it somewhat important, and **no-one thought it was not at all important.**

The category with the second highest number of participants (15 out of 17) rating it as important was working with a contractor you trust. Five of those 15 added additional emphasis to say that this was either VERY important, extremely important, or the most important. However, one participant explained that while this was important, it sometimes wasn't up to them to decide who they work with: "*Important, but if we have to bid, I don't have much choice in who we go with.*" For the one participant who rated this as unimportant, they chuckled first and said, ***"I'm not sure I've ever found that in 30 years—you know, a contractor that I actually trust."*** But they then continued and told us something similar to the previous comment, stating: "*Contractor is typically lowest bid, we don't have a choice. A trustworthy vendor with quality equipment is more important.*" Both participants were public employees.

While 11 participants said that sustainability and reducing carbon emissions was important to them, 3 of those 11 commented that that didn't always matter in the end. So, while for them personally it was very important, it may not matter to others they were making decisions with, and that if it were significantly more expensive, they would not be able to go with a more sustainable option: "*That is important for me personally, but if it were a huge cost increase it may not be important to my boss.*"

The category considered the least important was getting something similar to what they already had. It was ranked evenly, with six saying important (three of whom said VERY important) and six saying it was unimportant. Four participants said that it was somewhat important, and one participant said that they couldn't really answer that one way or the other and that it *"depends on which arena and the other equipment it has to interact with."*

Interviewers next asked participants if there were any additional considerations that were not included on that list. Most everyone said no, with 10 out of 17 saying flatly there was nothing additional that they considered.

The other seven participants provided additional considerations including:

- Available rebates
- Vendor reliability and brand name
- Quoted installation times
- Ease of use
- Limitations of their physical spaces

Given the wide range in priorities and considerations, researchers asked participants if there were any particular features that they looked for in new equipment to meet them. Nine out of 17 participants either said no or listed general benefits as opposed to features, such as saying "*Just the value, the liability, the environmental components. Nothing additional, though.*"

One participant said that they look for specific ratings, specifically "*SEER2 rating, seasonal performance rating.*"

Three participants mentioned digital controls for better communication and greater ease of use. However, one of them said, "*There is so much more tech out there that we don't have or cannot afford. Any kind of automated equipment would be something I want and look for—whether I can afford it is a different thing.*"

Two participants listed specific features they would look for. One participant responded with "*Everything has to be variable speed, whether pumps, fan motors.*" One participant responded saying that, "Heat exchangers and economizers are important," while another participant responded with *"Air source heat pumps primarily."*

Three participants said rebates were always looked at, even if specific features were not.

