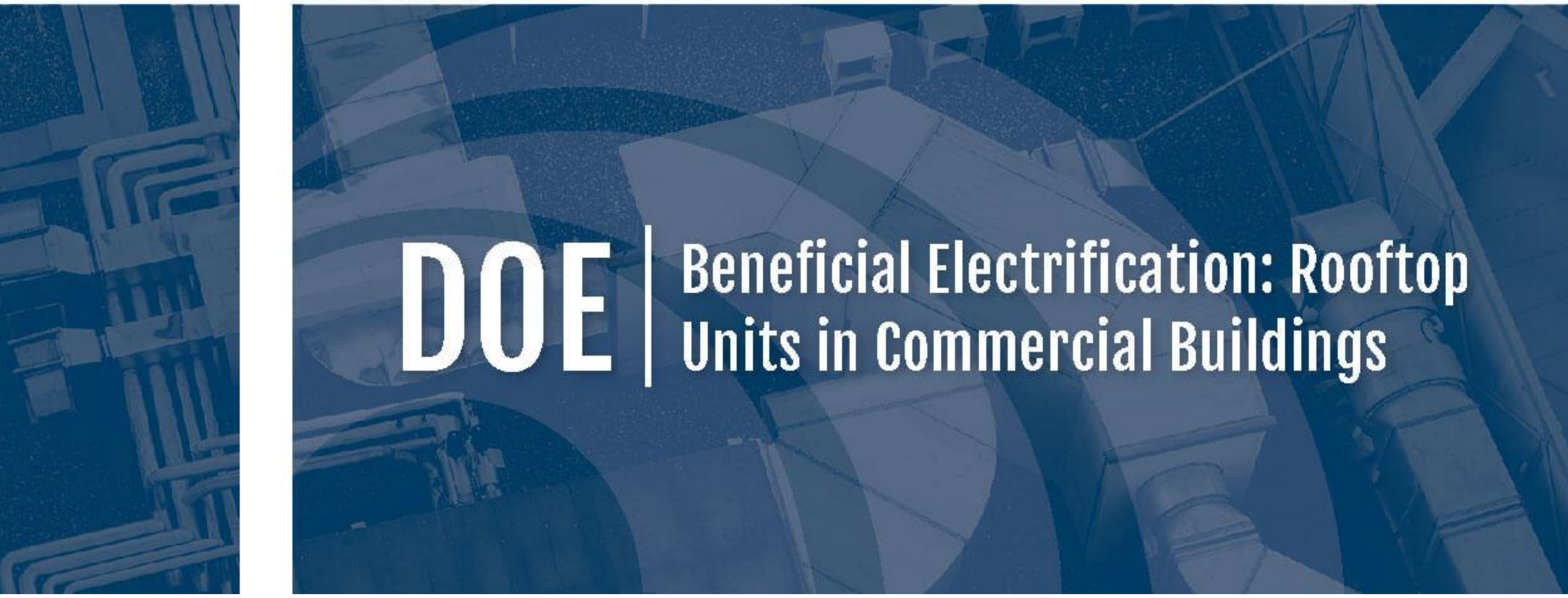

DAWNBREAKER®
The Commercialization Company
2117 Buffalo Road, Rochester, NY 14624
(585) 594-0025 // www.dawnbreaker.com

Project Team:
Kristen Johnson MLS, Bob Berkman, MA, Eliza Gough, MLS, and Jenny C. Servo, Ph.D.

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1.0 INTRODUCTION

This report is an extension of the Beneficial Electrification report prepared for the Building Technologies Office (BTO) in April 2021. The overall objective is to provide greater insight into the challenges associated with retrofit installation of Rooftop Units (RTUs) in commercial buildings with a specific emphasis on conversion to heat pump RTUs. A combination of primary and secondary market research methods were used to address three primary objectives:

> **Objective 1:** What are the installation challenges associated with converting from existing RTU to Heat Pump RTU by region
>
> **Objective 2:** How does consideration of operating costs affect the choices made by decision makers, and
>
> **Objective 3:** What is the distribution of RTUs by region, type, and age

Thirty-one in-depth interviews were conducted to probe the first two objectives. This sample drawn from a larger pool of 158 individuals was selected for their breadth of experience and was comprised of HVAC system design engineers, large mechanical contractors, and commercial HVAC installers all with experience in commercial HVAC design and installation. Also included were individuals affiliated with HVAC industry associations and various Net-Zero initiatives. Respondents represented different regions of the country including New England, Mid-Atlantic, the South, Southwest, Northwest, and Midwest regions. Details regarding the interviews and the methods used to gather the information can be found in Appendix A Secondary market research was also conducted to explore how operating costs affect the decision to purchase an RTU and to determine the distribution of RTUs by age, type and region.

This report summarizes the findings and makes a number of recommendations aimed at changing the “like-for-like replacement” paradigm which characterizes the decision making process of commercial building owners. Recommendations are also made for (1) providing on-going information to influencers (facility manager, property manager, consultant, mechanical engineers, professional management company) regarding the benefits of heat-pump RTUs; (2) establishing local demonstration sites: (3) mitigating the curb adaptor issue; and (4) providing training to local HVAC designers and installers. Also recommended are two methods for assessing the distribution of RTU types by region, type and age.

2.0 Trends, Installation Challenges, & Factors Influencing the Selection of Commercial Rooftop Units

2.0 Trends, Installation Challenges, and Factors Influencing the Selection of Commercial Rooftop Units

This section summarizes the information gathered during the interviews in response to the following questions:

- With commercial buildings in this region, what motivates a building owner to replace their existing rooftop unit?
- What type of rooftop unit do most of the commercial buildings in your region have?
- What seems to be most important to the decision maker when selecting a replacement rooftop unit?
- How often are heat pump rooftop units considered as an alternative replacement (and why do you think that is the case)?
- What are the installation challenges you anticipate when replacing an existing rooftop unit and how do you address these challenges?
- Do commercial building owners express a desire to lower their carbon footprint and decrease the use of natural gas?

2.1 Motivation for Replacing an Existing Rooftop Unit

Regardless of the region, the factors that motivate a building owner or decision maker (if not the building owner) to replace their existing rooftop unit were consistent. The most frequently reported reason for replacing an existing rooftop unit is that the unit is at the end of its service life and is no longer functioning properly (catastrophic failure, burnout, end of service life, in need of repair). Equipment failure was mentioned by 96% of the respondents. In this case, the equipment would have to fail to a point where it does not make financial sense to repair the unit.

Building owners will often wait until the unit needs repair, at which point they then consider the cost of the repair versus the cost of replacing the unit. Relatively few owners elect to replace a unit prior to burnout, except perhaps during larger renovations or as part of a phased equipment replacement plan. One respondent noted that it is typically the heat exchanger or compressor that fails. If these major components fail, building owners may be more inclined to purchase a new rooftop unit. The age of the unit does factor into an owner's decision to repair versus replace a rooftop unit. One respondent noted that people who own several buildings may have a service contract in place and a plan (budget) to replace rooftop units over time. Functionality of equipment is key.

With many units being replaced after a breakdown, this tends to encourage a "like-for-like" replacement. Owners or decision makers do not always have a lot of time to think through the decision because they must get a new HVAC system in place as soon as possible. While a heat pump rooftop unit or a more energy efficient system might make sense, from a long-term perspective, it is easier for the decision maker to simply choose the system they are most familiar with (which is likely to be the same type of system they had before).

The most frequently cited reason for replacing an existing RTU is that the unit is no longer functional and beyond repair. Few owners will replace a unit prior to burnout, with the exception of those doing larger renovations or those that have a phased equipment replacement plan.

Another reason cited by 17% of respondents for replacing a rooftop unit is a change in how the building space is used. If one tenant leaves and another comes in, changes to the HVAC system may be required to accommodate new use of the space as a restaurant, a gym, an office, healthcare facility or retail store. Simply put, a new building occupant may have different needs than the former occupant. One respondent, who has experience designing commercial rebuild projects of older buildings to accommodate new tenants, commented that these types of projects tend to keep as much of the existing equipment as possible. They will only change out units that are excessively old and would otherwise become a maintenance burden. That said, another respondent stated that tenant comfort issues (noise, temperature, indoor air quality) can be a major driver for replacement.

Tenant comfort and ensuring adequate heating, cooling, and capacity are important to both building owners and tenants. When a new tenant moves in to occupy a space, this can be a good opportunity to assess the tenant's HVAC needs and replace the existing equipment, if necessary.

Nine percent of the respondents mentioned energy efficiency (or lack thereof) and incentives as drivers for replacement. A more energy efficient unit could translate to fewer service calls and reduced operating expenses. Approximately 9% of respondents noted that a rooftop unit might be replaced if it uses outdated refrigerant (such as R22). One person (who is in the New York City area) mentioned that there may be building codes that a building owner may need to comply with. If this is the case, then a rooftop unit replacement may be required or warranted.

Other comments mentioned, although rarely included COVID-19 and how that has affected HVAC systems and preferences. A respondent from the New York City area indicated that building owners are interested in improving ventilation, air filtration, and fresh air intake in their buildings. While this does not always translate to a total system replacement, in some cases it may.

A respondent from the Northwest discussed climate change and how that impacts HVAC preferences. Oregon, for example, has historically been a heat-focused climate, but because the state experienced record high temperatures this summer, there has been an increased demand for cooling. If commercial building owners are interested in adding air conditioning to their building, this may factor into unit replacement.

There are some regions where building owners may be more inclined to explore RTU replacement—particularly those with incentives, mandates, or relevant buildings codes in place, as well as those in areas experiencing a shift in climate (their HVAC needs may change).

One respondent focusing on high-performance design in the Chicago area mentioned that often architects and engineers are looking to replace units and place them on a mechanical space or mechanical floor giving them the option to reserve the podium or roof for amenity space—such as green roofs, for example.

Table 1. Number and Percent Respondents Providing Reasons for Replacing a Rooftop Unit

Reason	Total Number of Respondents Who Mentioned This Reason	Percentage of Respondents Who Mentioned This Reason
Unit failure	22	96%
Change in how building space is used	4	17%
Energy efficiency	2	9%
Incentives/rebates	2	9%
Old unit uses outdated refrigerant	2	9%
Building code compliance	1	4%
Desire to add cooling	1	4%
Desire to improve ventilation or air filtration	1	4%

As respondents often provided multiple responses, Figure 1 represents the frequency with which specific responses were mentioned.

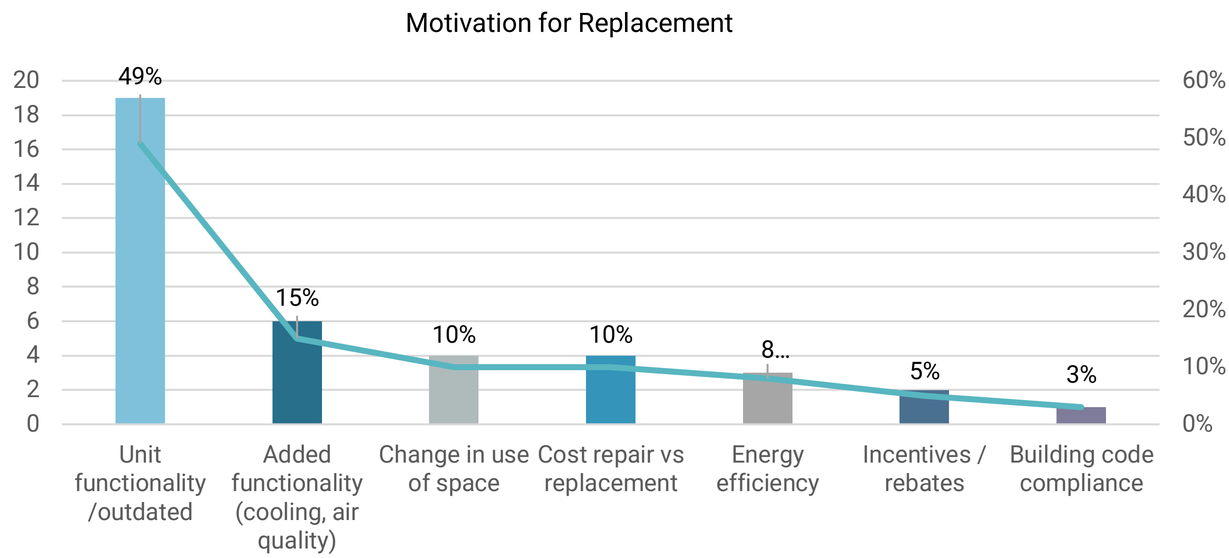


Figure 1: Frequency of response types mentioned in interviews

2.2 Most Common Types of Rooftop Units, by Region

As the respondents represented different areas of the country, all were asked about the most common type of rooftop unit in their region. N=21 people responded to this question. Their responses are summarized in Table 2.

