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HVAC/Very High Efficiency Dedicated Outside Air System Specifier Interviews Research

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Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) sought to build on prior research and program experience to better understand the dynamics in Heating, Ventilation, and Air Conditioning (HVAC) system design and installation. NEEA is particularly interested in the market actors and points of influence for new construction and major renovation projects in smaller commercial buildings, defined as 50,000 square feet or smaller. This work emerged from NEEA's High-Performance HVAC program, as part of the efforts on its first area focus- Very High Efficiency Dedicated Outside Air System (VHE DOAS). NEEA's definition of VHE DOAS is a high-efficiency HVAC system that includes dedicated ventilation air (decoupled from the primary heating and cooling system) with high-efficiency heat recovery and a high-efficiency heating and cooling system sized appropriately to reflect expected performance. The program requirements also include key design principles necessary to achieve optimum energy savings.

The primary objectives of this research were to:

1. Better understand how decisions regarding HVAC systems generally and DOAS systems specifically are carried out from initial conception to installation.
2. Learn how architects and engineers think about the components of DOAS systems.

The project was informed by several research activities including a focused literature review and in-depth interviews with 16 design professionals throughout the Northwest. Interviews occurred between December 14, 2019 and February 3, 2020.

The key findings related to these areas of inquiry are described below.

Procurement models affect communication flow and influence of construction pricing

NEEA sought to understand the extent to which architect and engineer influence might vary within different procurement models. We expected a more discernable split in the type of projects respondents reported working on, assuming that these professionals tended to work in either plan & specify or design+build projects. We found that this dichotomy was overly simplistic—in reality nearly everyone we spoke with had experience in multiple types of procurement models, including hybrid approaches that do not fit neatly into either the traditional plan & specify approach or the classic design+build.

This research identified four primary procurement paths through which new construction and major renovation typically occur:

- **Plan & specify[1]:** The classic approach to designing new spaces, typically driven by architect project managers. Pricing is not obtained until the bidding and procurement stage, which typically occurs after construction documents are submitted.

[1] This report uses plan & specify to refer to a common procurement model notable for consistent, staged design milestones. This can also be referred to as plan/spec, or plan and specify.

- **Design+build[2]:** In design+build, the general contractor/design builder is hired directly by the owner or client and is expected to manage the project from design through construction. The general contractor acts as the project manager, typically selecting the rest of the design team. This model is oriented around containing construction and building costs, and thus installed prices are considered as each building element is designed.
- **Progressive design+build:** Like design+build, except the entire design and construction team is selected by the owner instead of just the general contractor. These teams will submit their qualifications without detailed information on building requirements and then work together. In these projects, construction pricing is integrated into design decision making, similar to design+build.
- **General Contractor Construction Manager (GCCM):** GCCM is a hybrid of design+build and plan & specify in which the owner or client hires both the general contractor and the architect directly and expects them to work together. The owner maintains direct communication with both professionals and expects that the general contractor will also manage the overall construction project. Advocates of this approach note that it has the potential to balance design and cost pressures by ensuring both are represented to the owner.

In each model, design occurs in a logical sequence that reflects the requirements established by the owner or client. However, the established milestone sequence associated with plan & specify can be more fluid in the alternative procurement models, as pricing and input from construction professionals are more likely to alter design decisions early in the design process.

Mechanical design responsibility does not vary by procurement model

Mechanical systems are an important part of the function of new buildings and one of the top five building costs, according to the professionals we interviewed. Mechanical system design for commercial buildings is a customized and specialized process that requires substantial expertise and encourages decisions that reduce risk. In every procurement model, the final decisions on system design rest with mechanical engineers and their mechanical contractor counterparts.

Mechanical system procurement can be bundled into a design and construction package

While it is still common to have a mechanical engineer as part of a design team, it is not required. The overall "trades package," which can include mechanical, electrical, and/or plumbing (MEP) can also be procured by selecting a construction and installation firm to design and install the overall mechanical system. These firms may have a mechanical engineer on staff, or they may subcontract with one to review their design for permitting purposes. This process was described to us as "MEP design+build." Obtaining HVAC system design through this MEP design+build approach can occur in any type of procurement model (not just in design+build projects). In this scenario, the mechanical design is likely to reflect the equipment that can be installed profitably by the MEP contractor which could reduce recommendations for innovative

[2] Design+build is commonly referred to as design build and written with the "+" sign to indicate the two activities are procured together.

or super-efficient equipment. Profitability for MEP firms is driven by construction and installation, not design fees, and avoiding risk in installation costs is important for these firms.

Owner priorities affect the entire design team

Design professionals described their work as customized to reflect the requirements and priorities of their clients, the owners or developers of the property. Projects that involve owner-occupied buildings or institutional owners are more likely to have sustainability or efficiency objectives. They are also more likely to consider the operating costs (both of energy consumption and maintenance) than developers looking to build and then sell. The specific priorities for any given client or owner are more likely to affect the priority of energy efficiency than the procurement model used.

There is uneven familiarity with VHE DOAS equipment

Architects were far less familiar with the term DOAS and with specific HVAC equipment in general than their engineering counterparts. Even architects able to discuss system components reported relying on mechanical engineers to make final decisions on system design. Engineers, however, were consistently familiar with the term DOAS, and able to describe specific equipment options they associated with both decoupled systems and efficient systems. In addition, they mentioned a variety of equipment options that could be part of a VHE DOAS system, including energy recovery ventilators (ERV) or heat recovery ventilators (HRV), variable refrigerant flow (VRF) systems, chilled beams, smaller air handlers, and decoupled ventilation.

Equipment discussions revealed opportunities

Interviews revealed several opportunities for aligning VHE DOAS with existing trends. These opportunities included:

- Leveraging the pressure to meet new building codes, which emerged as a major driver for DOAS systems in Washington, where DOAS is mandated by code for many new buildings.
- Capitalizing on a trend indicating that mechanical system design may be occurring earlier in the design process as systems get more complex and code requirements are harder to design around, which could encourage consideration of mechanical solutions that differ from standard practice.
- Aligning promotion with the business model of energy service companies (ESCOs), who regularly recommend upgrades to lighting and mechanical systems in existing buildings to achieve energy savings.[3]

Recommendations

Several themes emerging from this work point to logical next steps for NEEA's VHE DOAS initiative and high-performance HVAC efforts more broadly.

[3] The ESCO business model depends upon identifying cost effective upgrades in existing facilities that will lead to specific contracted energy savings. They are not traditional mechanical contractors as their scope will include multiple types of systems (lighting, controls, HVAC, etc.)

Mimic vendor strategies for system promotion. Mechanical engineers universally reported learning about new equipment and innovative products from vendors (typically manufacturers and their representatives) who reach out for that purpose. To be successful NEEA needs to engage with mechanical engineers in a similar manner—through lunch and learns, demonstrations, and road shows with "kick the tires" models available. Partnering with distributors and other vendors could help demonstrate the accessibility of equipment and increase familiarity.

Engage proactively with MEP design+build firms, ESCOs and others that are in the trenches of mechanical design for high volume smaller projects. Given the variety of design scenarios and the role of the mechanical engineers in making major system recommendations, NEEA should consider efforts to ensure these professionals responsible for early system design have all of the information they need *before* they are engaged in a specific design process.

