Unlocking the Path to Decarbonized Building Thermal Systems: Strategies for Designers and Contractors

Preprint

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National Renewable Energy Laboratory

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Unlocking the Path to Decarbonized Building Thermal Systems: Strategies for Designers and Contractors

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ABSTRACT

The design and construction community plays a pivotal role in facilitating the transition to decarbonized thermal systems that maintain human comfort while reducing building emissions. Through the U.S. Department of Energy Better Buildings Initiative's Design and Construction Allies, a cohort of leading architecture, engineering, and construction firms have identified top ranked barriers that designers and contractors face when implementing solutions for building owners.

These barriers to decarbonizing thermal—especially heating—systems include equipment availability; electrical capacity constraints; space allocations; complex system configurations; and lack of experience in designing, installing, and maintaining heat pumps. These impediments significantly amplify the risk and financial burden associated with the adoption of decarbonized solutions. The barriers also decrease the likelihood that designers, contractors, and owners will adopt decarbonization strategies without clear plans and guidance on how to implement these solutions, mitigate risk, and overcome the identified barriers.

The National Renewable Energy Laboratory, the Design and Construction Allies, and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers have developed "how to" thermal decarbonization guidance based on best practices. The subjects covered range from the role of energy efficiency in facilitating decarbonized heating solutions to strategies for decarbonizing new and existing heating, ventilating, and air-conditioning systems. The focus is on overcoming barriers so that energy-efficient, electrified buildings—both new and retrofit—become the industry standard. This paper outlines 1) the method used to collect and organize this guidance, 2) industry barriers to decarbonization, and 3) decarbonization techniques that have broad market applicability.

Introduction

The building sector accounts for 30% of global final energy consumption and 26% of global energy-related emissions (IEA 2023). This uniquely positions building owners and operators as key players in the many countries and jurisdictions with goals for greenhouse gas emissions reduction. Carbon dioxide is the primary greenhouse gas, accounting for 80% of all U.S. greenhouse gas emissions from human activities in 2022. Carbon dioxide is emitted as a result of burning fossil fuels such as coal, natural gas, and oil as well as during the production of cement, metals such as iron and steel, and some chemicals (EPA 2024a).

The U.S. Department of Energy's (DOE's) Better Buildings initiative has more than 900 partners, of which more than 345 have energy goals and more than 110 have climate goals (DOE 2022). Often, partner companies lack the in-house expertise to achieve their zero energy and zero carbon (ZEZC) goals, requiring owners to seek external expertise to achieve these goals. In the United States, many building owners have committed to emission reductions in their existing portfolios. To support these efforts, DOE's Better Buildings Initiative launched the Better Climate Challenge (BCC) in 2022 (DOE .n.d.-a). BCC hosts more than 200 organizations that have committed to greenhouse gas reductions of 50% in the next ten years (DOE 2022). Achieving carbon goals in existing buildings requires significant reductions in energy consumption, electrification of on-site fossil fuel consuming equipment, and renewable energy deployment. Similarly, all new buildings need to be built using ZEZC strategies from design through finish to minimize emissions (ASHRAE n.d.).

Navigating the landscape of energy efficiency, renewable energy, and zero-carbon buildings can be complex for building owners, who rely on architecture, engineering, and construction (AEC) professionals to help design, build, and procure more energy-efficient buildings. By choosing AEC firms committed to energy efficiency, electrification, and renewable energy, building owners can achieve their emissions and carbon reduction goals.

Better Buildings recognized the design and construction community's importance to the success of owners' ZEZC projects and the need to provide the required expertise. That recognition led to the formation of the Design and Construction Allies group in October 2020 (DOE 2021) to help the AEC industry identify barriers and challenges to ZEZC and work collaboratively to develop and implement solutions. Small working groups of these AEC professionals regularly discuss, identify, and brainstorm solutions for delivering ZEZC buildings. Through these working groups, the Allies develop ideas, tools, and resources that can help the broader AEC community deliver ZEZC buildings.

Both BCC and the Allies identified energy-efficient retrofits and electrification in existing as well as new buildings as the primary strategies for meeting carbon reduction goals generally and building decarbonization goals in particular. The current commercial U.S. buildings stock has a median construction year of 1981, with more than half of U.S. commercial buildings built between 1960 and 1999 (CBECS 2018). These older buildings pose unique challenges to AEC professionals interested in retrofitting them to reduce carbon emissions and meet ZEZC goals. Some of the challenges associated with these older buildings include lower levels of insulation, higher rates of infiltration, historical building requirements, and existing electrical infrastructure constraints. Electric heat pumps are emerging as a promising approach to improving energy efficiency; electrifying heating, ventilating, and air conditioning (HVAC) systems; and meeting decarbonization goals.

Overview of the Design and Construction Allies

The Design and Construction Allies initiative (DOE n.d.-b) was formed to address the specific challenges faced by AEC professionals in delivering ZEZC buildings. Recognizing that building owners heavily rely on the expertise of AEC firms for decisions related to building design, performance, and functionality, this initiative aims to facilitate better coordination and knowledge sharing.