Table 2: Most Common Type of Rooftop Unit, by Region

Respondent's Location	Most Common Type of Rooftop Unit, as Reported by Respondent
New England	
Lexington, MA	Gas heat with electric cooling
Canton, MA	Gas-fired units
Newington, NH	Gas-electric
Mid-Atlantic	
Merchantville, NJ	Combination heating/cooling (eliminating need for hot water heating boilers)
Alexandria, VA	Mix of gas packs and heat pumps
Fairfax, VA	Gas-electric represents about 65% of commercial rooftop units, while heat pumps account for about 35%
New York, NY	Gas-electric are more common
South	
Winston-Salem, NC	Nearly all projects require gas heat if gas is available
Peachtree Corners, GA	Unsure, but heat pumps were the assumption
Decatur, GA	Gas-electric is most common
St. Petersburg, FL	Combination of package units and chilled water units
Kosciusko, MS	More gas-electric (unitary systems, packaged units) rooftop units, but they are seeing some trending toward heat pump units
Southwest	
El Centro, CA (Southern California, desert climate)	Nearly all systems are package heat pumps
Mission Viejo, CA (Southern California, near Los Angeles)	Half gas-electric, half heat pump
Midwest	
Northville, MI	Gas-electric units are much more common, they don't get many heat pump requests
Madison, WI	Smaller DX cooled gas-fired rooftop units (80% efficient rooftop units, or non-condensing rooftop units)
Chicago, IL	DX gas fired constant volume is most common, but it does depend somewhat on the application
Gahanna, OH	Gas-electric rooftop units are most common (about 90-95% of units)
Northwest	
Portland, OR	Gas packaged DX units
Portland, OR	Package gas-electric is most common
Portland, OR	Gas heat DX cooling (less than 10 tons), but with new construction there is a shift toward heat pump RTUs

Warm and dry climates tend to see the greatest adoption of heat pump RTUs, while gas-powered units are still most common in cold weather climates. The industry is broadly seeing increasing consideration of heat pump RTUs for newly constructed buildings.

Dry, warm weather climates—such as Southern California and desert areas close to Mexico and Arizona—tended to be the areas with the greatest adoption of heat pump rooftop units. In the deep South, there is some trending toward heat pump rooftop units, but according to a few people in this region, they are not currently the dominant type of rooftop unit. Gas-powered, gas heat, or gas-electric units are still the most common type of rooftop unit seen on commercial buildings in the cold weather climates of the Northwest, Midwest, and New England regions. The Mid-Atlantic region is looking at a mix of gas-electric and heat pumps, with gas-electric still comprising the majority.

2.3 Factors that Influence the Decision Maker

There are several factors that come into play which influence a decision maker when selecting a replacement rooftop unit. At least 74% of respondents cited cost—and more specifically, capital cost or initial cost—as a major factor that influences buying behavior, if not the most important factor. For some building owners, the decision comes down solely to cost. Several people expressed the sentiment that the decision maker often wants the least expensive installation cost; upfront and capital costs are going to be a key factor.

At least 74% of respondents cited upfront and capital costs as a key factor that influences the decision maker. Only 4% of respondents cited operating cost as a key factor.

One respondent, who reiterated that capital cost is the most heavily weighted factor, noted that this is especially true if the situation involves an emergency rooftop unit replacement. Rooftop units are not exactly considered to be the most high-end HVAC system available, so those that have rooftop units tend to have them because they are less costly. If a replacement is planned, there may be an energy saving component. Energy efficiency is regarded as an increasingly important consideration (22% of respondents mentioned energy efficiency as a key factor), but most decision makers will want to see the simple payback or ROI (about 1-3 years is generally perceived to be a good payback period).

The availability of rooftop units and spare parts is an important consideration for decision makers. This not only ties into pandemic-related supply chain issues, but general supply and demand, as well.

System availability is also a factor, particularly for those dealing with replacement upon burnout—which is quite common. In addition, ease of maintenance and availability of qualified servicing contractors and parts are also considered to be important factors. According to one respondent, after pricing, the availability of parts locally is an important consideration. The COVID-19 pandemic may increase interest in local sourcing, as supply chain disruptions have been observed since the beginning of the pandemic. Most decision makers want to know if the brand that is being recommended to them will have parts available if something breaks down. On that note—reliability of the system is also an important consideration for building owners.

Ease of replacement is another factor that influences decision making and buying behavior. Generally, replacing "like-for-like" is the easiest option for both installers and building owners. Owner and/or operator familiarity with the existing system also influences the type of system selected. It is helpful (i.e., faster to install and less expensive) if the replacement rooftop unit can fit on the existing curb. Sometimes, building owners can be persuaded to go with a different manufacturer and a transition curb, but this takes a bit more time and effort than if the new rooftop unit were to simply fit on the existing curb.

While cost was overwhelmingly cited as the primary factor influencing the decision-making process, one respondent noted that mandates and incentives have been effective in drawing attention to energy efficiency. He offered that because of these incentives, efficiency might start to overtake cost as a key factor. Another respondent, who cited availability as one of the major factors, stated that if there's time to decide (i.e., the unit did not breakdown) and they therefore can talk about higher efficiency equipment, this may become a viable alternative. He also offered that it also depends on who is responsible for the utility bill.

The majority of RTU replacements are made on an emergency basis and commercial HVAC contractors present options that can be obtained quickly. Local distributors stock what sells. If more energy efficient units are not being sold, the distributors may not keep many in stock (if they stock them at all).

A replacement rooftop unit will have to meet the needs of the user, as far as air quality and cooling are concerned. Capacity must be appropriate for the needs of the business or user. Product warranty (specifically, heat exchanger warranty) was mentioned as an important factor.

While capital costs and upfront costs were the most often cited influencing factor, very few people mentioned operating costs as an influencing factor—just one person mentioned that "operating costs are sometimes important."

Table 3. The Number and Percent of Respondents Citing a Specific Factor that Influenced the Decision Maker

Factor	Total Number of Respondents Who Mentioned This Factor	Percentage of Respondents Who Mentioned This Factor
Capital/initial cost	17	74%
Energy efficiency	5	22%
System availability	5	22%
Ease of replacement	3	13%
Availability of parts and servicing contractors	3	13%
System reliability	3	13%
Capacity of the unit/meets air quality and cooling needs	2	9%
Curb fit/compatibility	2	9%
Owner/operator familiarity with the system	1	4%
Ease of maintenance	1	4%
Mandates and incentives	1	4%
Product warranty	1	4%
Code compliance	1	4%
Noise	1	4%
Operating cost	1	4%

While this topic is discussed in greater detail within section 3 of this report, many of the respondents provided some insight, regarding the decision maker. Nearly everyone noted that the building owner is either the primary decision maker or has active involvement in making the decision. However, there are several other individuals involved in the decision-making process, usually playing an information gathering role. For example, larger buildings sometimes have a facility manager or property manager who may be responsible for soliciting bids. Once collected, they present the various options and estimates to the building owner for review and a final decision. If it is a small operation, it is more likely for a contractor to interface directly with the building owner. One respondent mentioned that in Massachusetts most commercial building owners employ a professional management company. This company is paid to manage the building and is also responsible for the financial management of the building. They represent the "first line" gathering options to present to the building owner. While the owner makes the final decision, the people who manage the building provide the owner with the information on the rooftop units.

If the building is owner occupied, then the building owner will make the decision on what rooftop unit to purchase. They too will turn to designers, contractors and consultants for recommendations based on their expertise and understanding of the unique situation. In this case, the consultants and engineers gather information and pass along pricing information to the building owner.

While the building owner will almost always have some level of involvement in the decision-making process, the decision maker could technically be either the owner or the tenant. If the building is a public sector building (such as a school, healthcare facility, government, etc.) then the owner will make the decision. In the private sector, it could still be the owner making the decision, but the rooftop unit is really serving the tenant leasing the space. In this case, there tends to be a bit of an interplay between the owner and tenant. It comes down to how the lease is structured and written, but the owner of the building—often—has the final say. In select cases, if the lease agreement is written in such a way that the tenant is responsible for the HVAC, then the renter would be the decision maker and the owner would put the onus on the tenant. The tenant may go back to the owner to get some compensation (full compensation or partial compensation, depending on the scenario) for the upgrade or replacement, but 100% of the repairs would be shouldered by the tenant. A renter typically must be faced with a complete breakdown of the system to seriously consider a replacement.

The building owner, more often than not, has the final say when it comes to purchasing a new rooftop unit. An exception is when it is written into a tenant's lease agreement that they are responsible for repairing and replacing the HVAC system.

One might wonder how these decision makers learn about rooftop unit pricing. This does not just refer to the capital cost of the unit, but rather encompasses how a more efficient unit would impact long-term utility bills and energy efficiency. To some extent, the size of the job appears to have an impact. With large jobs, it is likely that an engineer will design the system and will have a variety of detailed analysis tools at their disposal. According to a mechanical contractor in Mississippi, with a more basic commercial space like a retail store they provide several options and make recommendations, that consider efficiency and payoff. They use software tools available for mechanical contractors and other HVAC professionals.

The President of an HVAC installation company in California stated that an educated installation company will play a key role in helping the decision maker understand pricing and long-term cost savings. HVAC Op Cost is a website that their company uses to show clients how units compare, in terms of efficiency, options, and how that translates to cost. According to an engineer in Wisconsin, pricing and energy efficiency information predominantly comes from the HVAC contractor, who should be savvy enough to know that they will need to make the business case by discussing simple payback and ROI. Contractors can develop reasonable savings estimates and may be supported in certain regions by utility efficiency programs. There are often incentives and rebates to offset the cost of switching to a higher efficiency rooftop unit, as well as associated energy savings and cost savings of what could be.

With a larger job, an engineer may be involved, and this person may provide information relative to long-term cost savings to the decision maker. With most projects, the commercial HVAC installer or mechanical contractor will provide this type of information, as well.

Also, of interest was understanding the extent to which anticipated future electrical operating energy costs factored into the decision to replace an existing unit with an electrical heat pump rooftop unit. If the building is owner occupied, they tend to invest more in the building. If the building is being rented out, the decision maker will ensure that the HVAC system works and will keep the tenant happy, but they won't typically invest much into a new unit because they won't see the return as the tenant typically pays the utility bills.

According to a respondent working for a commercial HVAC installation company in the DC metropolitan area, they are not seeing future electrical operating costs factoring much into the decision to replace an existing rooftop unit, especially in smaller commercial buildings (those 10,000 square feet or less in size). However, larger commercial buildings are seeing Variable Refrigerant Flow/Variable Refrigerant Volume (VRF/VRV) product interests increasing, and these are higher efficiency options. If larger buildings can obtain LEED certification or accreditation, then these efficiency upgrades are more attractive. Generally, the larger the building, the better the ROI for an energy efficient unit.

A commercial HVAC installer in Portland, OR echoed the sentiments of other respondents, saying that when it comes to operating costs, this has very little impact on a building owner's decision. In about 99% of commercial sales, the single biggest factor is price. In his experience, customers could care less about energy consumption. They would try to highlight the benefits and make the case, but it made almost no difference in the final decision. The reason for this is because the tenant ends up paying the electrical bill. The owner is just concerned about the upfront unit cost. Even with an owner-occupied building, you still see a heavy emphasis on upfront costs. There are a few owners out there, of course, who can be convinced to go with a more energy efficient solution—but they are very rare.

In many cases, the building owner is responsible for replacing the unit, but the tenant pays the bills. Therefore, the owner is really just concerned about the upfront unit cost.

In terms of factors that would make a decision maker more likely to move forward with a retrofit (even if electrical rates might be higher), one respondent said that it comes down to the comfort of the people occupying the space. If it's a retail operation, it must be cool—always. There is little to no hesitation if a system must be replaced. If a space is not comfortable, people will leave. This is true for retail, restaurants, medical offices, and professional offices, among other types of commercial buildings. AC systems will be replaced when they have hit their lifespan or are having issues in terms of keeping occupants comfortable. Energy costs seem to be more of a “regulators” or “legislators” issue, but they don’t factor into the retrofitting of AC systems very often.

2.4 Heat Pump Rooftop Units as an Alternative Replacement

Respondents were also asked how often heat pump rooftop units are considered as an alternative replacement. The following table outlines the responses received and reflects the regions in which they worked.