Leverage relationships with ASHRAE. ASHRAE, an organization mechanical engineers and MEP contractors rely on for best practice information, has already published a Design Guide for Dedicated Outside Air Systems. Enhancing that guidance with a high efficiency option would provide a credible source of information to system designers and specifiers. Expanding the information available to include cases studies, local chapter presentations, and *High-Performance Buildings* articles will also help inform these professionals and normalize DOAS design.

Identify strategies for offsetting risk. Equipment and installation costs were cited by many as the primary factor stopping DOAS installations from being paired with high efficiency heat recovery. However, risks associated with soft costs, such as concerns about additional design time, performance, and realizing energy savings also emerged. NEEA should consider opportunities to overcome these barriers through subsidized design fees, provision of technical assistance, or calculators to assist in life cycle cost analyses, in addition to the education and awareness activities discussed above.

Help design professionals meet the requirements of their clients. Identifying non energy benefits will help mechanical system designers make the case for high performance systems and ensure that they survive value engineering. Potential benefits include smaller duct work, higher ceilings/larger windows, reduced noise, improved zonal control, improved air quality, and a smaller footprint for mechanical rooms.

Continue efforts to expand the target market and equipment set. Additional high-performance HVAC system options would likely enable NEEA to engage with a larger section of the market by having a more diverse qualifying product selection, providing more options for larger buildings or including solutions for scenarios for which the current VHE DOAS product definition is impractical.

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Introduction

The Northwest Energy Efficiency Alliance (NEEA) contracted with Cadeo Group to conduct a qualitative research study to obtain insights into how Heating, Ventilation and Air Conditioning (HVAC) projects are developed, from initial conception through equipment selection and specification by architects, engineers and those working in design+build firms. These professionals are all involved in the overall project design process that leads to eventual selection and installation of specific HVAC equipment in both new construction and major renovation projects.

This study sought to expand NEEA's understanding and insights related to two main research objectives:

1. Obtain a better understanding of the process through which HVAC projects generally and DOAS specifically are carried out—from initial conception to installation.
2. Learn more about how architects and engineers think about DOAS systems.

The content following this introductory section provides discussion of the qualitative data collected to explore these primary research objectives.

Data Sources

The project is informed by several research activities including a focused literature review and in-depth interviews with 16 design professionals throughout the Northwest. Interviews occurred between December 14, 2019 and February 3, 2020.

Literature Review

To inform the project overall and the interviews specifically, we conducted a literature review focused on investigating several topics most pertinent to the research questions the NEEA commercial HVAC teams had identified prior to project initiation.

We reviewed 10 documents (a list of which is provided in Appendix B: Documents Reviewed). The findings from this step are integrated as appropriate in the report content below.

Interviews

Recruitment efforts sought to complete interviews with a mix of architects and mechanical engineers. In early December 2020, we purchased a contact list from InfoUSA based on two primary NAICS Codes:

- 5413001 Architectural Services
- 54133077 Engineering Services

Guided by this list we ultimately completed 16 interviews with design professionals throughout the region (For more information on the population frame and contact disposition, see Appendix A). These contacts included seven architects, eight engineers, and one builder who worked exclusively on design+build projects. Interviews included professionals from

Washington, Oregon and Idaho. Interviews lasted 30-45 minutes and included questions designed to explore the research objectives listed above.

Sample characteristics

- Our sample included designers who work in a variety of procurement models. Eight of those interviewed reported that 50% or more of their work is in design+build projects.
- We sought to understand the volume of work respondents had experienced annually over the past two years in smaller commercial buildings (defined as 50,000 square feet or smaller). Many contacts reported that this was a rare building size for them. Only six reported working on more than 10 projects of this size per year.
- Interviewees reported a mix of experience in new construction and major renovations. All reported working on major renovations (which could include tenant improvements), however the volume of this work varied substantially with only three indicating that 50% or more of their work focused on major renovations, and 13 reporting 50% or more of their projects are in new construction.
- Respondents reported working on a variety of building and project types, from owner occupied production facilities to developer-driven multifamily buildings. When probed about their experience with smaller commercial buildings or spaces, contacts mentioned small office buildings, fire stations, retail spaces, health care clinics, schools, ancillary buildings on larger campuses, and tenant improvements within larger buildings.

The HVAC Design Process: Concept to Procurement

This project sought to understand how HVAC system design decisions are made within the overall design process. To understand this, the team sought to understand the overall design process, the dynamics that affect decision-making, and influences on decision-making. The research questions included:

1. To what degree do architects and engineers influence HVAC projects?
2. What unique influences over HVAC project decision-making do architects and engineers have?
3. How does the degree of influence change during specific design phases?
4. What are the drivers for selection of HVAC systems?
5. Where do design professionals get information needed to guide mechanical system design or selection?
6. What sources do architects and engineers trust for information about HVAC system design?

Influence: Key Market Actors

This project explored both the primary responsibilities associated with the design project generally and HVAC specifically, as well as sources of information on HVAC system innovations or best practice. This section provides a discussion of both topics.

The literature review found that the commercial HVAC decision chain is varied and multi-faceted. Projects have unique objectives and constraints that need to be navigated by those hired to recommend, specify, and install HVAC equipment. Multiple entities--contractors, distributors, manufacturer representatives, architects, and mechanical engineers--all have the potential to influence the owner's decision. Interviews confirmed this, with respondents describing the need to work with a variety of professionals to navigate the complex process of building or space design.

The professionals involved in designing new buildings or updating mechanical systems in existing buildings each have a specific role they are expected to play. The extent to which they do this effectively, meeting the needs of both the overall client (the owner) and their direct client (who may be a different type of design professional) builds their reputation and earns them additional work. Below we provide a description of the key market actors involved in the new construction, major renovation, and tenant improvement projects likely to require new HVAC system design.

Architects

Role

Architects' primary role is to design the boundaries, layout, and aesthetic of the building. They will consider orientation, finishes, function of the building, and what type of statement the owner or developer is trying to make. In plan & specify projects, they provide overall project management of the design process, but will often be less involved in the construction step, as that is often handed off to a general contractor.

Influence on HVAC Design

While they may provide input on the mechanical system in design team discussions, they are not responsible for the final details of the system design. After designing the space, architects work closely with clients and sub-consultants to provide support as needed. These sub-consultants can include mechanical engineers and other experts as needed (for example: glazing, structural engineering, civil engineering, plumbing). In plan & specify projects they tend to be the overall design project manager and seek to facilitate communication between the various experts and their client, the project owner.

The literature review indicated that architects could influence HVAC design by making the case for long-term benefits of energy efficiency. While they do not tend to influence specific HVAC system selection, they can influence their clients by setting sustainability or efficiency goals that may influence HVAC design and selection later in the process.