Within the building delivery process, various stages such as budgeting, design concept development, and aesthetics involve collaboration between AEC professionals and building owners. However, HVAC design stands out as a particularly complex area that requires specialized knowledge. As a result, AEC professionals often take the lead in identifying the optimal systems and equipment to achieve desired outcomes like cost efficiency, comfort, energy efficiency, and decarbonization, while keeping the building owners' goals in focus.

The Allies initiative fosters collaboration among AEC firms to tackle these technical challenges. Through small working groups, professionals regularly discuss and brainstorm solutions for achieving ZEZC buildings. These groups focus on developing practical ideas, tools, and resources that can be shared within the broader AEC community.

The primary strategies identified for achieving carbon reduction in buildings include energy-efficient retrofits and electrification. Given the aging U.S. commercial building stock, with a median construction year of 1981, retrofitting presents unique challenges such as low insulation levels, high infiltration rates, historical preservation requirements, and outdated electrical infrastructures. The initiative emphasizes the importance of overcoming these barriers and highlights electric heat pumps as a promising solution for improving energy efficiency and electrifying HVAC systems.

Program Motivation and Goals

The Allies' overall goal is to enable the routine design and delivery of ZEZC. To accomplish this, DOE is partnering with leading AEC firms to:

- Understand barriers to increasing energy efficiency and carbon savings
- Ensure transparency in their approaches so that others can understand the process and emulate the details
- Educate key market players about creating and delivering high levels of energy efficiency and carbon savings within current market conditions.

The Allies

The Allies program consists of AEC firms committed to taking practical steps to deliver ZEZC buildings. Allies must sign a nonbinding agreement that includes sharing company profile information as well as participating in Allies meetings and smaller working group meetings focused on solving specific problems and documenting and sharing progress towards measurable goals with DOE. Goal setting is an important part of the effort, and Allies must commit to goals for integrating energy efficiency, electrification, and renewable energy strategies into designs; sharing the strategies that work and the barriers encountered; and setting measurable goals to show progress towards ZEZC. They also commit to annual reporting on progress towards their goal(s).

Program Workflow

Figure 1 outlines the Allies program workflow. NREL leads the Allies through monthly feedback sessions in working group meetings to work through the solution development process. First, participants set strict goals for integrating advanced levels of energy efficiency or achieving ZEZC in their projects, after which they determine and rank the barriers to these goals. They form working groups around the key barriers, a process that includes determining whether the working group is the right entity to resolve the barriers.

The working groups develop resources to address the barriers and the Allies test the resources within their firms' internal workflows. They then report back to working groups on the effectiveness of the solutions in addressing specific barriers. The feedback loop may result in revisiting the barrier and refining the developed solution to improve its effectiveness and impact in addressing the barrier.

The last step is a collaborative effort involving all the Allies to disseminate and scale the solutions to ensure access to, and adoption of, the resources in the broader AEC community. In Figure 1, The green "checked" boxes indicate the current stage of the program cycle. The program cycles every year, as Allies identify new barriers and form new working groups to develop resources that meet industry needs.

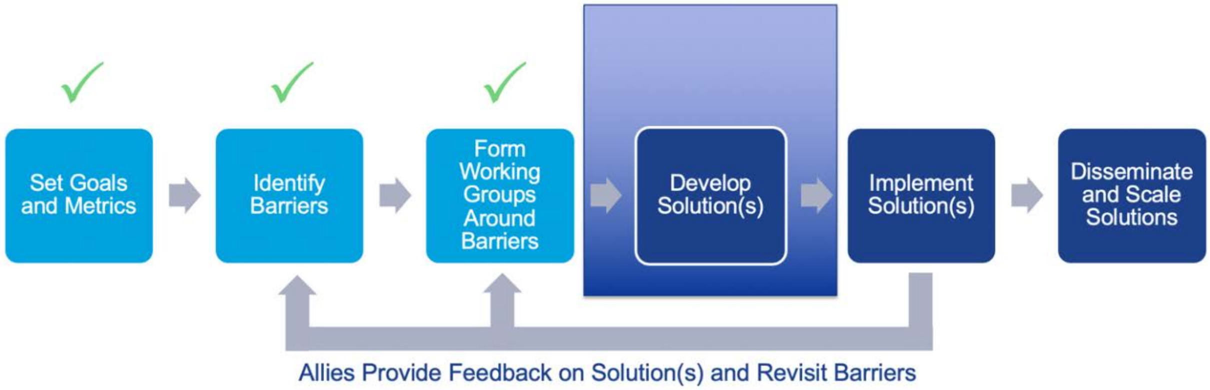

Figure 1. Schematic of the Design and Construction Allies program approach. *Source:* Torcellini et al., 2022.