Table 4: Heat Pump Rooftop Units Considered as an Alternative Replacement, by Region

Respondent’s Location	How Often are Heat Pump Rooftop Units Considered as an Alternative Replacement?
New England	
Lexington, MA	Almost never
Canton, MA	Very rarely
Newington, NH	Not very often
Mid-Atlantic	
Merchantville, NJ	They don’t have much experience installing heat pump rooftop units
Alexandria, VA	Gas continues to be considerably more popular
Fairfax, VA	Heat pumps account for about 35% of commercial rooftop units; VRF systems do sometimes make sense, but you must have time to plan for the switch
New York, NY	Heat pump RTUs are rarely considered at this time
South	
Winston-Salem, NC	Rarely—air conditioning with gas heat is still the preference
Peachtree Corners, GA	Frequently
Decatur, GA	Sometimes—typically if it is replacing an existing heat pump
St. Petersburg, FL	Very seldomly
Kosciusko, MS	Rarely (but on occasion)—they do a lot of heat pump installs, but they don’t see a lot of heat pumps with commercial rooftop units
Southwest	
El Centro, CA (Southern California, desert climate)	In their desert area, 100% of the time
Mission Viejo, CA (Southern California, near Los Angeles)	Fairly often
Midwest	
Northville, MI	Seldomly
Madison, WI	Rarely
Chicago, IL	Energy codes have sparked some interest in heat pump rooftop units
Chicago, IL	Not very often
Gahanna, OH	Rarely
Northwest	
Portland, OR	Rarely
Portland, OR	Not as often as they should be

Three interviews were conducted with organizations from the Northeast who consistently indicated that heat pumps are very rarely considered as an alternative replacement for a rooftop unit. In this region, gas is more efficient and less expensive to operate than electric heat. In a conversation with a respondent in the Northeast, it was noted that heat pumps are not available for large commercial rooftops and small heat pump rooftops tend to face the same uphill battle as residential heat pumps versus gas furnaces. That said, according to a mechanical contractor focusing on commercial HVAC in Massachusetts, there are a lot of communities trying to move to a zero-carbon footprint; so, there are a few communities trying to get away from natural gas. He believes that this is a trend that's here to stay for a while. In the Boston area, there are a good number of environmentalists, so heat pumps might be examined more closely over time, but probably to the expense of the building owners. One person that we spoke with in the New York City area mentioned that a marketing campaign to increase awareness of these units could be helpful, in terms of encouraging adoption.

In the Northeast, some communities are trying to move to a zero-carbon footprint, and heat pump technology might be attractive. Mandates are starting to pop up, but this technology shift is coming at the expense of business owners. Financial incentives would certainly be helpful, as would a marketing campaign to increase awareness of these more efficient units.

The Mid-Atlantic region sees greater adoption of heat pump rooftop units. Factors such as energy allowances provided by the utility companies are likely playing an important role, in terms of incentivizing people to make the switch to all-electric heat pumps. While gas is still the most popular option (primarily due to cost per BTUH), about a third of commercial rooftop units in the DC metropolitan area are estimated to be heat pump rooftop units. In speaking with a mechanical contractor in the Virginia/DC area, it was noted that, about 80% of the time, the replacement is an emergency replacement, meaning that time to decide is limited. In this situation, it is less likely that the building owner will go with something new because their goal is really to just get something installed as soon as possible so they can get up and running again. With that said, VRF systems can be significantly more efficient, so if time permits and it seems to make sense from an economic perspective, this can be a good option for some buildings. In some cases, customers are trying to get a tax write-off or take advantage of incentives—these can be good reasons to look into a replacement rooftop unit.

In the Midwest, it seems that heat pump rooftop units are not often considered as a replacement for existing rooftop units as the climate does not readily lend itself to the use of heat pump RTUs. While heat pump rooftop units are used very little in the region, it was thought by one of the respondents (located in Wisconsin) that they are at the start of the S curve on adoption for these units. Contractor familiarity is a significant factor. The technology is new, and contractors need to become more familiar with the technology and willing to recommend a heat pump rooftop unit. They are also hampered by the low cost of natural gas in the region. If you are switching from an 80% efficient gas-fired heat exchanger to a heat pump, that is a coefficient of performance (COP) of 2-3 (COP of natural gas is .8). The cost of natural gas is so low that the building owner or occupant would end up paying more in utility bills. One noteworthy exception is in new construction, where you can eliminate the need to put in a natural gas line if one were to decide on electric from the start (but doing this is rare). In the upper Midwest, it is estimated that less than 1% of rooftop units are heat pumps. Barriers to adoption include contractor familiarity, potential upfront cost, the low cost of natural gas hampering energy savings, and the performance of rooftop units at very cold ambient temperatures is still questionable. There are heat pump rooftop units that can operate at the coldest design temps, but there are also some that don't. Establishing a very robust cold-climate heat pump supply chain is important for the Midwest. It was mentioned by a respondent in Chicago that energy codes are playing a role, in terms of encouraging owners to consider heat pump rooftop units (and some of them have been installed in the Midwest).

Contractor familiarity (or lack thereof) may be a barrier to adoption. Heat pump RTUs are not used as frequently in certain parts of the country and HVAC contractors may feel most comfortable recommending systems that are familiar to them. Marketing and educational materials, as well as tools, to help HVAC contractors make a more convincing case and become better versed in the technology, themselves, could be beneficial.

In the Northwest region of the United States, it is still somewhat rare to see a heat pump rooftop unit replacing a gas-electric rooftop unit. This is primarily because of the additional cost of the equipment, as well as the additional electrical requirement costs. Air source heat pump rooftop units are not as familiar to owners and contractors, there are fewer models on the market, and they often come with a higher initial cost ("first cost"), and for those reasons they are all too often not chosen when a replacement is needed.

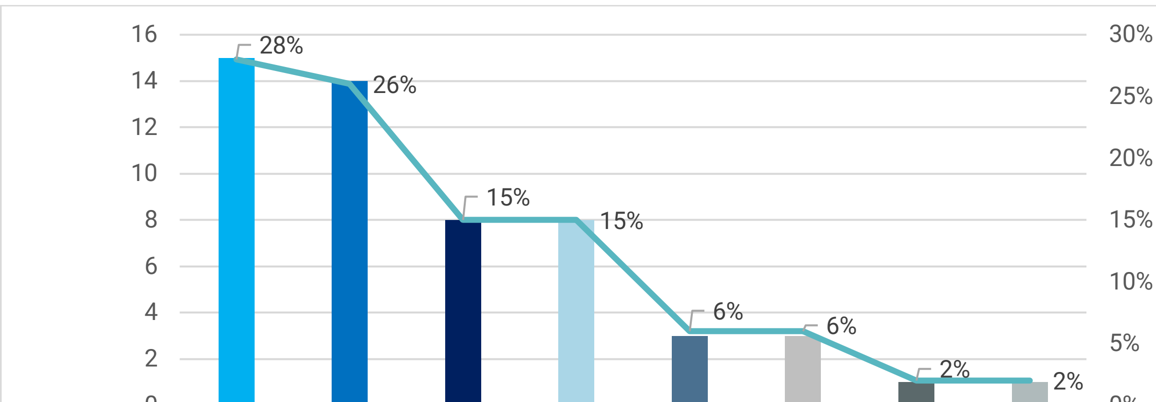
Establishing a very robust cold-climate heat pump supply chain is very important if heat pump RTUs are going to see increasing use in cold weather climates.

As for the South, responses varied considerably. In North Carolina, it appears there is still a strong preference for air conditioning with gas heat. Replacing a gas heat rooftop unit with a heat pump rooftop unit often requires that the electric branch circuit is upsized to handle the additional kW of the electric supplemental heat in the heat pump. Some of the respondents located in Georgia, Mississippi, and Florida said that heat pump rooftop units were seldomly considered as a replacement—mostly due to factors such as lack of demand, long period of time to reach the payoff and reap the benefit, most of the existing units have heat strips in the ductwork, and the fact that new wiring would be required if you were to switch from gas/electric to heat pump. A major international industry association for those in the HVAC segment (headquartered in Georgia), did note that heat pump rooftop units are frequently considered as an alternative replacement because they offer improved energy efficiency.

In the Southwest, it is common to replace a rooftop unit with the type of rooftop unit they had before. There used to be more resistance, in terms of moving from gas-electric to heat pump, but that's not so much the case today. If a building owner already has a heat pump, then clearly there would be much less resistance to them purchasing another heat pump rooftop unit. In Southern California, heat pump rooftop units are becoming more popular. Sometimes HVAC installers are resistant to change and hesitate to recommend something else. However, heat pump rooftop units have a lot of benefits—they provide optimal occupant comfort, they are quiet, and more efficient. In dry, desert areas, heat pump rooftop units are used very frequently (one respondent said pretty much 100% of the time). The reason for this is because they have a low power rate by their utility and heat is rarely used (even in the winter).

2.5 Installation Challenges

There are several installation challenges that may be anticipated when replacing an existing rooftop unit. These challenges tend to be widespread and not specific to a particular region or climate. One of the top challenges is trying to work with the "footprint" of the existing rooftop unit, when making a replacement. Many respondents cited this as a challenge but spoke to this issue in various ways. One respondent said that every effort is made to match the existing rooftop—size, weight, electrical characteristics, heat source, etc.—to avoid having to involve any mechanical, electrical, or structural engineers who would increase the project cost.



	Adaption i.e. curb, weight, size etc.	Logistics /downtime	Electrical considerations	Cost	Supply / labor shortages	Resilience	Training for new system	Air flow
Number	15	14	8	8	3	3	1	1
Percentage	28%	26%	15%	15%	6%	6%	2%	2%

Figure 2: Installation challenges by Frequency of Response

The existing rooftop manufacturer is at an advantage when a rooftop is going to be replaced because competitive systems may require a curb adapter to fit another manufacturer's curb. This increases the height of the unit above the roof, and it can be considered "unsightly." This used to be more of an inconvenience, in that each manufacturer had a different footprint and installers would need an adapter curb (which could take 2-3 weeks to come in) to ensure that the new system fits the old space properly. Within the past few years, manufacturers have started "copying" each other so that the footprint of their systems is very similar, if not the same eliminating the need for an adapter curb. At least 43% of respondents specifically mentioned the curb of the existing system—more specifically, matching the existing curb or acquiring a curb adaptor—as an installation challenge. One person that we spoke with thought that something like a universal curb adaptor could potentially help to address this challenge.

Like-for-like replacement is commonly seen with RTU replacements—people tend to stick with a technology, and even a brand, that they have used before. When decision makers deviate from the existing unit, they often try to find a new unit with a similar footprint or can work with a curb adaptor. The concept of a universal curb adaptor may be an idea worth exploring.

A commonly cited issue with moving from a gas/electric rooftop unit to a heat pump rooftop unit is the need to make changes to the electrical wiring. About 30% of respondents mentioned this as an installation challenge. Converting to a heat pump from gas is more costly than selling a gas replacement. A larger electrical service is going to be required in most cases, which will add to the cost. Even if the unit is higher efficiency, it still puts the user in a higher electrical power usage category, so it is common to need re-wiring and a larger electrical service (circuit breaker) to handle that heavier electrical load.

A primary challenge in moving from a gas/electric RTU to a heat pump RTU is the need to make changes to the electrical wiring, as a larger electrical service is going to be required in most cases. This will add to the cost of the replacement.

Several respondents did mention issues like space and weight—but these were discussed as more minor inconveniences or challenges that could be addressed with relative ease (in many cases, they can be addressed, but this just adds to the cost). When weight is a concern, the rooftop units may be divided into smaller zones to address weight restrictions. Overall, weight did not appear to be too concerning—but a challenge, nonetheless. According to one respondent, a heat pump rooftop unit might be a little heavier than an older unit—and it might require a little more space and refrigerant—but he did not think that would be a "deal breaker" for those who truly want that type of system and would benefit from it long-term. Newer units usually weigh more, but they require only a cursory review by a structural engineer to approve the added weight. One mechanical contractor noted that, prior to bidding, they check existing weights and, if the new unit is within 10%, they are good. If the difference in weight is greater than 10%, structural engineering and modifications will be required (this will add to the cost). If weight and space are issues that have come up, contractors may select an alternate mounting location or they may reinforce the roof, as needed.

If heat pump RTUs tend to be at least 10% heavier than more traditional gas/electric RTUs, it might be worthwhile to look at reducing the weight of the systems. If an energy efficient system is significantly heavier than the existing system, the expertise of a structural engineer may be required, along with other modifications or roof reinforcements, which would add to the overall cost.