In interviews, architects described following the lead of their clients—if a client is interested in sustainability, net zero construction, or energy efficiency those items are part of the program of requirements. For many of their clients, particularly developers, these considerations are subordinate to other building features. Architects identified a few areas where they will influence the mechanical system overall, often in indirect ways:

- **Influencing the overall program for the building or a basis of design document** that would include performance goals, target energy intensity, and minimum performance criteria communicated to the mechanical contractor or mechanical engineer
- **Selecting the mechanical designer** and thus ensuring that firm has the capacity to deliver a system consistent with the owner's priorities. As one architect noted: *"Mostly I'd influence through communicating the project objectives or higher-level goals. I'm expecting the mechanical engineer can help achieve that. It matters to have good mechanical engineers – someone that doesn't know or isn't keeping up on things, it's hard for them to engage."*
- **Allocating space for mechanical** rooms, ducting, and other building services.
- **Coordinating the overall work** of the design team and ensuring the building components will work together (for example, the mechanicals will not negatively affect an aesthetic consideration, or that special use cases such as laboratories or education are addressed). As one architect noted, anything that is visible will be influenced by the architect: "We will touch base on what the pieces will look like, we will provide thumbnail

pictures. VRF has a certain appearance. Can it be incorporated into the architecture? Does it matter? How does that look relative to other options, like a chilled beam?"

> ***"We know enough to be dangerous. We will stand back and let the engineer determine the system. Usually it's a team effort. [You need] rapport among the team. Biggest control we have is that we've often selected the engineer, we do that considering what the client wants." –Architect***

Mechanical Design Professionals

Mechanical design professionals include several types of people, all of whom are involved in the detailed aspects of designing, specifying, or constructing these systems.

Roles

Mechanical Engineer. Mechanical engineers provide expert design and review services to their projects. They can work for a large mechanical, electrical, and plumbing (MEP) firm, or they can be directly contracted by an architect or general contractor to provide recommendations on HVAC system designs that will meet the overall program for the building. These professionals have authority to "stamp" documents for submittal to permitting authorities and are expected to ensure that systems meet the needs of the building's occupants and the requirements of local code. They are considered the experts in HVAC system design and their recommendations will drive the solutions that are considered.

Mechanical Design Builder. Typically housed in MEP firms, MEP design builders are mechanical construction firms that will design and install mechanical, electrical, and/or plumbing equipment. These tend to be large firms that work on numerous projects and are able to estimate the procurement and installation costs for HVAC equipment based on their own experience. They may or may not have a mechanical consulting engineer on staff. If not, they will hire them as a subcontractor. MEP construction firms can also be procured at the end of the design process for installation services only. In this case they would simply be providing mechanical, electrical and/or plumbing system installation, and not design services.

Influence on HVAC Design

Mechanical engineers, consulting engineers and mechanical, electrical and plumbing (MEP) contractors are the professionals responsible for the final design of the system. They ensure minimum performance requirements are met and sign off on the system design for permitting purposes. Other members of the design team look to these professionals for in-depth knowledge about system performance (including noise, efficiency, and requirements for maintenance and controls). The most important requirement is that the system meets the state or local code requirements for ventilation and heating and cooling efficiency.

Mechanical engineers described how they influence the mechanical system overall:

- **Providing a design that meets the objectives of the client and effectively serves the building.** Mechanical engineers will consider the implications of integrating specific types of equipment, providing information to their clients about the viable options given building design constraints and system requirements from the owner or the energy code.
    - *"We are usually doing the entire design; once we've decided on what the system is going to be, we turn to load calculations and equipment sizing and then starting to get the duct work in as well."*
    - *"The consultant is sort of the 'bag holder' that will accept responsibility if things go awry. Everyone wants you to step up and make the final recommendation on things."*
    - *"We have a procedure we go through. We try to look at 5 or 6 different metrics that might be important to the owner: maintenance costs, efficiency of the equipment, installed costs, noise, first cost, things like that—we evaluate the systems on these metrics. We might recommend 2 or 3 system types. We try to evaluate the system on those criteria that we think the owner will care the most about. Owners have different priorities."*
- **Providing their expertise to the design team.** In plan & specify projects, they usually provide system recommendations early in the design process, most commonly during schematic design or design development**.**
- **Ancillary or additional services.** After designing the mechanical system, they may also remain involved to oversee equipment procurement, installation, and commissioning, if the owner desires. Since this construction administration service is an added cost, many mechanical engineers do not remain involved as the project continues, except for verifying the installation is consistent with the design at the end of the construction. This could be different if the system changes or if problems arise.

Owner/Developer

Role

The owner or developer is the client for which the design team or design builder works. These clients vary substantially in their motivations and priorities. On one extreme is a developer who might design a "core and shell" building and not bother with mechanical systems until a tenant is identified. In this scenario, the mechanicals reflect the tenant improvements required for the tenant space and will be installed as part of an occupancy permit. On another extreme is an owner who intends to occupy the building and views the building as an extension of their brand. In this scenario, the client may prioritize elements that pay off over a long time period or those that communicate the brand's commitment to sustainability.

The professionals involved all ultimately work for this client. They will seek to provide a design that meets their client's needs and protect their professional reputation by delivering for the rest of the design team.

Influence on HVAC Design

Owners or developers are the ultimate decision makers. They usually receive system recommendations based on requirements they have established early in the design process, which could include heating fuel and efficiency preferences, or comfort criteria, or air quality expectations. If there are multiple solutions, clients are provided with a limited set of system choices. Respondents indicated that owners will typically follow the recommendations of the professionals they've hired—provided their concerns about cost, performance, and reliability are addressed. In design+build, where these decisions are expected to be made more quickly and also reflect constraints associated with construction costs, an owner may keep mechanical system options open while the rest of the building is priced. In this scenario an owner might choose a "base system" which, depending on other decisions and available budget, can be upgraded to their "alternate system."

Other Influencers

Our interviews focused on architects and mechanical engineers, however, these respondents also mentioned other professionals that can affect the design process and the HVAC solutions recommended. These professionals include:

General Contractors. General contractors are responsible for overall construction management. In plan & specify projects, they are typically not brought in until the end of the process, at bidding and procurement. In other procurement models they are involved earlier, providing real time estimates that make tradeoffs more transparent for their clients. Some of the largest construction companies in the region will engage as design builders and will bid on plan & specify projects. Design builders are always general contractors, but not all general contractors are design builders.

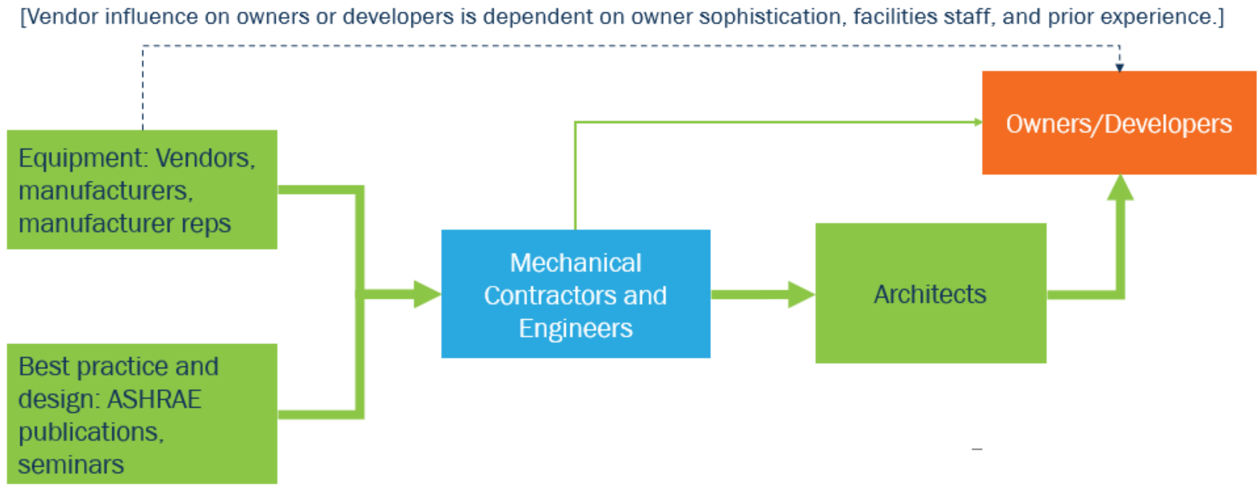
Vendors. Vendors include manufacturers, manufacturer representatives, and distributors who promote and sell specific types of equipment (brands) and solutions. Mechanical consulting engineers universally reported learning about new equipment, solutions, and options from vendors who will reach out directly to them.