Identifying Barriers to Decarbonization

In the early part of program, Allies focused on naming market and technical barriers associated with the routine design and delivery of ZEZC buildings within current market conditions. Allies created a list of barriers and prioritized these barriers on a scale of 1 to 5 with 5 being the most significant. The scoring results are shown in Figure 2, and indicate that the top three barriers are perceived first costs, customer demand, and risk aversion to new technologies. The lowest scored barrier was technology limitations. This list of barriers, although general, provides discussion points that working groups can form around with some confidence that solutions to these barriers will address industry needs.

Working Groups

The focus of the working groups is to identify top ranked barriers that 1) are real, 2) will result in substantial impact if addressed, and 3) can be addressed by the working group. In the first program cycle, which occurred in 2021–2022, the Allies formed two working groups.

- ***Working Group #1:*** **Financial and Client Demand**. Focused on cultivating "client demand" and developing resources that explored the relationship between the AEC community and its clients. This group also focused on how to make projects more financially attractive through the use of incentives and other financial pathways. Although this is a broad topic, this group could partially address the first six barriers.
- ***Working Group #2:*** **Embodied Carbon.** Took on a broad topic by addressing how to integrate embodied carbon into building design and delivery processes. Interestingly, this topic is outside the boundaries of creating a ZEZC building from an operational point of view, but was seen as a relevant topic.

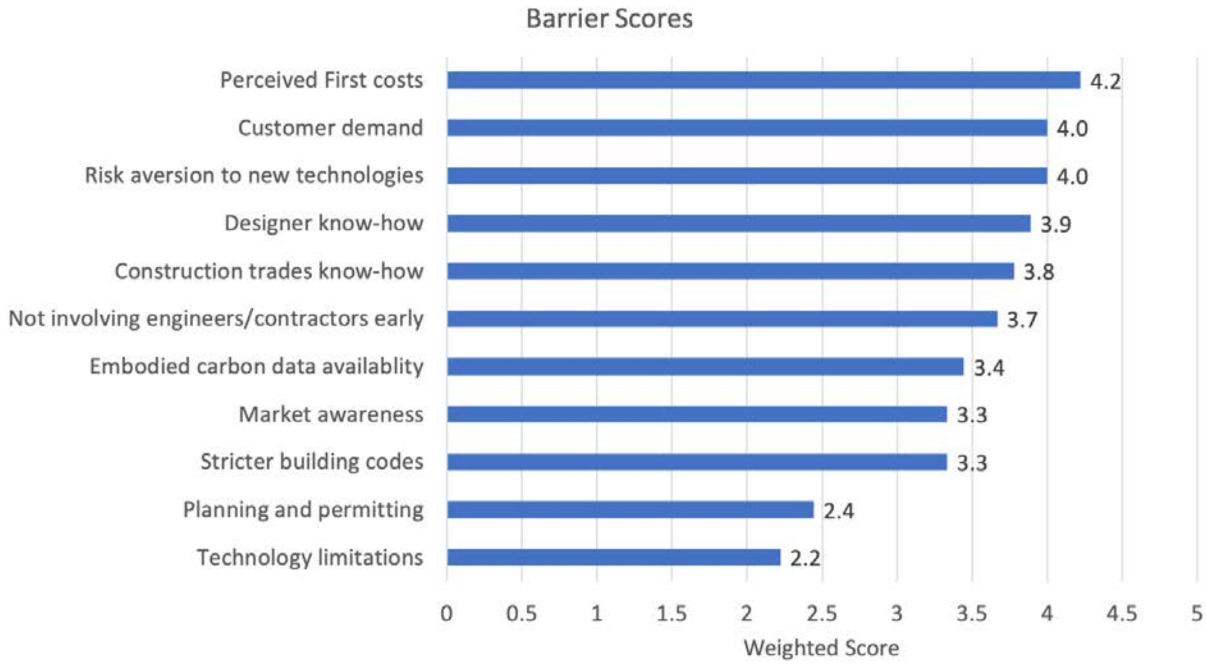

Figure 2. Barriers to routinely delivering zero energy and zero carbon buildings identified by the Design and Construction Allies. *Source:* Torcellini et al. 2022.

The Allies opted into participation in one or both working groups using different staff members for each working group. In 2023–2024, Allies addressed the "risk aversion to new technologies" and "designer know-how" barriers by forming the following working groups:

- ***Working Group #3:*** **Building Retrofits**. Identifies and addresses barriers designers and contractors face in decarbonizing existing buildings. Resource development options may include whole-building retrofit guidance for building end uses.
- ***Working Group #4:*** **Heat Pumps.** Identifies and addresses barriers to heat pump technology adoption. Resource development options may include heat pump design, sizing, and installation; architectural considerations; and maintenance guidance.

In 2023, the Allies' retrofits working group merged into the heat pump working group. The resulting group focuses on developing guidance for installing heat pumps in existing commercial buildings.