Issues tied to logistics were also mentioned by 30% of respondents. In New York City, for example, cost of installation can be quite high because much of the work for rooftop units must be performed on the weekends, when there is less traffic. To put a rooftop unit on even the smallest building, the contractor would have to block off the street for part of the day. They must think about securing permits for that kind of activity, as well as getting a crane. Accessibility is also a challenge. For example, how accessible is the roof and the location of the rooftop unit? Is the unit close to the edge of the roof? Is it a low building? Logistics-related issues can be a challenge—notably, where the unit is physically located and what equipment/preparations need to be in place to replace the unit?

Downtime was also cited as an installation challenge by 17% of respondents—referring to HVAC system/rooftop unit downtime. It can be difficult to do the installation in the middle of the week, if the building is occupied, for example. This can be addressed by a skilled contractor doing the replacement work over the weekend, when factors like traffic or building use are minimal. From a seasonal perspective, and with systems that are not emergency replacements, contractors may try to do the replacement during a “shoulder season,” where having a gap in heating and cooling capability is not as much of an inconvenience to the building occupants.

Availability of parts and equipment was discussed, as well. With the COVID-19 pandemic, manufacturing came to a near standstill with equipment. While manufacturing has picked back up, they are still catching up with production. Contractors and installers can sell equipment and systems, but they are experiencing some difficulty obtaining the equipment and materials. As curb adaptors are often required when switching from one system or manufacturer to another, the availability of the adapters is also important—and this was also a noted challenge.

Table 5: Number and Percentage of Respondents Mentioning Installation Challenges

Challenge	Total Number of Respondents Who Mentioned This Challenge	Percentage of Respondents Who Mentioned This Challenge
Matching the existing curb or requiring a curb adaptor	10	43%
Logistics (traffic, permits, equipment/crane rental, RTU accessibility)	7	30%
Required changes to electrical wiring	7	30%
Weight	6	26%
Cost	5	22%
Availability of parts and equipment	5	22%
Space	4	17%
Avoiding HVAC/RTU downtime	4	17%
Trying to match existing RTU (size, weight, electrical characteristics, heat source, etc.)	3	13%
Resilience	2	9%
Lead times	2	9%

2.6 Building Owners and the Desire to Lower Their Carbon Footprint

When asked if commercial building owners express a desire to lower their carbon footprint and decrease the use of natural gas, the responses boiled down to two schools of thought—no and "yes and no" (please note that one person responded with "unknown"). Approximately 59% of respondents who answered this question said no, in their experience, building owners are not expressing the desire to lower their carbon footprint and deviate away from using natural gas. Approximately 36% of respondents who answered this question arrived at "yes and no" (or "yes, but…"). An interesting observation is that the associations and engineering firms interviewed as part of this study tended to skew more toward the "yes and no" category, whereas the installers of commercial HVAC systems (mechanical contractors and other commercial HVAC installation companies) very often fell into the "no" category.

Table 6: Do Commercial Building Owners Express a Desire to Lower Their Carbon Footprint and Decrease the Use of Natural Gas? Responses by Respondent Category

Respondent Category	Yes & No (Yes, But…)	No
Association Respondents	5	1
Engineering Firms	2	1
Commercial HVAC Contractors	2	11
All Respondents	9	13

An interesting observation related to the location of the respondent is that all the respondents located in warm climates—notably the Southwest and Southern part of the United States—responded to this question by saying no, they are not seeing any commercial building owners expressing a desire to lower their carbon footprint. Part of this may have to do with the fact that more of our association points of contact—who tended to answer "yes and no"—are in the Northern half of the country.

Table 7: Do Commercial Building Owners Express a Desire to Lower Their Carbon Footprint and Decrease the Use of Natural Gas? Responses by Geographic Region

Geographic Region	Yes & No (Yes, But…)	No
New England	1	2
Mid-Atlantic	4	1
Midwest	2	3
Northwest	2	1
Southwest	0	2
South	0	4
All Respondents	9	13

> **According to one contractor in California, they get requests for more efficient models above SEER 14, but there are very few models and brands currently fabricating anything above SEER 14. Availability of equipment in a limiting factor in some cases (and in some regions).**

Several people responded “no” to this question and some elaborated upon this, stating that most building owners are driven by costs and, if or when they make environmentally conscious choices, it often ties back to being “trendy” or “green.” There are some large companies that want to be viewed as being environmentally conscious, but this is not the case with the broader population. A few people noted that price continues to be the primary factor in the decision-making process. If government or utility incentives or rebates are available, people will explore that and take more time to consider an energy efficient solution, but without those incentives, it’s very rare to see that kind of interest. A mechanical engineering firm in North Carolina mentioned that he does not recall an owner expressing a desire to lower their carbon footprint in his 30+ years in the engineering field. One exception might be big box retailers—where sometimes it is discussed—but he seldomly encounters a building owner who can be sold on additional capital costs to gain improved energy efficiency. As an engineer with expertise in commercial HVAC, he will design improved efficiencies, but the gains are typically lost during “value engineering,” resulting in the installation of a minimally efficient unit. One HVAC installation contractor in California did note that they get requests for higher energy efficient models above SEER 14, but there are very few models and brands currently fabricating anything above SEER 14. Trane has a SEER 17 model for commercial applications, and it is only available for a certain size capacity—so some interest might be there, but availability of equipment may be a limiting factor in some cases and in some regions.

Several others recognized that there seems to be increasing interest in lowering the carbon footprint of a building and reducing reliance on natural gas. However, this was also met with some additional comments and caveats. According to one respondent, some commercial building owners have expressed a desire to lower their carbon footprint but were surprised to learn that natural gas is a fossil fuel contributing to greenhouse gas emissions. Another respondent noted that building owners are expressing interest in reducing their carbon footprint; however, he doesn’t know how eager they are to stop using natural gas without first looking at other ways of reducing the carbon footprint (for example, better heating, windows, air conditioning units, etc.).

Building owners that have large portfolios of buildings or those seeking LEED accreditation are particularly interested in reducing their carbon footprint. For example, you might have a restaurant chain or major retailer looking closely at their carbon footprint, but that is stemming from a corporate goal to be more sustainable and energy efficient. However, this is rare with standard commercial building owners.

The motivation to minimize carbon footprint can vary by sector. There seems to be more commitment to decreasing greenhouse gas emissions in the public sector, and in certain cities and counties. Part of that is reducing natural gas consumption in their building stock. This tends to be less important in the private sector, smaller retail, and the service sector. When it comes to reducing emissions and minimizing carbon footprint, awareness is trending and desire is increasing, but this is not necessarily the case with electrification and fuel switching. In the Midwest, for example, they are just starting to really introduce electrification in the regulatory frameworks, in terms of how utility programs incentivize these activities. They are laying the groundwork for heat pump measures and people can recognize the benefits, but the benefits do not trump cost quite yet.

Building owners that have large portfolios of buildings or those seeking LEED accreditation are particularly interested in reducing their carbon footprint.

When it comes to reducing emissions and minimizing carbon footprint, awareness is trending and the desire is increasing, but this is not necessarily the case with electrification and fuel switching. That said, electrification is starting to enter the regulatory framework, in terms of how utility programs incentivize these activities.

According to one respondent focused on energy efficiency and environmental justice, contractors and building managers need to be champions of energy efficient rooftop units. They need a reason to increase the efficiency of the rooftop unit that aligns with their business model. A contractor would need to be able to quickly and easily integrate energy efficient technology or energy saving managers, while also making money off doing so. He noted that removing the barriers is instrumental in scaling things like high-efficiency heat pump rooftop units.

Another respondent representing an association focused on zero-energy confirmed that interest in reducing the carbon footprint of a building does seem to be increasing. Although there is some discussion, few building owners recognize the "outsized importance" of electrification of heating systems for greenhouse gas reduction. More customer education would help them make this connection.

Building owners are increasingly interested in reducing their carbon footprint, but few building owners understand how the electrification of heating systems relates to greenhouse gas reduction. Materials and resources to support customer education would help them make this connection.

Cost was cited as a major barrier by the New Buildings Institute. The first cost is most important to decision makers and air source heat pumps are more expensive to procure than gas pack rooftop units. Electricity is more expensive per unit of energy, but heat pumps are approximately three-times more efficient; often these two competing factors roughly balance each other out (so operating cost is similar). The lifetime cost is generally close for gas and electric. When a building uses propane—which tends to be much more expensive per unit of energy—the lifetime cost is more clearly in favor of the air source heat pump unit.

Comments regarding interest in decarbonization tended to be made by associations and/or firms involved with net-zero initiatives. According to one engineer and designer this emphasis on reducing carbon footprint is something that they bring up frequently in discussions with a building owner. There is a lot of interest in cost, but they also discuss emissions and air quality, as well as energy efficiency. Some firms are supporting decarbonization and pushing for electrification with their customers, and building owners are starting to give it more serious consideration.

3.0 Electricity Pricing Impact on HVAC Equipment Selection

3.0 Electricity Pricing Impact on HVAC Equipment Selection

A secondary literature review and targeted interviews were conducted to probe the role that future estimated economic operating cost factors (i.e., projected electrical costs) have on a buyer's decision to retrofit from an existing gas-electric package to an RTU heat pump. The methodology used is described in Appendix A. Also examined were associated issues that may serve to incentivize or de-incentivize the decision to go forward or halt a move to a heat pump unit.

The specific goals of this portion of the project will provide answers, insights, and relevant contextual information focused on the following key questions:

- What are the primary economic barriers to a decision to switching to a heat pump? How much, if at all, do the decision makers factor the anticipated/ projected new electrical heating and A/C operating costs that will occur after retrofitting to an RTU heat pump?
- Who, most frequently, is the decision maker when it comes to making this switch? For example, is it the building owner, a CFO, a facilities manager, a team, or somebody else? What factors influence who ultimately makes the decision?
- What party is most often given the task of gathering, calculating and presenting the new projected electrical operating costs to the decision maker? What kinds of processes or software is deployed to calculate that data?
- What are the primary factors that will impact whether the future electrical operating costs will be seen as a disincentive, a neutral factor, or even a benefit to moving to heat pumps? Within this larger question, two relevant narrower questions are addressed as well: How much, if at all, does a utilities' integration of time of day/demand pricing methods impact the economics of the decision? How are the split incentives that some building owners face when examining total-lifecycle costs of retrofitting to a more energy efficient HVAC technology playing out right now?
- Are there circumstances and conditions where a decision maker might choose to downplay, or even overlook anticipated higher energy operating costs, thereby making the switch more likely, despite the projected higher costs? If so, what are they? For example, how much do financial incentives and/or regional regulations help move the needle here?
- What are the key significant and relevant anticipated trends that could impact the future of heat pump retrofits in commercial buildings?

3.1 Primary Economic Barriers

Before examining the narrower, but important, key question on how much a building's projected new electrical operating costs is a factor in deciding to retrofit to an RTU heat pump, it is useful to recap the primary economic barriers and related concerns that building decision makers face when considering retrofitting an existing gas-electric package with a heat pump.

As has been examined earlier in this report, the major reason why decision makers decide against going with an RTU heat pump is the overall cost of the retrofit. But while it is accurate to simply cite cost as the primary barrier, it is important to break down this barrier into key components. It is useful to start by looking at the factors that can serve as impediments to moving forward that can occur even before the heat pump retrofit is being considered, and the matter of cost arises.

To examine this pre-decision time period, it's important to note the condition that most often prompts the desire to replace one's existing HVAC system - and that condition is a failure of one's existing system. When this happens, the owner will often feel that what's most important is speed and ease: there is a pressing need to get this critical system up and running ASAP.

The major reason why decision makers decide against going with an RTU heat pump is the overall cost of the retrofit.

Under this circumstance, the fastest and easiest solution is often to work with one's existing HVAC service team, typically a gas specialist, and ask for a replacement of the same system ("like-for-like") as soon as possible. Another path for the owner whose system has failed but does not feel quite the same time urgency, is to put a specification for a new system out to bid, without specifying energy efficiency standards. When this happens, there is of course an incentive for a mechanical contractor who submits a bid and wants to be in a competitive position, to propose a low-cost solution, which again is more likely going to be a like-for-like replacement.

In another scenario, the owner may have heard a bit about heat pumps and energy efficiency, and is curious to learn more, and decides to discuss that option with his familiar and friendly gas service company or technicians. If those persons are not well informed about heat pumps, or simply want to be sure the building owner remains with gas, the owner could end up getting incomplete or misleading information about heat pumps (e.g., people won't feel the nice warm air coming out; they won't work when it gets cold, what about maintenance…) and the owner could be dissuaded in choosing heat pumps, and, once again, chooses the like-for-like; gas-to-gas replacement.