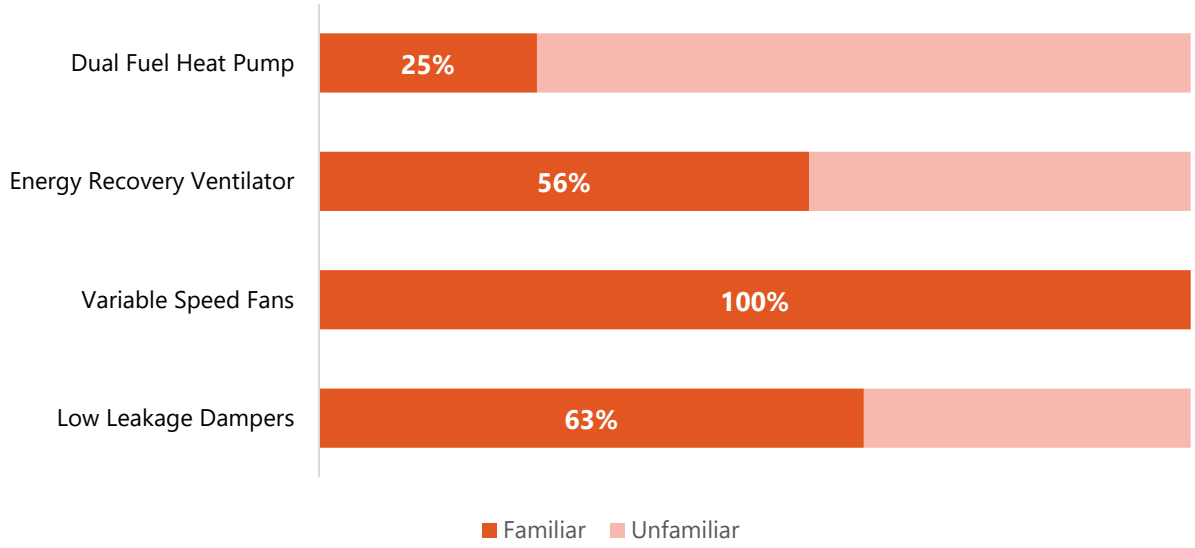
Efficient HVAC Equipment

Researchers next asked key decision-makers about four specific RTU features that deliver energy savings:

1 | Low-leakage dampers (also called economizer dampers)
2 | Variable speed fans
3 | Energy recovery ventilator (also called heat recovery)
4 | Dual fuel heat pump RTU (electric heat pump with gas backup)

One participant did not answer questions in this section because they did not, and had never, worked with RTUs. Respondent answers are depicted in Figure 10.

Figure 10: Familiarity with Energy Efficient RTU Features (n=16)



All participants (16 out of 16), who were asked these questions had heard of variable speed fans. Many said very positive things about them. "*They're great! Non-variable fans should be a thing of the past.*"

Ten out of 16 building representatives were familiar with economizer dampers, and nine were currently using them in their building(s). Two of those nine participants who had them commented that they had had some issues with them in the past, specifically that they had needed repair work, but that they still thought they were important. *"[Dampers are] something that goes bad and you have to replace them. It's a benefit though, so they are usually recommended."*

Nine out of 16 participants said they were familiar with an energy recovery ventilator. Two of those nine said they had heard of them, but they were not very familiar, or even sure if they had one. Another **two of those nine said that they were not worthwhile and only had energy recovery ventilators because they had to**, saying: "*I don't think it did very much? It functioned; I just didn't see a big "WOW" on savings.*" And: "*We have it... It's high maintenance, but we had to put it in due to code.*"

Four out of 16 building representatives were familiar with dual fuel heat pump RTUs, but only one participant had any actual experience with them. That participant thought they were great. Twelve out of 16 decision-makers were unfamiliar with them, and one participant commented: "*I'm not familiar. It sounds like an interesting option. My contractor always bids standard by default and won't recommend anything like that, you have to ask for high efficiency tech.*"

Information Sources on RTU Features

As a follow up to these questions, the 16 building representatives with RTUs were next asked where they would turn for information on specific RTU features like those listed above. Their answers varied but fell into the categories detailed in Table 17.

Table 17: Information Sources on RTU Features

Information Source	Count	Quote
Contractor or Vendor	6	*"Our contractors, absolutely."*
Building Engineer or Maintenance Crew	3	*"I would turn to our building engineer or someone in the service department."*
Outside Consultants	2	*"We would reach out to consultants we use for designing HVAC systems and commissioning projects. We have go-to people and firms. Our account manager can put us in contact with CEE or Franklin Energy staff for support."*
Conferences	1	*"Maybe at the conferences for Ice Rink Managers? They often have vendors come and talk about new tech."*

In addition to the sources listed in Table 17, 4 of the 16 respondents said that there was nowhere in particular they would turn to for this information.

Eleven of the 12 participants who listed any information sources listed people they would ask as their first step. Six said they would turn first to their contractor or vendor. However, one participant acknowledged that that information is probably incomplete. *"[I'd ask a] third party HVAC vendor—probably a young salesperson who doesn't know much. And it's disappointing that they're my main contact and are so uneducated. I'd like them to tell me more."* Three participants said they would ask their building engineer first: *"We'd start out with engineering contacts, see if they use them. If not, we'd have them go reach out to other contacts they know who have been there before and learn what the pros and cons are."* And another two mentioned outside consultants and specifically organizations like CEE.