Heat Pumps

Heat pump technology is nothing new. British mathematician Lord Kelvin (born William Thomson) described the theory behind heat pumps in the early 1850s. Later that decade, Austrian engineer Peter von Rittinger built the first practical heat pump, using the latent heat in water vapor to evaporate liquid from salt brine. Likely inspired by von Rittinger's work, Antoine-Paul Piccard of the University of Lausanne, Switzerland, and engineer J.H. Weibel of the Weibel-Briquet in Geneva, Switzerland, developed the first vapor-compression salt plant in 1876, which was installed near Zurich in the salt works at Bex, Switzerland, in 1877. By 1938, the City Hall of Zurich had replaced wood stove heating with a water-source (from Lake Geneva) heat pump system, which was in use until 2001, when it was replaced by a new, more efficient heat pump (Zogg 2008).

Today, heat pumps are energy-efficient, readily available appliances that can provide cost-effective space heating, space cooling, and water heating in buildings while also supporting efforts to decarbonize new and existing buildings. Building heating is typically one of the most difficult systems to address during a retrofit or new building decarbonization effort. Heat pumps are increasingly seen as the most promising technology for heating, because they are an electric solution that offers better energy efficiency compared to electric resistance options (IEA 2023).

However, BCC partners and Allies expressed concerns about unfamiliarity with heat pumps and perceptions that they would be difficult to retrofit in existing buildings. In parallel with the efforts of these two groups, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers' (ASHRAE's) Task Force for Building Decarbonization has been working on developing resources for decarbonization to help support the AEC community. ASHRAE is a leading HVAC industry group that promotes energy efficiency and develops and disseminates resources and standards used by the broader AEC community. The Allies' working groups, led by the National Renewable Energy Laboratory (NREL) in partnership with ASHRAE's Task Force for Building Decarbonization, joined forces to develop heat pump design guidance to help the building owners and the AEC community overcome the barriers to adopting heat pumps.

Guide to Decarbonizing Building Thermal Systems

Members of the heat pump working group (#4) were interested in developing guidance for decarbonizing building thermal systems focused on retrofitting commercial buildings with heat pumps. A uniquely collaborative effort between the working group, NREL, and ASHRAE resulted in a publication, *Decarbonizing Building Thermal Systems: A How-To Guide for Heat Pump Systems and Beyond*, which aims to educate AEC professionals and provide guidance on the intricacies of designing, installing, and maintaining commercial heat pump systems. In the next few sections, we describe the motivation, process, scope, and key principles detailed in the guide.

Motivation

This guide was developed for AEC professionals in response to an industry need for a comprehensive technical resource that includes detailed information on sizing a heat pump system, selecting an appropriate heating and cooling system, determining the heat source and sink (air, water, ground), and integrating the heat pump with existing commercial building systems. Moreover, it emphasizes best practices for ensuring operational efficiency, system longevity, and reliability.

Process

Through the Allies, NREL led the development of the guide by working with members of the heat pump working group to gather and review relevant content from designers and industry experts. The ASHRAE Task Force for Building Decarbonization is also involved in this process, reviewing drafts and offering technical expertise. The working group holds monthly calls to develop core content as well as review and provide technical feedback on content drafts, brainstorm content formatting strategies that clearly convey complex technical concepts, and brainstorm dissemination channels, among other efforts.

NREL released draft versions of the guide twice in an open peer review process. Reviewers included Allies; ASHRAE Task Force for Building Decarbonization participants; and other reviewers suggested by NREL, DOE, and ASHRAE. Researchers used a web-based form to collect reviewers' feedback, and reviewers referenced document line numbers to provide specific comments on items such as content, figures, text, and tables.

As intended, the open peer review resulted in feedback focused on the technical content in the guide, while keeping in mind the intended audience of the guide—architects, design engineers, and contractors. The authors, who are NREL researchers, indicated their interest in feedback on whether the guide includes sufficient technical content and detail to allow AEC professionals to successfully deliver ZEZC buildings. Although feedback on formatting and language was not a high priority in early versions, reviewers' suggestions on the content presentation format indicated that clarity in the text as well as in figures, plots, and other graphics was important to effectively convey the technical concepts.

Many peer reviewers embedded questions in red font, indicating that some issues were a high priority for feedback from the authors. These included requests for additional materials, references, and specific commentary on graphics, figures, and tables. The authors had encouraged reviewers to prioritize their reviews to address these questions first. Early versions of the draft contained content in green font, which indicated supplementary material that would be included in sidebars.

The guide will include two complementary parts completed and released in different time frames. The first part will be completed and released in Summer 2024, and the anticipated release date of the second part Winter 2025. The second part was not included in the peer reviews, although reviewers could comment on the draft outline and provide feedback.

On October 23, 2023, we released the 60% draft through the open peer review for a duration of three weeks. We received 190 comments, addressed those comments, received further revisions from the Allies heat pump working group, and released an 80% draft version for an open peer review that occurred between February 16, 2024, and February 25, 2024. As a result of the 80% peer review, we received and addressed 230 comments, a process that resulted in the development of the final 100% version of the first part of the guide.