But if the above scenarios do not occur, and an owner does have the opportunity to begin considering replacing his or her unit with a heat pump, this is when the barriers emerge. These are primarily related to costs and can further be broken down into:

direct/immediate costs; longer term costs and psychological/mindset & perspective factors.

Starting with the direct and immediate cost barrier, right off the bat, the decision maker is faced with considering the upfront, onetime cost of installation and the prospect of higher operating costs with more expensive energy bills. These are all real barriers—the future anticipated electrical operating costs consideration will be examined in more detail though further in this section.

In addition to these immediate considerations, the building owner also looks at longer term costs when making a decision. The first factor is the estimated number of years until the owner recovers their costs—the payback period. In most typical for-profit commercial businesses, owners want a payback in ideally 2-3 years, or at least no more than 5 years. One of the drivers for this strong desire for a shorter payback is that in certain commercial industries, building owners look at their investment in a building as a short-term investment, and plan to sell it within a set number of years, make a profit, and purchase another building. In that scenario a payback of 20, 15 or even 10 years may seem too far out—after all, the owner may not even own the building at that point.

Other long-term costs are more questions than realities, but this uncertainty can also serve as a disincentive to move forward with the heat pump. For example, is the owner assured about what their likely future maintenance costs are going to be? He or she may also worry about their building's electrical capacity—could the owner be in a situation where it is not possible to handle the new electrical demand? What would it cost if s/he had to rewire the entire electrical system?

Finally, there are barriers that could be categorized as more psychological, which can also be very real impediments to moving forward with a heat pump retrofit. An owner might think that they have already sunk money into gas piping, gas has worked fine so far, so why change what's already working? And if they are being presented with the alternative to switch over to heat pumps while the current gas-electric package is still operating, the owner might think that they can easily get another 5-10 years out of their current unit.

Another psychological barrier—one that is more fear based—is the concern by the person that makes the decision about making a bad decision. This may be a more common problem when the decision maker is not the owner (see section 3.2 on Decision Makers below). In this scenario, a facilities manager, energy manager or someone not in the C-Suite may be worried about a variety of "what ifs" and how it can impact their reputation or job security: What if people complain now that it's too hot or too cold—will we lose our tenants? What if there are some strange mechanical problems that we now must pay for, that hurt our budget? What if it just doesn't work well at all?

In summary, there are many forces and factors in place that can, and do, present real challenges to the owner or other decision makers decoding whether to proceed to switching to a heat pump RTU. The biggest factors relate to that initial up-front cost, but there are other economic, psychological, and even pre consideration at work, that together make it harder to make the change. One of our interviewees noted that "heat pumps are not very exciting" too—so perhaps unlike wind, solar, or other energy efficiency technologies, heat pumps don't even generate much excitement either.

The Impact of Projected Higher Energy Operating Costs

It is important to look more deeply at one of the primary focus areas of this study: whether, how much, and in what way are the decision makers thinking about and weighing those future projected electrical operating costs when making their decision?

Before addressing the question of how much and in what ways the decision makers integrate any projected future anticipated energy costs, it is worth reviewing the facts regarding what owners who are considering this retrofit are likely going to face when it comes to comparing their current energy costs to their new ones.

One analyst we spoke with says it will typically be 2-3 times more expensive to heat with electricity than gas; and that is true even with a heat pump with a high coefficient of performance.

The facts here are clear. In nearly all situations, the monthly energy bills of a building that is replacing gas heating with electric-even highly energy efficient heat pumps—are going to be higher. The simple fact is that gas across the country is cheap, and with rare exceptions, electric rates are going to be higher (and in some cases, higher by a significant amount).[1] One analyst we spoke with says it will typically be 2-3 times more expensive to heat with electricity than gas; and that is true even with a heat pump with a high coefficient of performance.

That's a big difference in energy costs, but even that alone is not the full story of the price differential. In cold climates where supplemental resistance heat is required to generate enough heat, the energy costs could be significantly higher.

But the key question to address here is whether, how much, and under what circumstances does this (very likely higher) future operating cost impact the decision that the owner makes to go forward with a heat pump retrofit? There are a few ways to answer this question: by addressing what is clear; what is contingent- the "depends on" factor, and what remains uncertain.

One of our interviewees also noted that "heat pumps are not very exciting."

[1] There are states where electricity rates are very low. For example, Texas and Oklahoma have very low commercial electricity rates; however, the demand for heating is lower in those and most other states with low electric rates as well. There are a few states that have low electricity rates and a somewhat higher demand, such as Nevada, Idaho, Virginia and Nebraska, but these are more outliers. See: https://www.eia.gov/energyexplained/units-and-calculators/degree-days.php

What is clear is that when the decision maker looks at all the associated costs with making the retrofit (the lifecycle costs), that the anticipated future energy operating costs is ***a much smaller consideration than that initial upfront cost***. As noted above, the big barrier to making the move to heat pumps is the cost, and the largest impactful part of the overall cost (acquisition/operating/maintenance) is the initial acquisition cost. So, to put it another way, yes, when the buyer is given the information about lifecycle costs, operating costs are considered, but it is not a major determinant of the decision.

Then there are the contingent factors that make it more or less likely that these higher operating costs are a major decision factor. These are described next.

The anticipated future energy operating costs is a much smaller consideration than that initial upfront cost.

Below are circumstances where the higher projected energy costs are more likely to *not* be considered and, therefore, do *not* become a barrier to the retrofit:

- When the building is relatively small. In these cases, there may typically be less sophisticated methods used to calculate future energy costs; and an accompanying reduced desire by the decision maker to get that data. In those cases, according to one energy consultant, the decision maker may simply be calculating their future operating costs by using current costs and adding a set escalation factor. If the building is small and there are tenants who pay their own electric bills, there is an even greater chance that the higher energy costs will not be examined and become a barrier.)

- When the building is *not* owner-occupied *and* the owner does not care about higher energy costs because those costs are paid by the tenants, *and* those tenants are not sophisticated enough to probe their energy costs for energy when signing/renewing leases. Note: In general, tenants are becoming more knowledgeable about their total costs when moving into commercial buildings, and it is increasingly likely that energy costs will be examined closely.

Here are the circumstances where the higher energy costs are more likely *to be* considered, and since they will almost always be higher than existing gas, *are* a potential barrier to the retrofit.

- When the building owner is sophisticated enough to want detailed lifecycle costs and cares about the future operating costs, and there are no other mitigating factors (related to tenant retention, or others listed below).

- When the building is *not* owner-occupied, but the tenants *are* sophisticated enough to probe their costs for energy when signing/renewing a lease and will potentially leave if their bills increase too much. *However*, this is a complex area and there are additional mitigating factors that can change this determination.

Say, for example, that there is a large office-retail building in Washington DC, and one of the tenants is Starbucks, and that company has a corporate mandate to only use energy from highly efficient sources, such as heat pumps, or must have an Energy Star rating, etc. Some localities have passed regulations (see section 3.4) that will expose the building's relative energy efficiencies to new tenants as well. This circumstance where tenants care a great deal about energy efficiency is currently most likely to happen in more urban centers, and on the coasts. In this case, the company may be willing (or even required) to pay more in energy costs to fulfill its corporate obligation.

These are conditions for which the decision maker *does* look at the operating costs carefully but is willing to *ignore* or lower the priority of the impact of higher energy costs.

- If the building owner is working towards LEED certification.
- If the building owner is obligated to fulfill a regional building energy efficiency mandate and will be legally required to pay significant fines if found in violation of those standards.
- If the building is large, owner-occupied, the owner sees the building as a long-term investment, and the lifecycle calculations show a good ROI for that building with an energy efficient system.

What Remains Uncertain

Although the above analysis can provide valuable insights into the probabilities that any individual gas to RTU heat pump retrofit will likely or not likely include a careful review of future energy operating costs, there is still uncertainty on two matters.

Time of day pricing seems to cut two ways when thinking about its impact on future energy costs.

The first is the impact of time of day/demand pricing by utilities on the owner's determination as to the economic impact of the future energy bills. Time of day/peak pricing is set up so that utilities can charge a higher rate for the use of electricity when traditional and anticipated demand is highest. The high demand charge is used as a disincentive for users so that the utility does not have to use its own higher costs for generating energy, or in a worst-case scenario to prevent running out of capacity and instituting methods like rolling blackouts. While these time-of-day periods vary by utility and state, the most common one is a 4pm-9pm slot in the summer for states that require air conditioning.

Time of day pricing seems to cut two ways when thinking about its impact on future energy costs. On the one hand, heat pumps are more efficient in the summer, and should not normally be impacted by these peak charges. Furthermore, in the winter, when the pumps are used for heating, the time when the unit is likely going to be working the hardest is likely during the night, when there is less demand in general on the utilities and it is less likely that there will be a peak charge assessed during that period.

But it is also possible that if a heat pump is installed in a very cold climate that requires the supplemental and expensive additional resistance heating, and that resistance heating is called for during an expensive time of day block period, that business owner could incur very high heating charges for that particular time period. If the building owner anticipates that this may happen, there are some adaptions and solutions that can be integrated by using smart controls to pre-heat, flex the load, and automatically take other steps to ameliorate getting that extra high rate. It is not clear, however, if the decision makers (or their contractors/consultants) even present this level of detail and contingency, let alone whether it will be a factor in an owner's decision.

The second, and larger, uncertainty relates to discovering just how often, on a more mass scale, decision makers pro-actively inquire about future energy costs. Are there any significant accompanying distinctions (e.g., who the decision maker is; type of industry; reason for retrofit etc.) that can be examined to categorize those that do or do not have that stronger inclination to uncover and examine these costs? The best way to locate answers to this question would be to create and administer a large survey of decision makers that are probed for answers to those questions. This could be best done by partnering with a vendor or industry association that already has contacts and a relationship with its members or customers.

3.2 Decision Makers

Who makes the final decision regarding whether to make the move to install an RTU electric heat pump system? The answer, not surprisingly, is "it depends."

There are a wide range of players that can play a key role in moving forward with a retrofit project, and there are many individual factors in any single company's decision that impact which of those players take the lead and ultimately are responsible for giving a final yes or no to the proposed project. These players are typically drawn from the same set of people: facility manager, property manager, energy manager, CFO and, of course, building owner.

A team effort, with multiple people working to present information for a final decision by the building owner is most typical for larger buildings and commercial entities, especially when the new proposed system is very costly.

There are several circumstances and conditions that make it more or less likely for each of these persons to take the lead as the decision maker. However, we can also step back and note, more generally, that the most common way decisions are made follows a similar path: a facilities manager (or property manager) identifies a need to replace an existing unit and gathers data on various alternatives, which *may* include heat pumps. The possibility of exploring heat pumps as a new energy efficiency option will often require a champion to present it as an appealing option and keep interest up in the organization.

The data gathering process is likely to be informed by initiating meetings with a mechanical contractor, and/or a consulting engineer (though consulting engineers are called upon more often for new construction energy design and less for retrofits), and those discussions better inform the manager of the various options and alternatives. Depending on the size of the organization and project, this information may then get discussed with the CFO who weighs in regarding financial and lifecycle cost matters, before getting the final buy in from the owner.

This team effort process, which leads to multiple people working to present information for a final decision by the building owner, is most typical for larger buildings and commercial entities, especially when the new proposed system is very costly. In a slight variation, some larger commercial enterprises will also employ a professional management company to put out the initial request for bids; the bids are presented to the owner, and the owner makes the decision.

But there are circumstances when the decision to move forward with a RTU heat pump does not need to go all the way to the owner or even to the C-suite. If the cost is below some internally set threshold, then the facilities manager/property manager may have the authority to say yes to the project, and only get a more pro forma sign off from the owner. Furthermore, even in larger operations when the project is a large and expensive one, depending on the relationship between the owner and the facilities manager and a whole host of intangible factors, an owner might just say to the facilities manager to go ahead and make the decision.

If the commercial entity and its building is small, there are other, different ways the decision process can unfold. For example, if there is a facilities manager who has the authority to do so, he or she may be empowered to decide by working with a mechanical contractor directly. Interestingly though, smaller operations can also mean that a contractor may choose to approach the owner directly, as that person will be more accessible than an owner heading a large operation.

> **The facilities manager mindset may be, "not how efficient I can make the building. It's how many "it's too hot" and "it's too cold" service calls will I get."**

In addition to size, the decision-making process can also vary based on type of business: whether it is a standard retail outlet, a public sector facility, or a building whose tenants have responsibility for the HVAC. In cases where tenants' do have responsibility, they can also have some decision making say in what is selected for their individual unit.