ESCO. Energy Service Companies provide consulting services to their clients for the purposes of identifying cost-effective energy savings opportunities in existing facilities. They typically have efficiency engineers on staff who will audit a facility and provide recommendations for upgrades to lighting, controls, and HVAC that are designed to save energy and money. These projects are typically completed by the ESCO, who is then paid through a performance contract based on energy cost savings realized.

Sources of information

To understand how design professionals become aware of innovations or best practices in HVAC design (an important component of influence), we asked contacts where they turn for information about new equipment or system design, and what specific sources inform their understanding of HVAC system design. Figure 1 provides an overall map of how information flows from vendors and industry sources to mechanical engineers and contractors, to architects and, ultimately, to the clients that must sign off on these decisions.

Figure 1: Typical HVAC Design Information Flow



Engineers universally described learning about new equipment or system designs from the vendors, manufacturers, and manufacturers' representatives who reach out to them to share information on product innovations. They also look to their colleagues with new or different experience when they are looking for information. Several engineers with decades of experience reported they "just know," while acknowledging that engineers tend to fall back on familiar or reliable equipment solutions, particularly in situations with compressed timeframes or limited design fees.

- *"Our vendors will let us know when they have new equipment coming up, they'll do a lunch and learn. It's in their interest to keep us up to date on their latest products and it works to our advantage too because of course we want to know what is out there"*

When asked about sources of information about innovations, best practice, or new equipment designs, engineers universally mentioned the journals, design manuals, and seminars available through the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE).

- *"They are the institution for design standards for HVAC. Nobody comes close to ASHRAE in that regard. We have all their standards, their manuals and so forth."*
- *"We are members of ASHRAE – it's a good source for information. We do get some magazines, and we might see something, but obviously we like to talk to people to get most of the information, including contractors that we trust."*

Nearly all architects reported relying on mechanical engineers to select an HVAC system consistent with the overall design requirements. If they do need additional information (for example to address a client concern about maintenance or installation costs) they may turn to mechanical contractors. Several architects emphasized the importance of building trusting relationships with HVAC subcontractors or other professionals in the field to obtain necessary information.

Architects were mixed on their reported commitment to building their understanding and practice of HVAC system design. While several reiterated their reliance on mechanical engineers, others reported seeking to build their general understanding through conversations with equipment suppliers, continuing education or seminars on sustainability, knowledge sharing within their firms, and from project experience.

- *"Architects are generalists. We have to know a little bit about a lot of things on a building (sprinklers, lighting, interiors). We can't specialize in this. We lean on the engineers, and we'll expand to other trusted professionals if they don't know the answers."*
- *"We know enough to think we know what we are looking at, but not enough to have the answers. Architects have to have hands in everything."*
- *"We are totally dependent on our mechanical engineers."*

Motivations

Our interview guide did not include any specific questions focused on the motivations of the key decision-makers involved in these projects. However, contacts spontaneously mentioned their own motivations and those of their colleagues and clients.

Owner/Developer Motivations

The literature review found that public image can be a driver of energy efficiency if an owner prioritizes sustainability and believes it is important to customers or to eventual tenants that a building contain sustainability features. Achieving building labels (LEED or Energy Star, for example) can elevate energy efficiency as a consideration in system design. Building codes are the primary driver, however, and if they are perceived as stringent or encouraging very efficient equipment systems designers are likely to be satisfied with code-compliant systems.

Interviewed contacts offered substantial discussion of what motivates their clients. Because the owner's priorities and budget limitations determine the scope and priorities of any given project, respondents framed their decision-making within the larger objectives of any given project. Consistent with findings from the literature review, contacts discussed the highly variable nature of owner priorities. The primary factors include:

- **Length of anticipated ownership:** Owners planning to occupy the building will be more attuned to the operational and maintenance costs associated with a given system. Developers planning to retain ownership approach the first cost/operating cost tradeoffs differently from developers planning to immediately sell the building.
- **Importance of the building:** Some owners see the building as a reflection of their brand. In these scenarios an owner could prioritize building a visual icon or sustainability, or both. For other owners the building is part of a larger income portfolio in which operating income is the primary objective.
- **Sustainability goals:** Owners who independently prioritize sustainability (net zero, zero carbon, achieving a building label) or who are required to meet statutory or policy objectives (common among institutional buildings) will weight a system's overall contribution to these goals higher. Interestingly, several architects who reported working

with clients like this discussed an overall objective of reducing mechanical systems completely by integrating natural ventilation and night flushing, and by getting agreement to allow wider temperature fluctuations.

- **Energy codes:** Designers working in Washington and California reported code requirements leading to DOAS specification. At the same time, many contacts reported that most of their clients are concerned with meeting energy code, not exceeding it.
- **Prior experience:** Owners with large portfolios or multiple previous projects can have opinions on equipment (manufacturer or specific component) that remove options.

Engineer motivations

Engineers focus on designing a durable, functional mechanical system that meets the building requirements and client expectations. Quick turnaround projects, tight timelines and budgets, and fear of damaging their reputations pressure mechanical contractors and their engineering counterparts to choose systems they are familiar with and that are considered the "standard practice" for a given type of building. However, if an owner or a design team communicates other priorities -for example, sustainability, net zero, or fresh air goals- they will respond with appropriate system recommendations.

The literature review identified performance uncertainty as a substantial barrier to designing and specifying unfamiliar HVAC system components. The professionals involved are mindful of their reputations and do not want to be liable for poor performing systems or absorb the cost of potential call backs if a system does not meet expectations. Interviews confirmed the tendency to prioritize mid-priced, easily installed, highly reliable products from vendors they know and trust. Existing relationships between contractors, distributors, manufacturer representatives and specifiers affect what gets recommended and selected.

- *"Engineers tend to be risk averse. If they haven't done those systems before they may be nervous about having to learn a whole new thing, nervous about making an error."*
- *"Mechanical engineers want to design a really good mechanical system so they avoid complaints about performance (everyone is too hot, everyone is too cold, how come the system is broken down after a year or two)."*

Architect motivations

Architects see themselves as generalists and overall project managers but focus mostly on the aesthetics, building exposure, and space divisions of the building. They are responsible for designing attractive spaces and ensuring the space meets the owner's and occupants' needs for look and functionality. This means they weigh the requirements of the mechanical system with that of plumbing, fire safety, accessibility, and other demands on the space. When considering the HVAC system, one architect mentioned they first consider cost, and then energy performance and flexibility in functionality.