Scope of the Guide

The guide does not assess the impact of heat pump systems; the intent is rather to provide sufficient technical detail to inform the proper design, sizing, installation, and operation of heat pump equipment.

Heating systems are in buildings to provide heat; the process requires many different inputs and outputs, as shown in Figure 3. The inputs include the fuels into the system and outputs include emissions from burning of these fuels as well as from refrigerant leakage. There are other inputs such as the emissions released by the production of the refrigerants, the equipment itself, and maintenance parts such as filters. Likewise, demolition of equipment and materials that are thrown away (like filters) can all produce emissions.

The guide is focused on reducing carbon emissions produced during the operation of the heating system as shown by the green arrows in Figure 1. These emission sources accounted for 73% of building emissions and 27% of global emissions in 2020 (ASHRAE 2022). Because the guide focuses on operational emissions, it excludes the flows that are shown in gray, including the embodied carbon of the equipment. When pursuing building decarbonization, however, all these emissions should be considered as part of the design.

The Allies heat pump working group reported encountering the following barriers to heat pump equipment adoption:

- Complicated design process, particularly in retrofit applications
- Lack of experience among owners and AEC professionals in designing, installing, and maintaining heat pumps
- Electrical infrastructure constraints and associated high upgrade costs
- Lack of available equipment that can deliver high supply temperatures similar to traditional boilers
- Limited space availability
- High equipment costs
- Poor cold climate operation and efficiency.

Part 1 of the guide addresses the first five of these barriers by bridging the gap between heat pump manufacturer equipment specifications and the design guidance required for proper adoption, installation, and operation. The objective is to maximize energy efficiency and minimize operational emissions and costs for new construction and retrofit projects. Key retrofit strategies include reducing building loads through energy efficiency measures, which can also help free additional electrical capacity, and using one system for heating and cooling rather than installing a dedicated heating-only heat pump (to replace a boiler, for example). In retrofit projects, the guide encourages designers and engineers to explore the possibility of leveraging existing cooling systems to also provide heat. A high-level outline of the major subsections contained within Part 1, and the planned complementary Part 2, is shown in Table 1.

Key Principles

The guide describes how heat pumps, often viewed as standalone components within HVAC systems, can be used in an integrated building system. Decarbonizing heating systems requires a holistic approach, and elements of the building system, including the envelope and distribution systems, significantly influence the performance of the heat pump. Compared with conventional heating equipment, heat pumps' three key differences include:

- Lower temperature air or water during heating operation.
- In an air-source application, cold outside air temperatures can result in reduced capacity, efficiency, and, in some cases, loss of service
- A single piece of equipment can provide both heating and cooling.