Only 6 out of 12 participants who named information sources said they would do any independent research beyond a trusted advisor. One participant said they would likely attend a trade conference, and another five participants list the internet as a secondary option, often listing it after their primary approach: "*Sometimes the internet? More often I'd ask my vendor.*"

Appendix C Interview Guides

This appendix includes the following data collection instruments:

- Manufacturer Interview Guide
- Contractor and Distributor Interview Guide
- Building contacts Interview Guide

RTU Supply Chain Research: Manufacturer Interviews

Table 1: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	In-Depth Interview
Estimated Time to Complete	45 minutes
Population Description	RTU manufacturers with sales in Minnesota
Call List Size	TBD
Completion Goal(s)	10 interview completes
Type of Sampling	Purposive
Fielding Firm	Cadeo

Table 2: Research Objectives and Associated Questions

Research Objective	Associated Questions
Identify available products and sales trends.	Q2, Q8, Q9, Q12, Q13, Q15, Q19, Q20, Q24 ,Q25, Q29, Q30, Q32, Q36
Understand RTU stocking practices.	Covered in contractor/distributor interviews
Understand supply chain perception of high performance RTU products.	Q1, Q3, Q5, Q14, Q21, Q26, Q33
Understand/confirm supply chain dynamics.	Q3, Q38
Identify customer and market segmentation for high performance RTUs.	Q11, Q18, Q31, Q35
Establish typical market criteria for high performance RTU.	Q1, Q2
Understand barriers and opportunities for high performance RTU expansion in MN.	Q6, Q10, Q15, Q16, Q17, Q20, Q22, Q23, Q27, Q28, Q34, Q36, Q37

Background

This interview guide targets RTU manufacturers with sales or projects in Minnesota. The Cadeo team is seeking insight into RTU supply chain dynamics, including understanding any barriers, opportunities, and leverage points for market intervention.

Instrument

Outreach

Email for Manufacturers

Hello XXX,

I work for Center for Energy and Environment (CEE) and I'm reaching out today to see if we can set up a call to introduce our organization and ask you some questions about the commercial RTU market and (Manufacturer)'s products. CEE is developing a commercial RTU market transformation initiative, so we're hoping to better understand manufacturer perspectives on the RTU market in Minnesota. We would greatly appreciate your insights on this market to help shape programs that reduce energy consumption and improve occupant experiences in Minnesota buildings. This conversation would be confidential and would take less than an hour.

If you're up for speaking with us, I'll have Lima from Cadeo (Cadeo is a consulting firm supporting CEE on this outreach) follow up to find a time that works for you. Please feel free to invite anyone else from your organization who would like to join, or please point us toward another contact that would be best for these types of questions.

Thanks!

Manufacturers

Background Questions

Q1. Are your RTU products sold in MN?

1. Yes
2. No

Awareness & Perception

Q1. How do you define a high efficiency RTU? What terms does your company use to distinguish your most efficient products from your other equipment?

Q2. What products or product features do you market as energy saving? (ask specifically about heating if not mentioned)

High Performance Product Features

We are interested in energy efficient RTU products that have specific high-performance features. I'd like to ask about some of these features.

1. Sealed or Low-leakage outside air dampers (also called economizer dampers)

   [Do not read, only for explanation if asked] Low-leakage dampers are those that meet or exceed MN 2020 energy code requirements (aligns with ASHRAE 90.1-2019 Table 6.4.3.4.3). For MN, AMCA Class 1 or 1A (4 or 3 cfm/ft2 at 1in WC).

2. Enclosure insulation

   [Do not read, only for explanation if asked] We're aware that standard enclosure insulation is ¼-1/2' of fiberglass insulation. Increased enclosure insulation would be 1-2" of fiberglass batting or an upgrade to double wall extruded foam construction. Resistivity of increased enclosure insulation would be approximately R-7 to R-12.

3. Variable speed fans

   [Do not read, only for explanation if asked] The ability to vary supply airflow by changing the motor speed of the fan. Typically, this would be through using a variable frequency drive (VFD) or an electronically commutated motor (ECM), though we're interested in any adjustable speed technology. This is not just 2-stage fans, but fully variable.

4. Heat recovery (HRV/ERV)

   [Do not read, only for explanation if asked] In systems with ventilation air, the ability to recover energy from exhaust air and transfer it to the incoming fresh air stream. This can either be sensible only recovery (heat recovery ventilator or HRV) or latent and sensible recovery (energy recovery ventilator (ERV).