- *"For us, the main considerations are access—no big pieces of equipment at the end of long narrow hallways. Can maintenance staff or contractors get to it?"*
- *"Most architects want to put more money into the aesthetics of the building. It's inherent in their profession to design great looking stuff. And frankly, that's how they get more projects, someone says 'Hey, I like the way that looks, I want you to design my building!'*

Relationships

One emergent theme from the interviews centered on the importance of trusted professional relationships among the design team members. Engineers talked about the importance of vendors establishing good working relationships with engineers, specifiers, and MEP contractors. These professionals prefer to work with vendors that provide support during the design process and on-going maintenance support, stating "a great product with terrible vendor relationships won't do well in the market."

Good communication is essential in all stages of the design process. Although specifying the equipment is mostly the engineers' responsibility, everyone involved needs to be aware of any decisions or changes in the design process in order to avoid problems in the future, especially with interior clearance or duct appearance. Once the general system approach is decided, the design team needs to remain coordinated on how the system will be developed. This is a common approach in both new construction and renovations. Forming a team and approaching initial discussions about the mechanical equipment with the owner and end user as a team allows them to make sure the client is getting what they expect and avoid making mistakes in the future.

One architect described the relationships formed with trusted professionals as analogous to dating, marriage, and divorce, and stated "some relationships don't work out, others become long term partners." Multiple architects mentioned most of their partnerships were relationship-based but also depended on the clients' needs. In many cases, architects are familiar with the team the contractor will hire and with the options and recommendations they are likely to provide. Several architects described working in design+build projects only if it involved working with a contractor with whom they already had a good working relationship.

A trusted specifier

All systems are specified. Specifying equipment is a defined step that involves identifying the equipment or parameters for equipment that provide clear direction to distributors, contractors, or manufacturers providing bids. **Specifier is more of a role than a defined profession**—they may work for mechanical engineering, design+build firms, or full-service design firms that offer myriad services to clients. Smaller projects, or those involving system replacement (as opposed to re-design) are likely to obtain specification-type services from distributors, contractors, or a manufacturer representative. Specifiers are likely to have unique relationships with vendors (including manufacturers and distributors). Trust and relationships built over time can lead to "rules of thumb" that limit the consideration set for any given project.

- *"The mechanical engineers we work with we work with regularly, so we know what some of their preferences are, we try to make sure that occurs. We try to make sure that the system works with the owner preferences as well as mechanically and what works with the* *architectural components of the projects. The level of engagement will depend on the sophistication of the owner and the operational staff they have."*

- *"Unfortunately, there are situations where, because the owner doesn't want to spend the money to hire an engineer, and we don't have a contractor involved early enough that the mechanical design gets put off until permitting is done. The lack of coordination can cause problems because unforeseen things come up."*

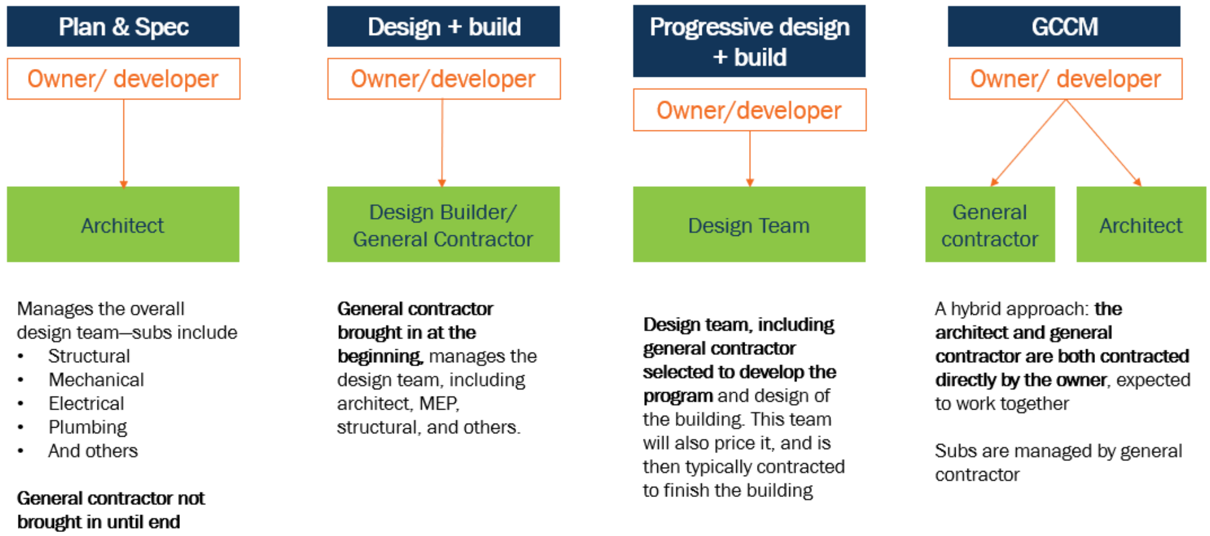
Design builders first select an architect and then select an engineering consulting firm teamed up with a construction firm. Once the team has been selected, the team discusses the type of mechanical system for the building together with the owner. The benefit of design+build is that during the design phase, the owner and architect get to work not only with design consultants but also with the team that will do the installation.

Procurement Models

NEEA sought to understand the extent to which architect and engineer influence might vary within different procurement models, specifically plan & specify and design+build. In designing our interview guide, we had expected a more discernable split in the type of projects respondents reported working on, assuming that these professionals tended to work in either plan & specify or design+build projects. We found that this dichotomy was overly simplistic—in reality nearly everyone we spoke with had experience in multiple types of procurement models, including hybrid approaches that do not fit neatly into either the traditional plan & specify approach or the classic design+build.

We asked interviewees about the nature of their work over the past 2-3 years. Among our 16 interviewees, 14 reported experience with design build, nine with experience in hybrid approaches such as General Contractor Construction Manager (GCCM, also known as Construction Manager General Contractor (or CMGC) in Oregon), and eleven had recent experience in plan & specify projects.

Figure 2: Map of Primary Procurement Models



The important differences in these models center on who works for whom, when the general contractor is hired, and the role of the general contractor. The green boxes reflect overall project management responsibility and relationship management with the owner or developer.

Note that in traditional plan & specify approaches, the general contractor (like most of the construction and equipment subcontractors) would not be selected until the end of the process, during a formal bidding and procurement step. In the other models, by contrast, the general contractor (and key subcontractors) would be providing construction estimates based on design decisions in near real-time. This process makes budget tradeoffs more obvious earlier in the process. For this reason, general contractors can be extremely important in that they are managing the overall design and construction costs simultaneously. While the general contractors are unlikely to control the design of mechanical systems they will exert budget pressure on mechanical systems (and other elements of the building) and are more likely to go straight to an MEP construction firm for system design than procure the services of a mechanical engineer. Their job is to deliver a building on time and budget, which may not be consistent with ensuring the best possible mechanical designs occur.