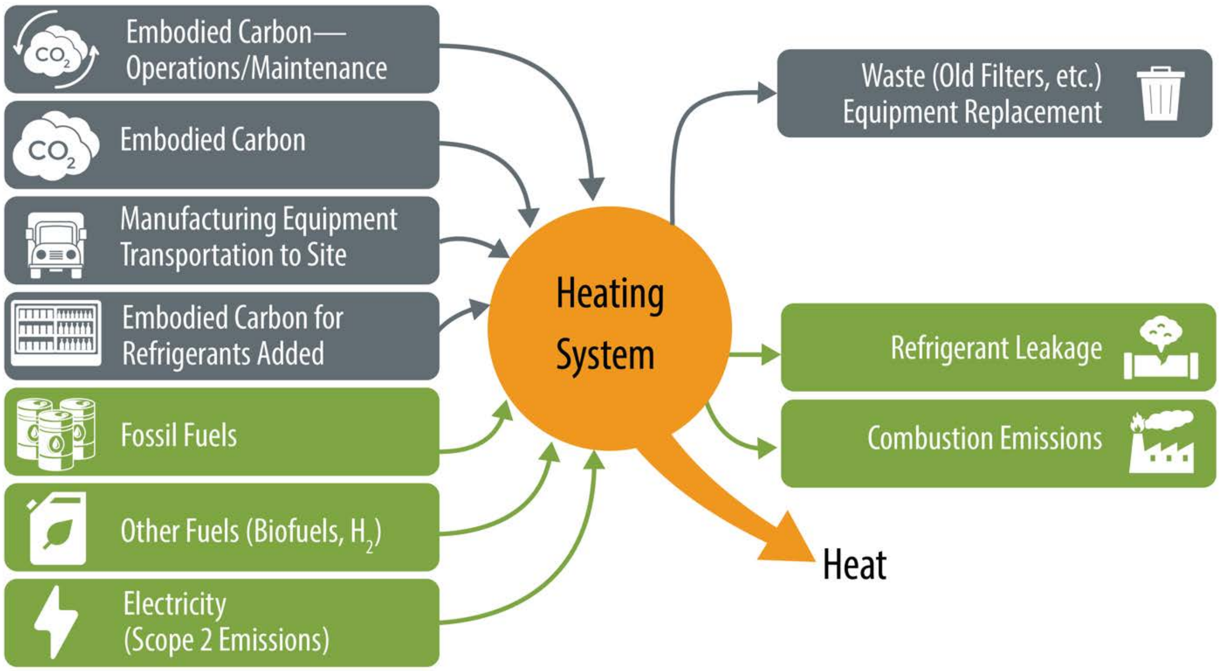

Figure 3. Sources of heating system emissions. *Source:* Marjorie Schott, National Renewable Energy Laboratory. Note: Scope 2 emissions are indirect greenhouse gas emissions associated with the purchase of electricity, steam, heat, or cooling (EPA 2024b).

Table 1. Guide to decarbonizing building thermal systems—Part 1 and Part 2 outlines

Part 1 Outline *(Planned For Release Summer 2025)*	**Part 2 Tentative Outline** *(Planned for Release in Winter 2025)*
1. Introduction	8. Technology Types
2. Selecting the Right Heat Pump for Your Project	9. Functional Applications
3. Designing and Sizing Heat Pumps	10. Building Applications
4. Retrofit Applications	11. Cold Climate Applications
5. Case Studies	12. Thermal Storage Applications
6. Best Practices in Heat Pumps System Installation	13. Cost Comparisons
7. Heat Pump Fundamentals	14. Installation and Commissioning
	15. Operations and Maintenance Considerations
	16. Resources

These differences require changes to engineering and design practices and strategies to ensure successful heat pump deployment. Although they work well in most buildings, heat pumps are most effective when integrated into buildings with well-insulated, high-performance envelopes. Investments in building thermal performance can reduce heat pump system capacity requirements, which increases efficiency and reduces cost. Design considerations must account for specific building load conditions and temperature ranges, because these factors impact heat pump efficiency and performance. For optimal performance in existing buildings, the guide suggests a few key strategies.

Reduce building loads to reduce the required heat pump capacity. Strategies for reducing building loads include:

- Improving envelope energy efficiency
- Reducing internal loads such as lighting and plug loads
- Minimizing ventilation loads
- Exploring heat recovery options for simultaneous heating and cooling loads
- Evaluating setback temperature strategies to prevent morning warm-up peaks.

Reducing building loads is important in any energy-efficient HVAC system, but it is particularly important in heat pump deployments because it allows owners and AEC teams to reduce equipment size and capacity and thus cost. With reduced building loads and improved envelope, heat pumps can also operate at lower supply temperatures (the delivery temperature of air or water to the building), which has major implications for performance, equipment availability, and the unit's ability to operate at higher efficiencies in existing building distribution systems. Minimizing building loads can also make it possible to reduce heating and cooling loads sufficiently that they can be met by a heat pump without sacrificing comfort, especially considering the heat pump supply temperature limitations mentioned above.

Use integrated heating and cooling systems. Specifying an integrated heating and cooling system takes advantage of heat pumps' ability to provide both heating and cooling from one piece of equipment. If an existing heating system is replaced one for one with a new heating-only heat pump, this will increase project cost and the building's electrical capacity requirements. In contrast, replacing the existing cooling system with a heat pump that provides both heating and cooling decreases operational costs and allows the existing electrical capacity in the building to be used for both heating and cooling. For example, practitioners should avoid installing dedicated heating-only heat pumps to replace boilers. Choosing systems with heating and cooling capabilities can streamline operations and reduce costs.

In many climates, a single heat pump will provide all the heating and cooling required in the building, although in heating dominated climates, supplemental heating systems might be required. Given that heat pumps could meet a portion of the heating load at peak heating conditions, designers should avoid sizing backup heat to meet the full peak load of the building and consider sizing backup heat to meet the remaining unmet load from the heat pump. This can reduce project costs and free up electrical capacity for the electrification of other end uses.

Select equipment with an adequate turndown ratio. Turndown is the ratio of maximum to minimum heat pump compressor capacity. Sufficient turndown ensures that the maximum capacity is sufficient to meet the maximum building load, and the minimum capacity is low enough to meet most of the heat load in the building throughout the year and efficiently adjust output to match varying heating demands.

Direct expansion equipment can have issues with inadequate turndown. When heat pump minimum available capacity is larger than the building load during a given operating time step. the equipment will short cycle to avoid over-conditioning the space, resulting in improper temperature/humidity control, decreased equipment life, and reduced efficiency. Because heat pumps provide both heating and cooling throughout the year, their runtime is significantly greater than conventional cooling and heating-only equipment. If turndown ratios are not sufficient (i.e., not large enough), short cycling can occur frequently enough to result in premature equipment failure.

Use a phased deployment approach. Adopting a step-by-step process for heat pump deployment that allows for gradual implementation over time can be an affordable and successful approach. This strategy allows building owners (and the AEC professionals they rely on) to develop an implementation plan and become familiar and comfortable with decarbonization principles and solutions over time.