5. Dual fuel heat pump

   [Do not read, only for explanation if asked] An RTU with both a gas furnace and electric heat pump heating systems. Typically, the gas furnace will serve as backup auxiliary heat to the heat pump.

6. *[Do not read, only for explanation if asked]* Variable capacity heat pump

   Variable speed or variable capacity heat pumps (VSHP) are those that can vary compressor speed to match the heating/cooling load (instead of cycling on and off).

7. *[Do not read, only for explanation if asked]* Cold climate heat pump

   A heat pump that is designed or optimized to operate at colder temperatures, and therefore maintains its efficiency and heating capacity at colder temperatures better than a "standard" heat pump.

Let's start with Dual-fuel heat pumps

Q3. How familiar are your customers (contractors and distributors) or the market in general with dual fuel heat pumps?

Q4. What portion of your products have dual fuel heat pumps?

Q5. What are the main benefits of dual fuel heat pumps, in your perspective?

Q6. What are the barriers to increased market adoption of dual-fuel RTU heat pumps?

Q7. What are the differences in equipment costs between a standard RTU and a dual-fuel HP RTU (as a percentage)?

Q8. Do you plan to increase the number of products with dual fuel heat pumps? If yes, when will they be available? (Probe for timeframes)

Q9. What is the adoption trajectory you expect for dual fuel heat pumps? (probe for duel fuel options with variable speed heat pumps)

Q10. Do you see more opportunity for all-electric cold-climate RTUs or dual fuel heat pump RTUs in the next year? Next 5 years? Are you developing both products?

Q11. Are there any specific building or customer types that you specifically market dual-fuel heat pump RTUs to?

ERVs

Q12. What portion of your products have an option for an ERV? (Probe for bolt on vs integrated)

Q13. How can customers include an ERV in their RTU? (probe: Are these ERVs integrated into the box or are they a bolt-on or 3rd party option? Does it vary by product line?)

Q14. What are the main benefits of ERVs from your perspective?

Q15. Do you plan to increase the number of products that have ERVs as a standard feature? (What product development plans do you have for ERVs?)

Q16. What are the barriers to increased market share of products with ERVs? (Probe for differences between bolt-on vs integrated)

Q17. What are the differences in equipment costs between a standard RTU and an RTU with ERV (as a percentage)?

Q18. Are there any specific building or customer types that you specifically market ERVs to?

Additionally, we are interested in sealed or low-leakage outside air dampers (also called economizer dampers). Low-leakage dampers are those that meet or exceed MN 2020 energy code requirements.

Q19. What portion of your products include options for low-leakage dampers? Do you have products available now with low-leakage dampers as a standard feature?

Q20. **Do you plan to increase the number of products that have low-leakage dampers as a standard feature?** (What plans do you have with low-leakage dampers? Do you plan to make these a standard feature on all units in the future? What is the likely timeline for that shift?)

Q21. What are the main benefits of low leakage dampers from your perspective? (e.g., Increased control, fewer heating/cooling losses, ability to market as a premium product, or just meeting code requirements)

Q22. What are the barriers to increased market share of products with low-leakage dampers?

Q23. Is there an additional cost for low-leakage dampers? If so, approximately what percent would they add?

Let's turn to variable speed fans. These are not just 2-stage fans, but fully variable (i.e. VAV and not multi-stage).

Q24. About what portion of your products include variable speed fans as a standard component? What portion of products have variable speed fans as an option (or upgrade)

Q25. Do you plan to increase the number of products that have variable speed fans as a standard feature? What plans do you have for variable speed fans?

Q26. What are the main benefits of variable speed fans from your perspective? (e.g., improving tested ratings, helps meet DOE 2023 cooling standard, increased control, decreased start/stop wear and tear)

Q27. What are the barriers to increased market share of products with variable speed fans?

Q28. Is there an additional cost for variable speed fans? If so, approximately what percentage would they add?

Finally, we'd like to ask about cabinet or box insulation.

Q29. What thickness of cabinet or box insulation is standard on your products? (ask to provide R-value if known)

Q30. Do you have products that offer increased enclosure insulation? If yes, what level of insulation do those products have? (ask to provide R-value if known)?