Procurement Model Terminology

Plan & Specify	The classic approach to designing new buildings, and the source of the traditional design milestones (programming, schematics, design development etc.). In this model, the architect serves as the overall project manager and has the direct relationship with the client. The architect will work with the client to develop a "program" for the building and will often manage all of the design subs, including the mechanical engineer, until a general contractor or other construction subcontractors are hired

Design+Build	In classic design+build, the general contractor/design builder (these terms are used interchangeably) is hired directly by the client and expected to manage the project from design through construction. Key members of the design team are hired by the design builder, including the architect, structural engineer, mechanical engineer (or MEP construction firm), and other specialties. Some large design+build firms will have architects or structural engineers on staff, but mechanical design and construction is typically subcontracted. Pricing is part of the design process, which tends to reveal priorities and tradeoffs early in the process. Value engineering is integrated throughout the process in an effort to stick to the budget while meeting the client's needs. There is no formal procurement process, as the people who will be doing the work are involved from the beginning. An independent reviewer may be obtained to ensure the overall design and pricing proposal makes sense. In design+build, the classic design milestones are less prominent as the overall process is less "staged."
Progressive Design+Build	Progressive design+build has many of the elements of design+build, with the slight difference that the entire design team (instead of just the design builder) is selected by the owner. This provides a bit more confidence that design options are not limited to the ones the design builder is most confident in. Like design+build, in this model the design team is also expected to be contracted to finish the building.
GCCM	General Contractor Construction Manager (known as CMGC in Oregon) is a hybrid approach in which the client hires both the general contractor and the architect directly and expects them to work together to design and price a building that meets their needs. Like design+build, the general contractor is involved from the beginning, and like plan & specify the architect also has a direct connection to the owner. Subcontractors, including MEP contractors, work for the general contractor, but the architect will have visibility into mechanical system schematics. The architect may still staff consulting engineers, but they will work closely with the general contractor's team to ensure that project timelines and budget are met. The general contractor would typically also serve as the construction manager in this model

Effect of Procurement on Design Approach

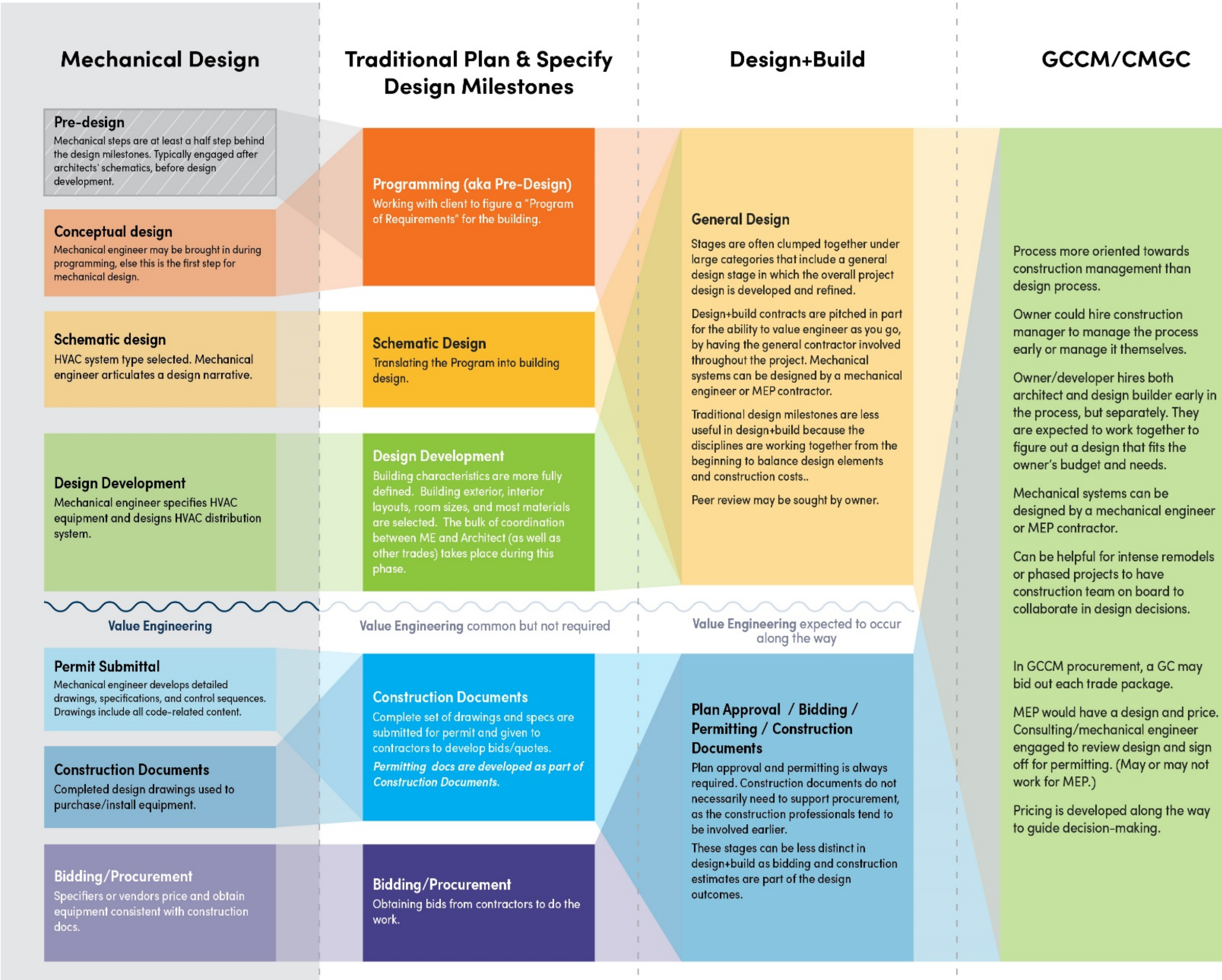
The procurement models discussed above can affect the sequence of design tasks, with plan & specify projects being much more staged and sequentially designed than the other models, which tend to be oriented more towards completing projects quickly and within a set budget. According to one architect with substantial design+build experience the traditional design milestones listed in Figure 3 are less applicable:

- *"The process is less "staged." A lot of decisions are sort of being worked out simultaneously. A lot of times on design+build projects, the traditional design milestones are not that meaningful. Some of the steps are helpful for the design team and professionals to keep the architects and engineers operating at a similar level of development. But the design build projects I do these days, those milestone documents are just not all that meaningful. They might give the owner a chance to see how designs are evolving, help with coordination, and it can help with estimation (ensuring that it's on budget) but that formality is going away."*

Figure 3 presents the results of the interviews and information from the literature review to clarify how each procurement model compares to the classic stages of mechanical system design. It is important to note that these descriptions represent a "typical" project, and that any specific project could deviate from the steps outlined below.

While plan & specify is commonly understood by design professionals and used to procure many new buildings, design+build has grown in popularity over the past 20 years and become a standard approach. Design+build is deployed for projects of all sizes. In small projects, design+build enables rapid design/pricing and construction. In large projects it is typically used to control costs and speed up the process. Public entities can be directed to use design+build for this reason.

Figure 3: Mechanical Design and Procurement Models: Mapping the Differences in Design Stages



Timing and HVAC Design Sequence

We sought to understand how the HVAC system decision-making progressed throughout the design process. To guide this conversation, we referred to the traditional design milestones outlined in Figure 3. These milestones are well understood by the professionals involved, even if they are not as important in design+build or other hybrid approaches in which the design and pricing tasks are linked.