If equipment fails and must be replaced quickly to avoid downtime, having an owner and AEC team accustomed to solving building problems using decarbonization strategies makes it more likely the replacement equipment will move the building further along the path to decarbonization. Similarly, reducing building loads and improving the existing building envelope might be too costly for a building owner to consider all at once, but timing building and equipment upgrades to coincide with natural milestones such as roof replacements or renovations as a result of tenant build-outs can make them financially viable. Another strategy might be to replace a failed direct expansion cooling system with a heat pump and keep the existing natural gas heating systems to provide heat only when the heat pump can't meet the building heating load, the so-called "dual-fuel" strategy. By adopting a phased approach, the focus will be on solving current building problems with solutions that reduce on-site fossil fuel consumption and support the effort to achieve full decarbonization as time and budget permits.

Minimize electric backup heat. Reducing the reliance on backup heating systems, particularly electric backup can have a substantial impact on operational performance and can reduce the costs associated with electrical capacity expansion. Deciding on backup heat requirements involves considering factors like existing building electrical compatibility, heat pump capacity, and operational constraints. Common practice with air-source heat pump deployments is to provide 100% backup heat as redundancy in the event of equipment shutdown due to defrost or cold outdoor air temperatures. This can exceed existing building electrical infrastructure capacity, resulting in expensive upgrades and in some cases making the project unfeasible.

Properly sized and designed heat pump systems can help alleviate the need for backup heat and free up building electrical capacity to support further upgrades if needed. The decision tree in Figure 4 can help designers select backup heat options, with an emphasis on avoiding full-capacity backup heat to minimize costs and inefficiencies.

Supply temperatures and heat source conditions also influence heat pump performance. Strategies to minimize supply temperatures include thermally stress testing the building, reducing building loads, reducing ventilation loads, adding heat emitters, upgrading and/or adding fan coil units, integrating outdoor air reset controls, and optimizing heat emitter configuration for parallel operation. Figure 5 offers examples of possible strategies.

Conclusion

The AEC community is crucial to the decarbonization of new and existing buildings. DOE's Better Buildings Allies engages ZEZC building design and construction leaders and works with them to develop solutions for the broader market. These practicing professionals have valuable insights into the barriers to achieve ZEZC buildings and have found solutions to deliver these buildings to building owners. Through this collaborative effort with the Allies, the team was able to create a unique resource for identifying, assessing, and developing solutions to common barriers in the delivery of the heat pump solutions for ZEZC buildings.

By leveraging the expertise of practicing professionals and engagement with ASHRAE, the team developed industry leading guidance for heat pump implementation. This novel method of crowd sourcing and developing guidance with industry experts has resulted in fast timelines and industry tested practices that are not found in other design guidance. In contrast to other guidance that is more “what” focused, this guidance provides actionable “how-to” solutions for the broader community on heat pump design implementation and deployment. The “how-to” focus leverages firsthand experiences of this group of practicing professionals and helps disseminate their expertise to the broader AEC community. This group identified some key principles for successful heat pump deployment, including reducing building loads and required heat pump capacity, using integrated heating and cooling systems, selecting equipment with adequate turndown ratios, implementing a phased approach for deployment, and minimizing electric backup heat. These principles, in tandem with actionable decision trees, provide the AEC community the tools to successfully deploy heat pumps in buildings.