Q31. Are those products with increased insulation marketed for a specific application (such as DOAS units)?

Q32. Do you plan to increase the number of products that have increased insulation as a standard feature? (What plans do you have for increased enclosure insulation?)

Q33. What are the main benefits of increased enclosure insulation from your perspective? (e.g., increased enclosure strength, decreased solar gains)

Q34. What are the barriers to increased enclosure insulation? (e.g., re-tooling of production lines, product redesign, space constraints)

All features – Overarching questions

Q35. Overall, are there any specific building or customer types that you specifically market high efficiency RTUs and their features (like dampers, variable speed fans, and insulation) to?

Q36. What do you think the Minnesota RTU market will look like over the next 5 years?

Q37. What are key factors that you think will influence the trajectory of adoption for more efficient RTUs with these features?

Supply Chain Dynamics

Q38. Through which channels do you sell your RTUs? (Probe for primary channel, to understand scenarios for different sales.)

Conclusion

Thank you so much for answering our questions!

[Manufacturers] For this research effort we are also hoping to interview distributors and manufacturer reps as well. Can you refer us to distributors or manufacturer reps that you think would provide good insight into the MN market? They will receive $100 for their time.

RTU Supply Chain Research: Contractor and Distributor Interviews

Table 1: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	In-Depth Interview
Estimated Time to Complete	20-30 minutes
Population Description	Distributors and contractors in Minnesota
Call List Size	TBD
Completion Goal(s)	17 interview completes (7 distributors/man reps, 10 contractors/installers)
Type of Sampling	Purposive
Fielding Firm	Cadeo
Incentive Plan	$100 incentive delivered through Tango

Table 2: Research Objectives and Associated Questions

Research Objective	Associated Questions
Identify available products and sales trends.	Q3, Q4, Q5, Q9, Q12, Q16
Understand RTU stocking practices.	Q26, Q27, Q28, Q29
Understand supply chain perception of high performance RTU products.	Q2, Q3, Q5-Q20, Q23, Q24
Understand/confirm supply chain dynamics.	Q28, Q30, Q31, Q32, Q33, Q34, Q25
Identify customer and market segmentation for high performance RTUs.	Q5, Q9, Q12, Q16, Q21
Establish typical market criteria for “high performance” RTU.	Q2, Q21
Understand barriers and opportunities for high performance RTU expansion in MN.	Q5-Q18, Q22, Q29

Background

This interview guide targets RTU manufacturers, manufacturers' reps, distributors and contractors with sales or projects in Minnesota. The Cadeo team is seeking insight into RTU supply chain dynamics, including understanding any barriers, opportunities, and leverage points for market intervention.

Instrument

Outreach

Email for Contractors/Manufacturer Reps/Distributors

Hi <insert contact name>

My company Cadeo is working with Center for Energy and Environment (CEE) to better understand contractor/distributor experiences with efficient RTUs in Minnesota. We would greatly appreciate your participation in a brief interview to help shape programs to reduce energy consumption and improve occupant experiences in Minnesota buildings.

We would like to incorporate your insights into this work and as a thank you for your time, we are offering a **$100 e-gift card** for those who participate.

Are you available within the next week for a short **15-20-minute call**? Please use the Calendly link below to set up a time that works best for you.

Calendly link to schedule: https://calendly.com/d/2md-ybp-fgn/cee-rtu-contractor-distributor-interview

Your responses will be kept confidential and used for research purposes only. Please do not hesitate to reach out if you have any questions about this study. I look forward to hearing back from you!

Phone

Hi, my name is _____ and I'm calling from Cadeo, an energy efficiency research firm. We are conducting research to better understand the dynamics of the Midwest RTU market. We are working with the Center for Energy and Environment. I'd like to understand your perspective on this market. My questions should take about 15-20 minutes. We are offering a $100 e-gift card for those who participate.

Is this a good time, or should we schedule a follow up call?

[If referred to a different contact, collect their name/email/number and release contact.]

Thank you for your time today—do you have any questions for me before we get started?

Screening [ASK ALL]

Thank you for taking the time to chat with me! This interview is voluntary and confidential, and no quotes will be directly attributed to you. If you're comfortable, we would love to record this interview just to help with the note taking.