Another factor relates to how a new product could impact a decision maker's day-to-day job life. One consultant said that when a facilities manager is given the authority to sign off (or at least be a major influencer) in the decision to move to a heat pump, that person's desire in moving to a more energy efficient technology may depend on their knowledge or confidence in what the new systems can do as to how it may impact their working life. "The facilities manager mindset," he told us, "is not how efficient I can make the building. It's how many "it's too hot" and "it's too cold" service calls will I get." And, he added, this is of particular concern when a facilities department is not fully staffed, a common problem. Because of these real and practical factors, some facilities managers without a motivating interest in the value of energy efficiency, may be more inclined to go with a like-for-like replacement.

Another potential disincentive for facilities managers with decision making power to move to heat pumps occurs when their current HVAC system is still operating, even if working poorly and close to failure. It can be easier to let the unit fail which allows the replacement costs for a new unit to come out of the organization's full capital expenditure, rather than incurring any costs from the FM operational budget.

In summary, in larger operations where replacing an HVAC system represents a major cost item, there are typically many players that end up playing a key role in taking steps towards a decision to move to a heat pump. They may be categorized as taking on the following roles, as part of a loosely coordinated team effort:

Table 8: Roles of key stakeholders who provide information to decision maker

ROLE	WHO	MESSAGE TO BE SPREAD
Initiator/Champion	Interested facilities managers, (but potentially anyone with related responsibilities).	"We need to look into this idea"
Data Gatherers	Facility Managers; Property Managers	"We are finding out more details about this concept"
Presenters	Facility Managers; Property Managers	"We need you to look at this information we've collected"
Influencers/External	Mechanical Engineers; Energy Engineers	"Here is what we've determined will be your costs, payback, benefits, etc."
Influencers/Internal	CFO	"We need to carefully evaluate these upfront and lifecycle costs"
Decision Maker	Owner	"Let's do this"; OR "It's too expensive" etc.

Keep in mind that the above represents just one, though common, process leading to the final decision. Smaller businesses with fewer staff, and smaller footprints will have a different process, as well some public sector operations.

3.3 Source of Energy Operating Cost Data

There comes a point in the discussion of a potential retrofit where the decision makers will need information on the total cost of the proposed plan. It is at this point where complete project costs and lifecycle cost calculations are performed, and this calculation will also include surfacing anticipated future estimated electrical operating costs.

These calculations are almost always performed by someone outside of the organization. In some cases, it will be a mechanical engineer, while in other cases it could be an energy engineer, an energy consulting firm, or the heat pump vendor the organization is working with. According to an engineer in Wisconsin with extensive HVAC system design expertise, pricing and energy efficiency information would predominantly come from the HVAC contractor, who should be savvy enough to know that they will need to make the business case by discussing simple payback and ROI.

Cost calculations are almost always performed by someone outside of the organization. It may be a mechanical engineer, energy engineer, energy consulting firm, or the heat pump vendor.

Variations on who does this work, and the sophistication of the tool and method they deploy to perform these calculations will typically vary based primarily on the size of the building and project. With a larger job, there would likely be an engineer that is designing the system, and they will have some detailed analysis tools at their disposal. According to a mechanical contractor located in Mississippi, with a more basic commercial space (like a retail store, for example), they will provide some options and will make recommendations, considering efficiency and payoff.

There are various software packages to perform these calculations which are available for mechanical contractors and other HVAC professionals. Some of the better-known ones include **EnergyPlus, DOE's eQUEST,** as well as proprietary software from the big vendors, such as "**Trace**" **by Trane and Hourly Analysis Program or "HAP" by Carrier**. While these are all different software programs, in essence, they all basically work the same. The vendor or contractor/consultant enters details regarding the size and loads of the building, adds relevant heating and cooling information and other data to surface annual energy operating costs. (A valuable and detailed review of how energy lifecycle costs can be analyzed in buildings, along with names of leading software packages, including those from the DOE, can be found from the *National Institute of Building Sciences' Whole Building Design Guide*)

Note that for very small projects, contractors or consultants helping commercial buildings look at project costs may not always use sophisticated software packages. One consultant told us that he has seen simple degree day calculation charts used against the building's loads with calculations performed on a simple Excel spreadsheet.

Owners and other decision makers appreciate these calculation tools, as it makes determining project costs and estimated operating costs, along with potential payback fast and easy. It also provides a kind of objective and trusted method for estimating these costs that the buyer can feel confident in as it takes complex sets of numbers and quickly makes it all understandable.

The President of an HVAC installation company in California stated that an educated installation company will play a key role in helping the decision maker understand pricing and long-term cost savings. That company uses a simple website called HVAC OpCost as one way to show clients how different units compare, in terms of efficiency, options, and how that translates to cost based on cooling and heating requirements based on the location of the building.

3.4 Circumstances that Can Change the Economic Calculations

Much of this report has outlined how the projected costs of a new heat pump retrofit is a primary barrier to a decision to move forward with the project. And, as outlined in this section, the likely higher electrical operating costs is part of that economic disincentive.

The fact is that, at least for the near future, gas prices are expected to remain low and electricity rates are expected to remain high. So, for those who are scrutinizing their future electrical operating costs, this economic calculation is not going to soon be favorable to moving to a heat pump. This is particularly true when, as is quite common, the owner is looking for a payback in five years or less.

There are, however, some factors, policies and special buyer circumstances that can help mitigate and soften these unfavorable economics, potentially weakening the strength of the unfavorable operating costs barrier, and thereby move the needle for some buyers enough so that they will be more likely to move forward with the heat pump retrofit.

Incentives are an imperfect tool: the building owner needs to be made aware of their existence and they must be large enough to influence the economic determinations of going to heat pumps.

These factors, policies and special buyer circumstances include the availability of financial incentives; internal corporate sustainability initiatives and governmental regulations and will be examined below. Note that these additional considerations don't *solely* relate to energy operating costs but impact the full project's lifecycle costs. They are useful for discussion here as an important consideration in the larger economic calculations for a retrofit project.

Looking at incentives first, there have been and continue to be a variety of loans, financing schemes, tax credits, rebates and incentives that are offered by utilities, vendors, and local public entities. These are often created by the creation of a new governmental energy efficiency policy, which HVAC vendors publicize to potential customers and utilities publicize to relevant communities. (A comprehensive database of state incentives and rebates for renewables and energy efficient projects can be searched on DSIRE, a site operated by the N.C. Clean Energy Technology Center at North Carolina State University.)

Strictly from a logical and common-sense standpoint, financial loans, rebates, and the like should serve as incentives for decision makers to consider switching to a heat pump or other energy efficient system by making it more affordable. In circumstances when the owner is on the fence about changing from gas to heat pumps, then a better lifecycle/shorter payback period is going to move the needle towards going forward.

But incentives are an imperfect tool, and there are problems that prevent it from being as effective as it could be. First, of course, the incentive must exist and be large enough to influence the economic determinations of shifting to heat pumps. Secondly, the building owner needs to be made aware of its existence. Despite the efforts of utility company announcements, vendor marketing pieces or other ways word is spread, if a building owner, facilities manager, or other decision maker must find a replacement quickly and is not already or quickly made aware of an incentive program, it's existence will be irrelevant for that person.

A factor that can help soften objections over current and future costs occurs when a company has created a robust, clearly stated and publicly announced value around corporate sustainability.

Finally, another problem with incentives is that when monies are offered up as a one time, one shot financial incentive, if the business is a larger future-focused operations—say, a large retail company which runs lifecycle costs out many years or even decades—that initial influx of cash or tax credit etc. will likely not make much of an economic difference.

Another factor that can help soften objections over current and future costs occur when a company has created a robust, clearly stated and publicly announced value around ***corporate sustainability***. While such companies still represent a very small part of the total commercial building market, it is also true that, more than half of the Fortune 500 companies now have sustainability plans, and the number of companies that have created these plans have increased over the years; and is expected to continue to increase.[1]

Those increases are due to a few key forces. One key factor is the increased importance of "ESG" scores and ratings that companies receive based on their operations in environmental, social, and corporate governance. More investors are examining a company's public ESG scores in making an investment decision. Furthermore, while the U.S. Securities and Exchange Commission (SEC) only requires voluntary ESG reporting by public companies, a recent proposal by the SEC is to increase ESG disclosure requirements among companies and is likely an indicator of the increasing importance of this kind of reporting.[2] This push to expose ESG ratings has been putting pressure on companies to do a better job in demonstrating what they are doing in the areas of environmental, social, and corporate governance.

Another factor is likely the growth of millennials in higher decision-making positions within their organization, a demographic with a much higher concern over environmental issues, particularly as it relates to climate change. There is a greater awareness among larger and more prominent corporations, which attract increasingly socially aware and activist younger workers. These younger professionals—and often customers, as well—will base employment, purchase, and service decisions on the social reputation of a company, which often ties back to the firm's "greenness." There are many sites now on the Web where anyone can look and browse at companies who have garnered a high reputation in corporate sustainability, along with ranking of those companies in various corporate responsibility areas and find companies too that have violated EPA or other environmental regulations. Although there is no doubt that millennials have increased social influence, data are not available to indicate how many millennials are commercial building owners and therefore, decision-makers.

> **Younger professionals often base employment, purchase, and service decisions on the social reputation of a company, which often ties back to the firm's "greenness."**

Ultimately, what this means in practice is that—theoretically perhaps—but logically, an increasing number of companies may be willing to accept, for certain initiatives and at least to a certain degree, higher costs (upfront or ongoing) to be able to make and show progress on other important sustainability related goals that could be as or even more important than maintaining or reducing certain operating costs. Achieving those goals could be aligned with standard practical business ones: better employee recruitment and retention, marketing, and customer satisfaction, but could also be connected to the employees' and corporate culture and mission of doing social good. Although it is not uncommon for corporations to make significant contributions to advance social good, sustainability constitutes a different focus.

Finally, there are the ***regulations and policy related incentives*** initiated by government agencies, which have the power and penalty of law, and vary based on region of the country. If a building owner is living in a city or region where there is a carbon-based building performance standard, this too will have an influence. As of this writing, only three cities (Washington D.C., New York, and St. Louis) and one State (Washington) have created carbon-based building performance standards. New York City's regulation (Local Law 87) exposes the relative building energy efficiencies to tenants and is particularly stringent and mandates, a carbon emissions limit set to begin in 2024. There are many ways energy efficiency goals can be achieved in New York City including improving a building's cladding, changing the windows, and shifting from oil to natural gas. If the buildings are not already in compliance or do not make the necessary retrofits to comply by 2024, fines will be assessed. In California, Senate Bill 32 (SB 32) requires that by 2030, renewable energy resources must supply 60 percent of total retail sales of electricity and that by 2045, a combination of renewable energy resources and zero-carbon resources must supply 100 percent of retail sales of electricity.[3] All eyes are watching how these natural experiments unfold.

While creating these standards is still not at all common, the number of cities that are looking to do so is increasing. According to a June 2021 article in *Facilitiesnet*, an online magazine for facility managers, "at least 20 other U.S. cities or counties are examining the concept of building performance standards and how to implement a policy in their jurisdiction."[4]

At least 20 other U.S. cities or counties are examining the concept of building performance standards and how to implement a policy in their jurisdiction.

There are various political, economic, and logistical hurdles and challenges for passing such laws, and there are organized opposition groups to work against such regulations. For example, there are certain free market-oriented industry associations that have been sharing information regarding the negative aspects of what call forced electrification, and of course many building owners themselves may feel it is unfair to bear direct costs and penalties to serve larger social goals, while others do not have a responsibility to bear those costs.

The energy industry continues to be in a high state of flux. Multiple forces: global, national, and regional decarbonization initiatives; changing economics of renewable energy sources; and the human and economic impacts of increasing severe weather all mean that energy plays a highly volatile and dynamic role for the economy, politics, and citizens' day-to-day living. Incentives, sustainability goals and government regulations are some of the primary forces that can change a building owner's cost calculations when assessing the lifecycle costs of installing a heat pump.

4.0 Distribution of RTUs by Region, Type, and Age

4.0 Distribution of Rooftop Units in the United States

As the focus of this report is on rooftop units, and the retrofitting of more traditional rooftop units with electric heat pump RTUs, this section briefly explores key statistics pertaining to the installed base and geographic distribution of rooftop units in the United States. Several existing resources were consulted which provide information on RTU type and age by region. The most common challenges that surfaced during these efforts include age of the datasets, and the specificity of available figures—specifically information was frequently presented for packaged cooling units, however, this grouping was not limited to RTUs.