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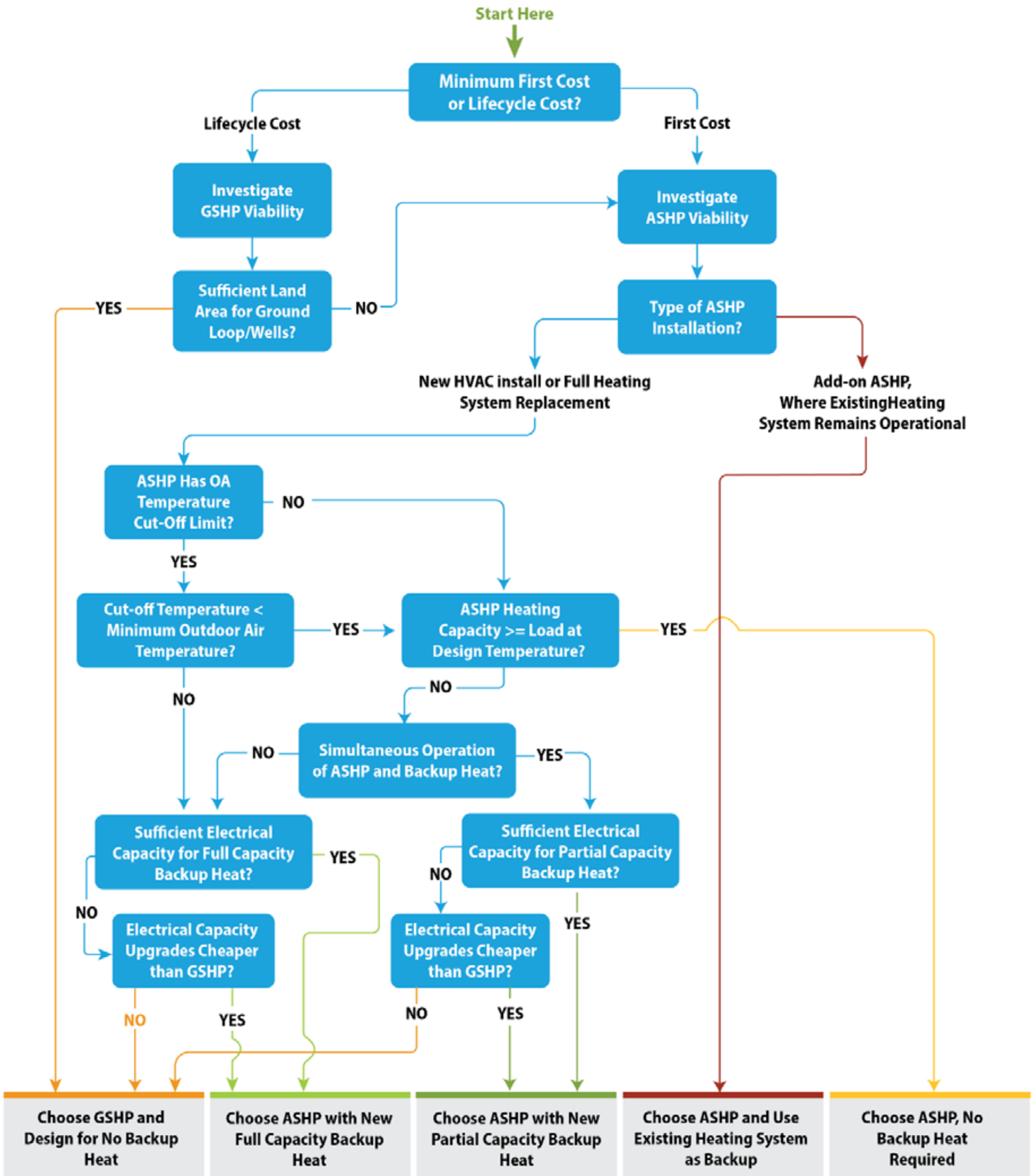

Figure 4. Decision tree to help designers identify backup heat requirements for air-source heat pumps. Source: Houssainy et al. 2024

Key: GSHP: ground-source heat pump; ASHP: air-source heat pump; OA: outside air

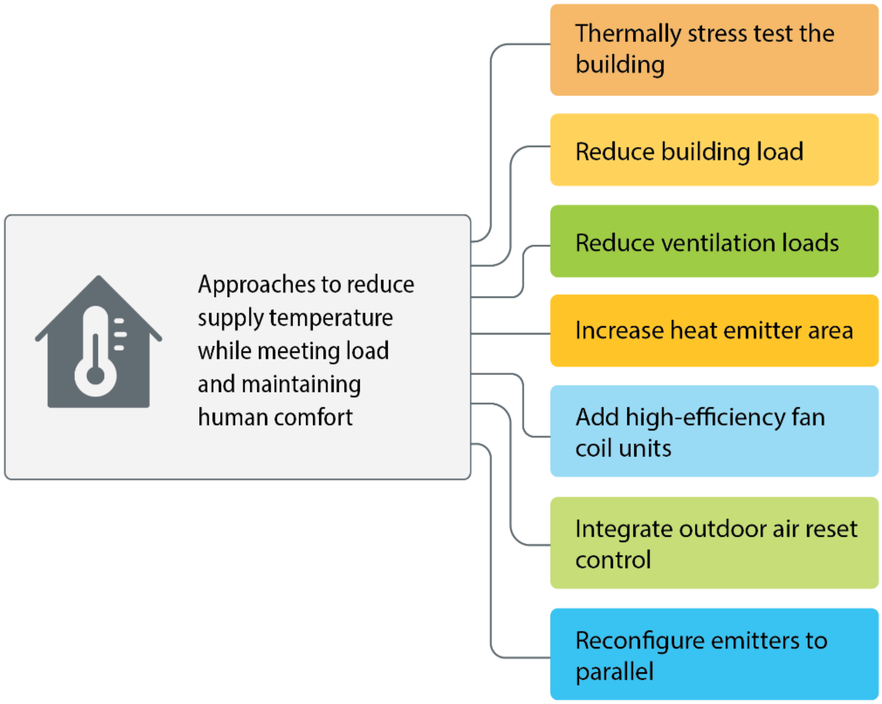

Figure 5. Strategies for reducing supply temperatures and maximizing the operational efficiency of heat pumps. Source Houssainy et al. 2024

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