First, I'd like to confirm your role:

S1. Do you sell or distribute RTU equipment?

1. Yes
2. No
3. Sometimes
-98. Don't know

S2. Do you install RTU equipment?

1. Yes
2. No
3. Sometimes
-98. Don't know

S3. Does your company assemble or manufacture RTUs?

4. Yes
5. No
6. Sometimes
-98. Don't know

[**IF NO TO ALL THREE SCREENING QUESTIONS, THANK AND TERMINATE**]

S1=1: Distributor, Manufacturer Rep

S2=1: Contractor

S3=1: Manufacturer

Distributors, Manufacturer Reps and/or Contractors

Awareness & Perception

Q2. How do you define a high efficiency RTU? What **terms** does your company use to distinguish your high efficiency products from your other equipment?

Q3. What terms do customers use when they want something above code-minimum products? How often do they request these products?

Q4. What products or product features do you recommend for customers hoping to save energy (for example, in order to keep operating costs low)?

Market Baseline: High Performance Features

We'd like to understand if or how you sell specific RTU features. The features we're particularly interested in learning more about are:

1. Sealed or Low-leakage outside air dampers (also called economizer dampers)

   [Do not read, only for explanation if asked] Low-leakage dampers are those that meet or exceed energy code requirements. (ASHRAE 90.1 Table 6.4.3.4.3). For MN, AMCA Class 1 or 1A (4 or 3 cfm/ft2 at 1in WC).

2. Variable speed fans

   [Do not read, only for explanation if asked] The ability to vary supply airflow by changing the motor speed of the fan. Typically, this would be through using a variable frequency drive (VFD) or an electronically commutated motor (ECM), though we're interested in any adjustable speed technology. This is not just 2-stage fans, but fully variable.

3. Heat recovery (HRV/ERV)

   [Do not read, only for explanation if asked] In systems with ventilation air, the ability to recover energy from exhaust air and transfer it to the incoming fresh air stream. This can either be sensible only recovery (heat recovery ventilator or HRV) or latent and sensible recovery (energy recovery ventilator (ERV).

4. Dual fuel heat pump

   [Do not read, only for explanation if asked] An RTU with both a gas furnace and electric heat pump heating systems. Typically, the gas furnace will serve as backup auxiliary heat to the heat pump.

Feature Set Questions

I'd like to ask about some of these features.

Let's start with sealed or low-leakage outside air dampers (also called economizer dampers). When we are talking about sealed or low-leakage dampers, we mean those that meet or exceed energy code requirements.

Q5. About what portion of sales (or installations) over the past two years included sealed dampers?

Q6. What are the main benefits of sealed dampers from your perspective?

Q7. And, what are the challenges in selling sealed dampers?

Q8. Have you considered other box improvements, like insulation, when recommending systems?

Let's turn to variable speed fans. *These are not just 2-stage fans, but fully variable (i.e. VAV and not multi-stage).*

Q9. About what portion of sales (or installations) over the past two years included variable speed fans?

Q10. What are the main benefits of variable speed fans?

Q11. And, what are the challenges in selling variable speed fans?

ERVs

Q12. About what portion of sales or installation over the past two years included RTUs with ERVs incorporated or bolt on ERVs?

Q13. What are the main benefits of ERVs?

Q14. And, what are the challenges in selling ERVs? (probe for availability)

Q15. How confident are you in installing ERVs (probe for challenges, bolt on, electrical, weight, training needs, etc.)?

Dual-fuel heat pumps

Q16. About what portion of sales or installations over the past two years were dual fuel heat pumps?

Q17. What are the main benefits of dual fuel heat pumps, in your perspective?

Q18. And, what are the main challenges in selling dual-fuel heat pumps?

Q19. How confident are you in installing dual-fuel heat pump RTUs (probe for challenges, electrical, weight, etc.)?

Q20. How confident are you in talking to customers about dual-fuel heat pump RTUs?

All features – Overarching questions

Q21. What types of customers or buildings would you be most likely to recommend these high performance features for? Is the answer different for any of the features (e.g., different applications for units with HRV vs. dual fuel HP)

Q22. How important is the roof curb in RTU product selection? (Is this a major driver in the decision-making process, or just a consideration?)