4.1 Regional Definitions

The first step in providing regional segmentation was to review the existing regional descriptions used by the U.S. Energy Information Administration, as these serve as a common reference point in the literature.

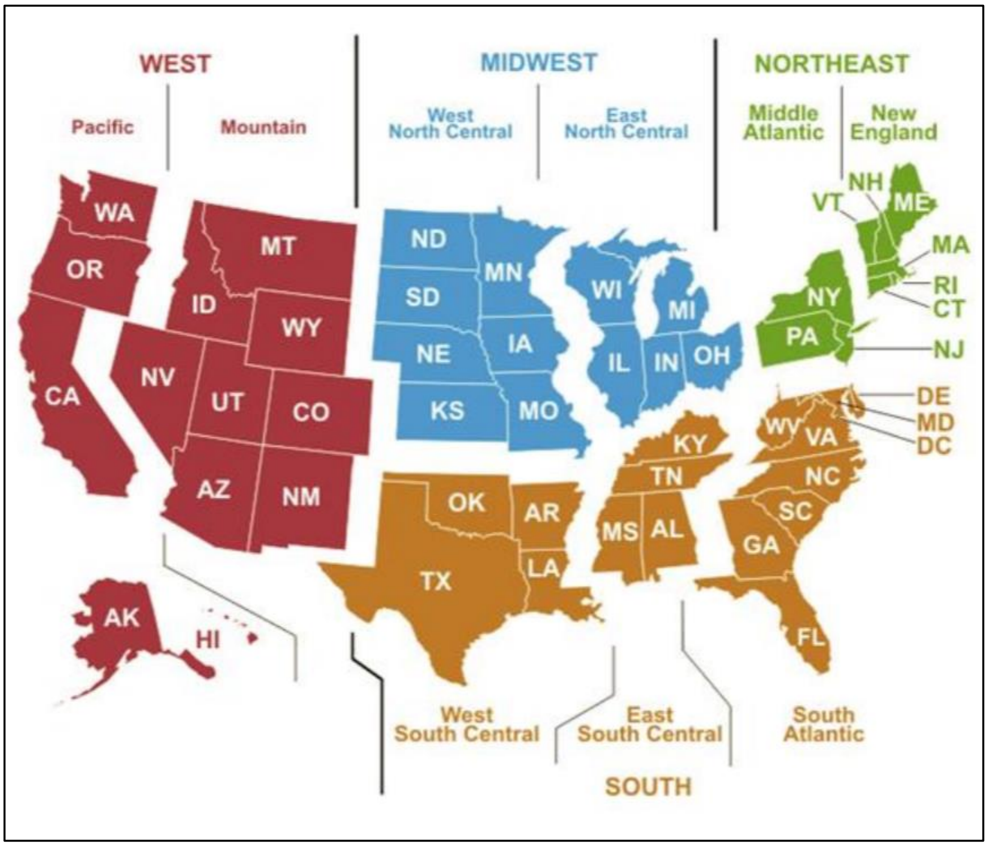


Figure 2: U.S. Census Regions and Divisions, U.S. Energy Information Administration[5]

In list format, the Commercial Buildings Energy Consumption Survey (CBECS) data cover the following U.S. regions:

- **Northeast**
  - New England (CT, ME, MA, NH, RI, VT)
  - Middle Atlantic (NJ, NY, PA)

- **Midwest**
  - East North Central (IL, IN, MI, OH, WI)
  - West North Central (IA, KS, MN, MO, NE, ND, SD)

- **South**
  - South Atlantic (DE, DC, FL, GA, MD, NC, SC, VA, WV)
  - East South Central (AL, KY, MI, TN)
  - West South Central (AR, LA, OK, TX)

- **West**
  - Mountain (AZ, CO, ID, MT, NV, NM, UT, WY)
  - Pacific (AK, CA, HI, OR, WA)[6]

This segmentation is supported by the Regional Energy Efficiency Organizations (REEOs). There are six participating organizations that work through funded partnerships with the U.S. Department of Energy.

- **The Midwest Energy Efficiency Alliance (MEEA)** oversees a 13-state region including Ohio, Kentucky, Michigan, Indiana, Illinois, Missouri, Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, Nebraska, and Kansas.

- **The Northwest Energy Efficiency Alliance (NEEA)** includes four states, Washington, Oregon, Idaho, and Montana.

- **The Northeast Energy Efficiency Partnerships (NEEP)** includes New Hampshire, Vermont, Massachusetts, Rhode Island, West Virginia, and several allies

- **The Southeast Efficient Energy Alliance (SEEA)** covers 11 southeastern states including Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia.

- **The Southwest Energy Efficiency Project (SWEEP)** covers Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming,

- and the **South-Central Partnership for Energy Efficiency as a Resource (SPEER)** consists of Texas and Oklahoma.[7]

While these groups provide a wealth of data, primary research uncovered that they do not track information at the level needed to provide information on the number, type, or age of RTUs by region.

4.2 Calculation Methodologies and Sources of Data

There are several methodologies commonly used to estimate the number of RTUs in various locations and which present the core datasets used for these calculations. One overarching limitation is the availability of updated CBECS data as it is scheduled to be released in the November 2021. Additional limitations include the scope of shipment and product data as it tends to be broader than RTUs. Nevertheless, these data could likely be used to calculate the number of RTUs by region. This section provides an overview of the different methodologies used, but does not yield an answer to the question of interest: "How many RTUs are there by age, type and region?" It is recommended that the November 2021 CBEECS data be used to generate an estimate when those data become available.

Method Used by NEEP to Estimate Installed RTU

In December 2016, NEEP published, *Northeast and Mid-Atlantic High Performance Rooftop Unit Market Transformation Strategy Report*, and reports that **approximately 1,018,342 packaged commercial rooftop HVAC units (RTUs) are installed and serve the Northeast and Mid-Atlantic region**.[8] This calculation relies upon shipment data from the U.S. Department of Energy: Energy Efficiency and Renewable Energy Office *Direct Final Rule for Small, Large, and Very Large Commercial Package Air Conditioning and Heating Equipment.*[9] This document uses shipment data for certain industrial equipment including: Small, Large, and Very Large Air-Cooled Commercial Package Air Conditioning and Heating Equipment and Commercial Warm Air Furnaces. The shipments model includes three market segments: (1) new commercial buildings acquiring new equipment, (2) existing buildings acquiring new equipment for the first time, and (3) existing buildings replacing broken equipment. This corresponds with the National Impact Analysis spreadsheet[10] that includes detailed shipment information for various types of equipment.[11]

Therefore, when looking to devise a strategy to provide the number of RTUs by region the December 2016 *Northeast and Mid-Atlantic High Performance Rooftop Unit Market Transformation Strategy Report* published by Northeast Energy Efficiency Partnerships, Inc. provides a helpful framework laid out below. This analysis uses figures from the aforementioned National Impact Analysis.

> "In January 2016 the U.S. DOE released the Direct Final Rule for the Small, Large, and Very Large Air-Cooled Commercial Package Air Conditioning and Heating Equipment. In the supplemental National Impact Analysis Spreadsheet, DOE calculates 2016 national shipment data at 160,114.

To estimate the shipments for the Northeast and Mid-Atlantic region, NEEP applied a regional percentage of commercial floor space. Drawing from CBECs Census divisions 1 and 2, a regional percentage of 17.8% brings the regional total to 28,500.

[…]

For units below 65 kBtu/h, the shipments are calculated in the DOE's Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: ASHRAE Equipment Final Rule. Given that most of the units installed in commercial applications are less than 65 kBtu/h, it is imperative that this size bin is considered.

According to the supplemental National Impact Analysis Spreadsheet, Packaged AC projects 122,270 units shipped in 2017 and given the Northeast regional percentage of 17.8%, the regional total amounts to 21,764 units.

To account for the entire Northeast and Mid-Atlantic region, and states not covered in the Census Divisions 1 and 2, (i.e., District of Columbia, Delaware, Maryland, and Pennsylvania) the unit sales were proportionally increased by applying the number of commercial monthly bill customers. Using the information to incorporate the additional states, the total annual sales for units <65 kBtu/h in the region is estimated at over 31,497 units."[12]

Others using the NEEP method to estimate number of RTUs

Additionally, a March 2017 report on RTUs in the state of Minnesota applies a similar methodology and draws from similar sources to NEEP's report. The Minnesota analysis concludes that there are currently **20,700 statewide buildings with RTUs**, with a 95 percent confidence interval of ± 3,100 buildings. The paper goes on to estimate that approximately 80% of these commercial buildings or 730 million square feet are served by RTUs.[13]

This approach was also used by the **American Council for an Energy Efficient Economy (ACEEE)**[14] to analyze RTUs – this report references the NEEP assessment, the Minnesota assessment as well as the core information sources from DOE, AHRI, and CBECS.

Another source used in the NEEP analysis and others is the **Commercial Buildings Energy Consumption Survey (CBECS)**, which is a national sample survey that collects information on the stock of U.S. commercial buildings, including their energy-related building characteristics and energy usage data (consumption and expenditures). These data are updated every few years – the newest release is in process, however, as of mid-September 2021 only the preliminary results have been released.

Table 9 provides the projected schedule of 2018 CBECS data releases.

Table 9: 2018 CBECS data releases project schedule[15]

Detailed tables on building characteristics	August/September 2021
Public use microdata on building characteristics	Nov-21
Consumption and expenditures (C&E) preliminary estimates	Spring 2022
C&E detailed tables and microdata	Summer 2022

Source: U.S. Energy Information Administration

Presently, the 2012 figures, released in 2015 and 2016, are widely used in reports seeking to calculate commercial building stock and associated building characteristics.

The **Air-Conditioning, Heating, and Refrigeration Institute (AHRI)** is another commonly used source when looking to calculate the number of RTUs in various locations. AHRI issues a monthly report of combined U.S. manufactured shipments of central air conditioning, air-source heat pumps systems, gas and oil furnaces, and gas and electric tank water heaters. These figures are frequently studied alongside CBECS data in this space. However, these data do not report which units are RTUs. During primary research efforts the team reached out to AHRI to gain a better understanding of how its information could be used to make the requested calculation and the following response was received:

> *The short answer is that AHRI's shipment reports are not a good indicator of the number of RTUs sold each year.*
>
> *The Central Air-Conditioners (CAC) and Air-Source Heat Pumps (ASHP) include all types of CAC and ASHP configurations. This includes equipment like split systems (the kind commonly found in a residential household), packaged systems (commonly the same category as RTUs), and other systems that do not use ducts.*
>
> *Generally, RTUs are larger types of equipment with a cooling capacity above 65,000 BTU/hour. This is a typical cutoff for commercial equipment. Residential equipment falls below this cooling capacity and would not traditionally include RTUs.*
>
> *AHRI's shipment data page has a breakdown of CAC and ASHP equipment by capacity, but we don't have associated breakdown for RTUs. For this reason, summing all CAC and ASHP above 65k BTU/h might be useful for determining an upper bound for the reasonable number of RTUs. We've found the Energy Information Administration CBECS Microdata to be especially helpful in determining how different types of equipment is installed in the United States. The updated 2018 data is scheduled for publication in November 2021.* ***The 2012 packaged equipment data (variables 'PKGCL' and 'HPCPKG') are likely a good proxy for RTUs in commercial buildings, but not all packaged equipment is an RTU.***

I don't think AHRI has a good way to get you the percentage of RTUs in the packaged equipment category, but if distributors or other contacts can supply you with a breakdown by region (or even ballpark estimates), that should be somewhat generalizable to the national-level data from CBECS.

To this point, the most recently available detailed data by region from CBECS follows.