Mechanical engineers reported they would typically be brought in after the architect's schematic design stage. At this point the building should be far enough down the design path to enable the mechanical engineer to develop their own schematic design. In traditional plan & specify projects, engineers are often included in a project at schematic design and work together with the owner and architect to evaluate system options for each building. According to both architects and engineers, the overall system design would typically be set by design development. It is important to note that this overall system design would not necessarily include a full equipment schedule, as the overall system performance requirements and building requirements would establish a floor over which myriad combinations of components could qualify. Minor changes are possible during value engineering, at permitting, and even in procurement as reviewers and bidders provide recommendations to improve performance or reduce cost as the design moves forward.

The stages discussed above are most obvious in plan & specify projects. While the basic steps hold true in other procurement models, the precise sequencing is less formal as many tradeoff decisions are made simultaneously. In these scenarios, the design stages are typically occurring without a formal stage gate. Regardless of the procurement model, HVAC design decisions are still the domain of the mechanical engineer or MEP contractor engaged to support the project.

The main implication for NEEA in the alternative procurement models is that there are fewer steps in which to exert influence and thus influence would need to have occurred before the design process starts.

Early considerations in HVAC

We asked contacts about the stages involved in HVAC design and specification to understand how early in the process HVAC considerations are likely to be discussed. Contacts most commonly used the design milestones associated with classic plan & specify projects, even if they often worked in other procurement models. While these design stages are an effective way to communicate progression, design+build and GCCM can upend the stage-gate process a bit, as discussed later in this section.

Architects universally described considering HVAC early in the process, typically during their schematic design phase. In buildings where the mechanicals are very important or specialized (hospitals, laboratories), discussions about HVAC could occur during programming. As the design process shifts from programming to schematics, architects will begin to discuss the need to reserve space for the mechanical systems and consider implications of different systems, both functionally and aesthetically. They also noted that the phase at which these decisions are made can vary: *"it's so project specific,"* said one architect, *"some projects, where the HVAC system is fully integrated into the design, it's part of the program. It's always the intent to think about it."*

Engineers had a somewhat different take on this process, reporting that their work occurred a full step to half step behind the architect's milestones and musing about the value of being included earlier. Engineers reported being invited into the process when the architects are done with their schematic design, typically after the building boundaries and basic layout have been determined. Everyone agreed that it was unlikely a project would advance past design development without an HVAC system design, even if the detailed equipment schedule emerged at later stages. As one engineer noted, *"Sometimes we are involved at conceptual, but certainly by schematic design you need to get involved. Later than that is too late. Conceptual is the best time."*

We heard mixed reports from those with design+build and GCCM experience. On the one hand, design+build is expected to speed up the overall process and favors convening the entire design team early on to enable more rapid decision making and alignment among disciplines. On the other hand, many mechanical design+build projects are expected to be simple and are not procured until late in the process—sometimes not until a building is at the permitting stage. One contact noted that in design+build, once the architect and MEP are hired, there is typically a discussion with the owner about the type of mechanical system that will go into the building. According to him, *"Those discussions are early on in design+build projects, and there is often a back and forth tension when tradeoffs get discussed."*

Mechanical upgrades to existing buildings (similar to what would occur in major renovations, tenant improvements, or ESCO-driven upgrades) are even less predictable as they range from like-for-like change outs in an otherwise cosmetic upgrade to a major overhaul to improve function, efficiency, or look.

The special case of public buildings

Many contacts noted the difference between public and private owners. The distinction included the effect of expected long-term ownership and the extent to which procurement rules can affect the choices for public owners. Where private owners can choose whatever procurement model works best for them, public owners are often required to follow statutory direction, which can vary by state and entity. While the default method for procuring design services is to hire an architect, obtain a complete design, and then bid the design out there are also rules that enable "alternative procurement." In Washington, a public entity can choose alternative procurement that includes GCCM or design+build. The procurement laws can include stipulations on size and type of project. According to one contact, design+build is increasing as jobs that would have previously used GCCM shift to design+build, including the major universities in Washington who exclusively choose design+build for any project over $2M.

Regardless of the procurement model, mechanical engineers note that their recommendations can be limited by supply, owner requirements, and code:

- *"Usually that's decided early on. For larger equipment there aren't that many choices, large manufacturers will meet the code minimum requirements. There usually might be one high efficiency option but that's usually cost driven, most people will be content meeting the code minimum requirements."*
- *"Approach can be different if an owner brings a system requirement, code level requirement, vs. scenario where we provide the options"*
- *"With more heat pump technologies being kind of mandated, especially in the City of Seattle. That requires more interface with the atmosphere, so we have to be on board pretty early to track that."*

MEP Design+Build

It is also important to note that mechanical, electrical and plumbing work (MEP) can be procured separately using a design+build-type contract in any type of project. This means that the MEP design builder (a full service firm that will develop the system design, price it and install it) is hired directly by the general contractor, owner, or architect (depending on the procurement model) to develop an HVAC system. Procuring mechanical design in this manner means that the cost of the system is integrated into the design from the start, and obtaining the sign off of a mechanical engineer (required for permitting) is the responsibility of the MEP contractor or design builder, who may or may not have an engineer on staff. In this scenario, the MEP is typically selected based on qualifications, experience, and references associated with installed projects.

One architect explained how this works: *"Mechanical (MEP) are often pulled out for design+build approach within a larger project. For MEP specifically there are a lot of ways to go about that. It depends on the capabilities available. It's more common in California, where there are large complicated mechanical design+build projects. In those cases, you may go into a project with those people, bring them on right at the beginning. In Oregon, design+build is kind of new, even in the MEP model. There aren't as many firms that have that kind of capacity…. When we decide to do that there are a couple of options, depending on complexity. If it's really simple, we'll select the MEP based on qualifications or experience. Not*

Takeaway: Procurement

There are a variety of procurement models and few "bright lines" between them. The owner/developer is the client for which all of the professionals involved work. The overall requirements for effective design do not meaningfully change within any procurement model. The main difference is who manages the relationship with the client, when the general contractor is brought in, and when things are priced. Regardless of the procurement model used for the overall project, mechanical engineers and mechanical contractors (MEP) are major factors in the HVAC systems that get designed, specified, and installed. MEP services can include system design and be procured through the contractor's side of the design process. This can occur when mechanical design is subcontracted within a plan/spec project, or in hybrid design models more driven by the general contractor. In some scenarios the MEP design portion of the project could be deferred until the end of the project and design decisions made while a building is in permitting or already under construction.

many firms have in-house engineering though, so they'll team up with a consulting mechanical engineer and take responsibility for the consultant. The owner, architect and general contractor only deal with the MEP subcontractor, not the sub-consultant engineer. We do that a lot on simple projects."

This dynamic is important to understand as it indicates that the system design will be heavily influenced by the installation experience of the MEP firm, as opposed to the design options that a consulting mechanical engineer might suggest. The profitability of the MEP construction firms depends on their ability to procure and install projects on time and budget, not on the innovation of their HVAC designs. Because the consulting mechanical engineer has little direct contact with the general contractor or owner in this scenario, the efficient solution would need to be championed by the MEP contractor directly. Understanding the overall volume and nature of projects procured this way could be important for NEEA to understand as the initiative moves forward.

What about Value Engineering?