Training

Q23. How do you stay up to date on the latest RTU product offerings and features? (For example, do you hear from colleagues, from professional associations, distributors, manufacturers, some other way?)

Q24. How do you and your staff receive training on proper installation, controls, etc.? (Probe where this training happens)

Q25. How do you think the Minnesota RTU market will change in the next 5 years?

Market Segmentation

We'd like to discuss two scenarios for RTU replacement. Some customers choose to replace products because they want an upgrade, it's in tandem with other remodeling, there are roof issues or just general poor performance of existing equipment. We'll call this segment the "planned replacement" market. Others

purchase products because of complete failure of previous equipment. We're going to call these folks part of the "replace on fail" market.

[ASK IF S1=1, DISTRIBUTOR]

Q26. [Distributors/Man Reps] With these definitions in-mind, which products do you typically stock for urgent (or replace on fail) replacements?

[ASK IF S1=1, DISTRIBUTOR OR S2=1, CONTRACTOR]

Q27. Which types of products typically get ordered for replace on fail projects? Are they different from planned replacements? (Probe for size, efficiency standards, fuel source)

Q28. What portion of replacement product orders are replace on fail compared to planned replacement?

Q29. Are the products you order typically available immediately "off the shelf" or is there a lead time? (Probe has this changed in the last few years with supply chain issues, how do you see this going forward)

Supply Chain Dynamics

[ASK IF S2=1, CONTRACTOR]

Q30. Focusing on the last two years, what portion of RTUs were sourced from a distributor?

Q31. What about the portion ordered through a manufacturer rep?

Q32. And, what portion were sourced directly from a manufacturer? (Is that different from manufacturer rep in their minds?)

Q33. [IF MULTIPLE PATHS] What drives the decision to order from one source over another?

[ASK IF S1=1, DISTRIBUTOR OR S2=1, CONTRACTOR]

Q34. Do you tend to install/sell products from a single manufacturer, or do you order from multiple manufacturers?

Q35. How do you stay up to date on the latest RTU product offerings and features? (For example, do you hear from colleagues, from professional associations, distributors, manufacturers, some other way?).

Q36. How do you and your staff receive training on proper installation, controls, etc.? (Probe where this training happens)

Q37. How do you think the Minnesota RTU market will change in the next 5 years?

[ASK ALL]

Conclusion

Thank you so much for answering our questions! Can we use the email we have on file to send you the $100 e-gift card?

RTU Building Contacts Interview Guide

Table 1: Overview of Data Collection Activity

Descriptor	This Instrument
Instrument Type	In-Depth Interview
Estimated Time to Complete	30 minutes
Population Description	Commercial building facility staff and decision makers.
Call List Size	TBD
Completion Goal(s)	~20
Type of Sampling	Purposive
Contact Sought	Contacts with experience procuring or maintaining building systems, including HVAC.
Fielding Firm	Cadeo
Incentive Plan	$100 incentive delivered through Tango

Background

This interview guide targets building owners, third-party property managers, facility managers, and/or building engineers involved in selecting, operating, or maintaining HVAC equipment. Research objectives for this guide are summarized in Table 2.

Table 2: Research Objectives and Associated Questions

Research Objective	Associated Questions
Understand the decision-making process for commercial HVAC customers	Q6, Q7, Q8, Q9, Q11, Q12, Q13
Determining the key influencers and decision makers in purchasing RTUs	Q5, Q10, Q18
Documenting products and features that are most appealing to those decision makers	Q13, Q14, Q15, Q16, Q17
Investigate target markets and customer segments for high-performance RTUs	Q1, Q2, Q3, Q4, Q9
Determining methods for engaging with target markets	Q5, Q6, Q10

Instrument

Outreach

Hi, my name is _____ and we are conducting research on behalf of Center for Energy and Environment to understand the needs of commercial building representatives in Minnesota when it comes to maintaining and replacing HVAC equipment. I'd like to ask you some questions about your experience selecting or maintaining HVAC systems in commercial buildings. My questions should take about 30 minutes. We are offering a $100 e-gift card to say thank you for your time.