Table 10: Number of Buildings by Floorspace, Region, and Cooling Equipment, 2012[16]

	Number of Buildings (Thousand)					Total Floorspace (Million Square Feet)				
	All buildings	North-east	Mid-west	South	West	All buildings	North-east	Mid-west	South	West
All buildings	5,557	805	1,237	2,247	1,267	87,093	15,534	18,919	34,279	18,360
Building floorspace (square feet)										
1,001 to 5,000	2,777	372	645	1,159	601	8,041	1,057	1,858	3,383	1,744
5,001 to 10,000	1,229	171	257	491	310	8,900	1,248	1,872	3,535	2,245
10,001 to 25,000	884	152	183	327	221	14,105	2,408	2,889	5,209	3,599
25,001 to 50,000	332	47	83	127	75	11,917	1,644	3,029	4,528	2,716
50,001 to 100,000	199	36	40	88	34	13,918	2,676	2,729	6,139	2,374
100,001 to 200,000	90	18	18	37	17	12,415	2,542	2,400	5,152	2,321
200,001 to 500,000	38	8	10	13	7	10,724	2,232	2,726	3,681	2,084
Over 500,000	8	2	2	3	1	7,074	1,727	1,418	2,652	1,277
Cooling equipment (More than one may apply)										
	All buildings	North-east	Mid-west	South	West	All buildings	North-east	Mid-west	South	West
Residential-type central air conditioners	1,546	178	480	633	255	14,765	1,695	4,347	5,895	2,828
Heat pumps	692	53	65	409	165	12,538	1,490	1,024	7,108	2,916
Individual air conditioners	709	190	147	257	114	12,420	3,845	2,585	4,263	1,727
District chilled water	54	7	2	35	9	4,608	794	585	2,479	749
Central chillers	163	26	37	70	29	17,041	3,489	4,475	6,460	2,617
Packaged air conditioning units	**1,909**	**253**	**362**	**786**	**508**	**45,153**	**8,697**	**9,816**	**17,185**	**9,455**
Swamp coolers	109	Q	Q	Q	89	1,918	Q	Q	469	1,340
Other	Q	Q	Q	Q	Q	328	Q	Q	Q	Q

Additionally, in 2015 DOE reported RTU air conditioners serve cooling to ~60% of U.S. commercial building floor space.[17] However, it is not known how this figure was calculated.

In terms of lifecycle and age of units, in the April 2018 *EIA - Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case*, presented to U.S. Energy Information Administration, and prepared by: Navigant Consulting, Inc. the average life for Commercial Rooftop Air Conditioners is 21 years. The objective of this study carried out by Navigant Consulting was to develop baseline and projected performance/cost characteristics for residential and commercial end-use equipment.

Table 11: Commercial Rooftop Air Conditioners Average Life[18]

DATA	2012	2017				2020***		2030****		2040		2050	
	Installed Base	Current Standard	Typical	ENERGY STAR**	High	Typical	High	Typical	High	Typical	High	Typical	High
Typical Output Capacity (kBtu/h)	90	90	90	90	90	90	90	90	90	90	90	90	90
Efficiency (EER)*	10.6	11.2	11.3	11.7	12.8	11.8	12.8	12.2	12.8	12.2	12.8	12.2	12.8
Part Load Efficiency (IEER)*	12.4	-	11.6	11.8	21.5	13.1	21.5	15.1	21.5	15.1	21.5	15.1	21.5
Average Life (yrs)	21	21	21	21	21	21	21	21	21	21	21	21	21
Retail Equipment Cost (2017$)	6,600	6,600	6,600	6,650	10,350	7,150	10,350	7,150	10,350	7,150	10,350	7,150	10,350
Total Installed Cost (2017$)	8,800	8,800	8,800	9,400	14,900	10,250	14,900	10,250	14,900	10,250	14,900	10,250	14,900
Annual Maintenance Cost (2017$)	310	310	310	310	310	310	310	310	310	310	310	310	310

* Values shown are for air-cooled units with either electric resistance heating or no heating within the same enclosure.
** In 2018 the ENERGY STAR levels will change to 12.2 EER and 14.0 IEER.
*** In 2018, new energy conservation standards for Small (<135 kBtu/h) Commercial Packaged Air Conditioning and Heating Equipment will take effect. At this time the DOE-regulated metric will change from EER to IEER, and the minimum IEER will be 12.9.
**** In 2023, new energy conservation standards for Small (<135 kBtu/h) Commercial Packaged Air Conditioning and Heating Equipment will take effect. These projections reflect the 2023 minimum efficiency requirement, 14.8 IEER.

Furthermore, DOE used CBECS estimates of stock saturations and historic shipments data for each equipment class. DOE then calibrated the shipments model by varying both the equipment lifetime and the CBECS stock saturation. These calculations by DOE provided mean lifetimes of 21.1 years, 22.6 years, and 33.7 years for small, large, and very large equipment classes, respectively.[19]

In conclusion, the NEEP method seems to be the most frequently used approach for estimating the number of RTUs. In the absence of a survey addressed specifically at the issue of RTU type and age, it is recommended that once the newest data are released from CBECS that this analysis be conducted using the NEEP method with the newest data set.

5.0 Summary and Recommendations

5.0 SUMMARY AND RECOMMENDATIONS

In an effort to better understand the decision making process of commercial building owners when faced with a RTU retrofit decision, thirty-one in-depth interviews were conducted. This sample was selected for their breadth of experience and was comprised of HVAC system design engineers, large mechanical contractors, and commercial HVAC installers all with experience in commercial HVAC design and installation. Also included were individuals affiliated with HVAC industry associations and various Net-Zero initiatives. Respondents represented different regions of the country including New England, Mid-Atlantic, the South, Southwest, Northwest, and Midwest regions. Secondary market research was also conducted to explore how operating costs affect the decision to purchase an RTU and to determine the distribution of RTUs by age, type and region.

The interviews were supplemented with a literature search in order to benefit from what others have surfaced on this topic and to determine what data are currently available on the age and type of RTUs on commercial buildings by regions.

Based on the themes that emerged in the interviews, the following are suggested recommendations.

- Work with local utilities, asking them to suggest to commercial building owners that they check on the age of their RTU units and incentivize the building owners to start planning for potential replacement three years before predicted end of life for their units. Work with professional organizations to include this idea and documentation as part of continuing CEUs.

- Provide methods to quickly anticipate the retrofit cost of electrification in a commercial building, as this is a recurring need in converting from gas to electric.

- Fund competitions in cold climates regions to install heat pump RTUs on local. state or academic buildings that can serve as demonstration sites.

- Incentivize and authorize qualified HVAC suppliers to provide training on pros and cons of alternative RTUs for HVAC contractors.

- With split lease situations, develop a federal policy that will enable the building owner to receive some benefit from their initial investment in a new RTU system (assuming the building owner pays for the unit and installation). Recommend to start with HUD.

- In a split lease situation, if the lease indicates that the tenant must bear the cost of replacing an RTU, provide an incentive for them to do so.

- To complement this study, conduct a large survey of distinct professional types that function as influencers (architects and designers, HVAC suppliers, HVAC installers, utilities) to determine how prevalent the trends are that were presented in this report within a much larger group.

- One item that would be good to explore in the survey is the reluctance in cold climates to shift to RTUs because the heating loads are larger than the cooling loads. Our technical consultant noted that "In many climate zones (colder ones) the heating loads are larger than the cooling loads. Since there are few compressors designed to operate down to zero degrees (or less) [most stop around 20F], this requires installing an alternate heating system to make up the difference. Once an owner installs electric resistance heat or a natural gas furnace or boiler, there is little desire to spend more money on the heat pump option - especially in colder climates where larger coils and compressors are needed. If compressors are made to operate in 20F to zero range option (this covers DC and St. Louis regions, but not much farther north), this would require sizing compressors and the refrigerant coils much larger to meet the winter peak loads, which is significantly more costly.

- Have an impartial entity monitor and provide data on the operating costs of different types of RTUs on specific commercial building types within every state and promote the release of good data.

- Carefully monitor the programs in New York City, Washington DC and St Louis and promote the methods that are most frequently used to decarbonize these cities. There are many methods by which net-zero goals can be achieved. It would be useful for others to know what these cities have found to be the most successful in increasing energy efficiency, as well as efforts that did not work well. These methods need to be publicized and made readily available.

- With those cities that have committed to a low carbon future, local government should provide numerous options for achieving the targeted goals, considering the local building stock, the current sources of energy inefficiency and alternative ways of achieving compliance. A good example of a typology for different building stock types can be found in the report from New York City entitled One City Built to Last – Technical Working Group Report (see pages 76-91).[20]

- Consult with EIA to see if in the future they will include questions regarding specific RTU types and their age as part of future commercial building surveys. Important data to include: MFG, model number, and age.

Appendix A: Methodology

Appendix A

This report is based on both secondary sources, as well as primary research. For this report, we reached out to a total of 158 people (123 people for Objective 1 and 35 people for Objective 2), with 31 (23 interviews for Objective 1 and 8 interviews for Objective 2, with some overlap among their responses) interviews held. This report is heavily based on primary research, which involved reaching out to individiuals and corresponding with them using the phone, email, social media platforms, and Zoom.

The questions that were asked during the interviews associated with Objective 1 follow:

- With commercial buildings in this region, what motivates a building owner to replace their existing rooftop unit?
- What type of rooftop unit do most of the commercial buildings in your region have?
- What seems to be most important to the decision maker when selecting a replacement rooftop unit?
- How often are heat pump rooftop units considered as an alternative replacement (and why do you think that is the case)?
- What are the installation challenges you anticipate when replacing an existing rooftop unit and how do you address these challenges?
- Do commercial building owners express a desire to lower their carbon footprint and decrease the use of natural gas?

In addition to these questions, in some cases individuals were also asked about the decision makers, as this is another area where insight and perspective would be beneficial. The goal was to better understand who the decision maker is (the building owner, tenant, facilities manager, or someone else), how the decision maker learns about rooftop unit pricing (not just the capital cost of the unit, but how a more efficient unit will impact long-term utility bills), and the extent to which anticipated future electrical operating energy costs factor into the decision to replace an existing unit with an electrical heat pump rooftop unit.

A secondary literature review and targeted interviews was also conducted to probe the role that future estimated economic operating cost factors (i.e., projected electrical costs) have on the buyer's decision to retrofit from an existing gas-electric package to an RTU heat pump. Also examined were associated issues that may serve to incentivize or de-incentivize the decision to go forward or halt a move to a heat pump unit.

The specific goals of this portion of the project will provide answers, insights, and relevant contextual information focused on the following key questions:

- What are the primary economic barriers to a decision to switching to a heat pump? How much, if at all, do the decision makers factor the anticipated/ projected new electrical heating and A/C operating costs that will occur after retrofitting to an RTU heat pump?
- Who, most frequently, is the decision maker when it comes to making this switch? For example, is it the building owner, a CFO, a facilities manager, a team, or somebody else? What factors influence who ultimately makes the decision?
- What party is most often given the task of gathering, calculating and presenting the new projected electrical operating costs to the decision maker? What kinds of processes or software is deployed to calculate that data?
- What are the primary factors that will impact whether the future electrical operating costs will be seen as a disincentive, a neutral factor, or even a benefit to moving to heat pumps? Within this larger question, two relevant narrower questions are addressed as well: How much, if at all, does a utilities' integration of time of day/demand pricing methods impact the economics of the decision? How are the split incentives that some building owners face when examining total-lifecycle costs of retrofitting to a more energy efficient HVAC technology playing out right now?
- Are there circumstances and conditions where a decision maker might choose to downplay, or even overlook anticipated higher energy operating costs, thereby making the switch more likely, despite the projected higher costs? If so, what are they? For example, how much do financial incentives and/or regional regulations help move the needle here?
- What are the key significant and relevant anticipated trends that could impact the future of heat pump retrofits in commercial buildings?

Below is a description of the methodology utilized to obtain answers to the above questions:

In-Depth secondary literature research: Iterative and advanced keyword searching was conducted on selected market research and industry databases, as well as online academic and scholarly resources. Targeted open web searching was also performed directly on websites of federal governmental agencies, industry associations, HVAC vendors, and on social media platforms. One focus area of the search was to discover if any organization (HVAC vendor, facility manager/building association, energy efficiency advocacy group, etc.) conducted a survey of commercial building owners and asked any of the targeted questions. We were looking for precise answers to two key questions: Who are the decision makers? How much, if at all, do future projected electrical operating costs factor into a retrofit decision?

Although research did not reveal any surveys that asked those specific targeted questions, nor were there any reports that contained specific and clear answers to those two specific questions, the searches did turn up approximately 100 relevant studies; of those we downloaded and reviewed 30 reports, sites and documents with highly contextually relevant information, and that contained answers to some of the broader questions, such as the major overall barriers to a decision to retrofit to heat pump and factors that can overcome economic disincentives. These search results also included the names of report authors and affiliated experts who are likely to be able to have the experiences and expertise to respond to the targeted questions.

Reach Out to Identified Authors and Experts: Through reviewing these relevant and useful reports and sites, we were able to identify 35 individuals where we could locate contact information to request an interview. Contact was made via direct email, email to the larger organization, on a Web site directly, and via two social media platforms (Twitter and LinkedIn). Of those we reached out to, we ultimately heard back from and were able to conduct in-depth conversational interviews with 8 individuals: 4 via Zoom; 3 via phone and 1 through email.

Endnotes

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