Is this a good time, or should we schedule a follow up call?

[If referred to a different contact, collect their name/email/number and release contact.]

Thank you for your time today—do you have any questions for me before we get started?

Introduction

(If scheduled) Thank you again for taking the time to speak with us about your experience. As we mentioned in our initial outreach, we are conducting research on behalf of Center for Energy and Environment to understand the needs of commercial building representatives in Minnesota when it comes to maintaining and replacing HVAC equipment. Your answers will help us design programs that are informative and helpful for building owners/representatives like yourself.

Before we get started, I wanted to let you know that this call is voluntary and confidential - it will not be shared beyond the CEE team. Do you have any questions for me?

Great – we also like to record these calls so the research team can use them to augment note taking. Is it okay with you if we record?

Role

Q1. First, can you tell me a little about your role?

Q2. Do you work with/manage one building, or a portfolio?

Q3. Please describe the building, or the portfolio. (Probe: for example, do you work mostly with office buildings, health care, retail, or some other type? Or if one building, please describe the "size" in number of stories or approx. sq. ft.)

Q4. What types of heating and cooling systems are most common your building(s)?

Q5. Do any of the buildings you work with have rooftop units (also known as RTUs, gas packs, DOAS)? *[Interviewer note: RTUs are packaged HVAC equipment installed on the roof that provide heating, cooling, and ventilation in one "package."]*

Decision making process

Q6. Who maintains the HVAC equipment in your building (e.g., you, mechanical contractor, maintenance team)?

Q7. How do you determine when you need to replace equipment? (Probe to understand the scenario when full replacement might occur, versus on-going repair work.)

Q8. Do you have a preventative maintenance program, and if yes, are HVAC replacements part of that program?

Q9. How many times have you gone through the process of replacing equipment)?

Q10. How many of those replacements are like-for-like replacement versus an upgrade/redesign to the system?

Q11. Who is involved in the decision to select and purchase new HVAC equipment?

a. Do you typically get multiple bids?

b. Do you have an established contractor relationship that would guide this?

c. Do you ask others for input or advice?

d. About how long does this process typically take?

Q12. What challenges do you face when reviewing bids and selecting new equipment?

Q13. How do these challenges change when equipment has failed or is failing as opposed to a planned replacement? (Have you experienced both scenarios?)

Efficient HVAC equipment

Q14. What procurement guidelines or sustainability objectives does your organization operate with?

Q15. There are a variety of considerations in selecting new HVAC equipment. I'm going to list several and I'd like to know if each is important to your organization. Please answer: important, somewhat important, or not important. *[Interviewer note: this isn't a rating task, list each one, ask how important it is in their decision-making and why something is important or unimportant and how that might affect their decision.]*

1. Improving indoor air quality
2. Lead times, or how quickly you can get the replacement equipment
3. Improving occupant comfort
4. Lowering operating costs through lower energy bills
5. Lowering maintenance costs
6. Improving the reliability of the system
7. Minimizing the first cost (purchase and installation)
8. Getting a similar system to what you already have
9. Working with a contractor/dealer you trust
10. Carbon emissions reduction or sustainability

Q16. Are there other important considerations? Anything we didn't mention?

Q17. What specific features or technical characteristics do you look for in equipment to meet the priorities we discussed above?

Q18. We're interested in how familiar you are with the following RTU features that deliver energy savings. [*Interviewer note: if familiar, probe to understand their opinion of them – do they work/save energy? Have they implemented them or are they interested in trying them? What would make them consider/try them and/or what has stopped them from selecting these?]*

1. Low-leakage dampers (also called economizer dampers).
2. Variable speed fans.
3. Energy recovery ventilator (also called heat recovery)
4. Dual fuel heat pump RTUs (electric heat pump with gas backup)

Q19. Where would you turn for information on specific features like this?

Conclusion

Q20. Thank you so much for answering our questions! Can we use the email we have on file to send you the $100 e-gift card?

Q21. We are also conducting interviews with building contacts about efficient lighting controls. Do you know anyone that we can contact that may be willing to speak with us about lighting controls, or even better is that also you? If you're interested in another conversation like this (and another $100) can we reach out again with those questions?