Value engineering is often required in public procurement and is the step during which tradeoffs are discussed. It's not a design stage, and often will involve an independent review to identify cost savings. If the project overall is on budget it may be skipped entirely, but projects are often designed over budget. Value engineering is when discussions would occur about how to maintain the overall building program and stay within budget. It's possible that equipment could be substituted for less expensive options or any number of modifications made that result in reducing the efficiency of a given HVAC system to save money. HVAC is one of the top five building construction costs, so it's unsurprising that it's frequently a focus of VE, as are interior and exterior finishes.

Reasons for System Change

All contacts noted that system details can change after they are "set" in design development. Typically, these changes would be minor—changes in tonnage, in duct routing, or in one aspect of a system—rather than a complete change in system type. Architects noted that radical change after design development would be difficult to incorporate if the system is fully integrated into the building design. However, as one architect said: *"I'm seeing changes occur – when there is an alternative system that is pretty close to the original system. Maybe we've gone from chilled beams to VAV boxes, and it's not a substantial upsize to ductwork and we already have hydronic piping overhead and we already have the fundamental pieces in place and it's not a major change. There are components you can switch over that don't have a big 'trickle through' to the rest of the building."*

In addition, an owner may decide to add square footage, a permit review may require an update, or a tenant signed on to the unbuilt space could each bring requirements that trigger a change to plans.

Engineers report that while the system is "pinned down" at design development, periodically things come up that changes the design at later stages. Finding an opportunity for additional efficiency or heat recovery, or an opportunity to simplify the system were all mentioned by the ESCO-affiliated engineers who work primarily on energy efficiency projects. Engineers agreed that it is very rare to change the full system design. *"It does happen,"* said one, *"it's never happened to me. This seems to happen more in the design+build realm."*

System changes in design+build

Design+build projects are managed by the design builder, a general contractor who also selects an architect and MEP design-builder or mechanical engineer. Because the projects are designed to move quickly and price options in real time, the pressure to make decisions is enormous. There are several mechanisms for procuring a building this way, each with slightly different implications. In one scenario the MEP design builder or mechanical engineer will be engaged early with the design team to discuss options for the building mechanical systems and work directly with the architect and general contractor to navigate the tradeoffs associated with building finishes, size, and mechanicals. In another scenario, the design+build team is focused on building a "core and shell" building without resolving HVAC system specifics. In this scenario, a mechanical engineer or MEP contractor might be brought in very late in the process, perhaps not until the building is ready to apply for an occupancy permit, which tends to limit the options available to the mechanical designer.

Constraints

Contacts also discussed constraints in the design process or building specifics that would affect their recommendations or the level of influence they have. From a mechanical system perspective, the mechanical engineer or MEP contractor needs building information and a basic layout in order to home in on the best system for the project. Engineers mentioned several constraints they typically confront:

- **The project budget.** The most commonly mentioned constraint had to do with the system cost and the owner's willingness to pay for high performing energy efficient systems. While the overall budget and priority will vary by owner and project, budget constraints can limit options—both in the systems considered and the time allocated for design. When design fees are limited, engineers and MEP design builders are likely to fall back on a familiar system or standard approach.
- **Physical site constraints.** The second most common constraint centered on the physical site: how big is the building, is natural gas available, how much space is available for duct work or mechanicals, are there building aesthetic concerns that limit access to the roof? This element also includes considerations about heating and cooling zones within the building and expectations for zonal controls and comfort.

  > *"Decisions have to be made about where we're going to go with unitary packaged equipment or split systems, which is determined by whether there's a place for large package equipment either on the roof or on the ground next to the building. Otherwise we'll be forced to use split systems where we have to have indoor units located inside or in outdoor units."*

- **Time and information**. The need to collect information about different options and systems and to address concerns about reliability can discourage both architects and engineers to push for a specific system or manufacturer. One engineer reported his firm avoids specifying systems that the local contractors are unfamiliar with because of the risk that they will not install it properly: "the contractor needs to know what they are doing," he said, "we were burned by VRF early on."

- **Existing equipment.** In tenant improvement or renovation projects engineers will try to leverage the existing equipment if possible and may face constraints associated with the electrical panel/electrical service that limit adding electrical load.
- **Priority of efficiency.** While the overall efficiency of a system will be a consideration, it typically falls lower on the priority list than overall cost. Institutional owners may operate with mandates that direct them to procure the most efficient equipment or consider life cycle cost analyses. Both of these directives can affect how the total cost is perceived and understood. As one engineer noted: *"energy efficiency usually costs more (not always, but usually), so it has to be a priority."*

Architects offered fewer overall constraints to HVAC system design, noting that they relied primarily on mechanical engineers to design and recommend systems that will serve the building layout. Specifically, they added:

- **System reliability**. Architects noted that some of their clients refused to consider equipment by a certain manufacturer or even a specific type of equipment if they had a poor experience in the past.
- **Maintenance requirements**. Architects also reported that some of their clients wanted to avoid complex systems and controls out of concerns over the sophistication required to maintain the system.

Heating Fuel Considerations

We asked contacts about the extent to which heating fuel affected their recommendations or their client's. Responses revealed two primary considerations for heating fuel: access to natural gas and the effect of codes that favor electrification.

The availability of the fuel is often determined by the location of the project and whether it is a new construction or a renovation. For major renovations, for example, the existing fuels already in the building would usually be leveraged.

- *"If the existing system is gas, might still go to VRF, in fact I have done this. But the DOAS follows the VRF. Heating fuel is assumed electric if it has VRF."*
  "If there's a hydronic loop with a gas fired boiler, you aren't going to change the whole system, you'll probably look at how to make that existing system more efficient."

Code requirements and climate, which will vary by location, affect the fuel decision. Natural gas has been the default choice for heating fuel in many places in the region. With the updated energy code in Seattle, engineers working in that area report an increase in electrically heated space.

- *"There are only two or three heat types: natural gas, resistance heat, and heat pump. There is propane (not used except where you can't get natural gas). Heat pumps are becoming more popular due to energy code, which is favoring electric systems, especially in Seattle.*

They don't like natural gas and electric resistance. Commercially natural gas has been the popular choice for many years around here."

- *"We are in Idaho, so we do natural gas a lot for cold climates. We also have an office in Vegas, so that's a hot climate. We rarely do natural gas there and will do heat pumps. More of a climate driver than anything."*

Several contacts offered more specific scenarios in which fuel type emerges as an issue: commercial kitchens and existing buildings with older electrical systems.

- *"Typically, with a commercial building (less than 50,000 square feet) we'll typically have gas going in, gas packs. Or, we might put a small gas-fired boiler in there and run a hot water loop around the building. In multifamily, the only place we use gas is the cooktops and central domestic hot water. The space heating in apartments is almost always going to be electric."*
- *"Somethings you have to have natural gas or propane for, things like kitchens in restaurants, you just can't heat the outside air that efficiently with electric heat; it would cause the electric system to be oversized or you would use above the existing electrical panel. In those cases, you would have to have gas. In other projects like offices you can use heat pumps, which would be all electric and are more efficient. In those situations, you can go either way. It might depend on availability. If gas is onsite, that might be a more efficient or cost-effective option. If gas is not on site, then electric heat pumps will probably be more cost effective than propane."*

Owner influence did not emerge as a clear driver of fuel choice. While two engineers mentioned they occasionally work for clients who don't want to use fossil fuels, others mentioned they would rarely get any input about the heating fuel used in the building.

Designer Perspectives on DOAS and HVAC Components

In addition to exploring the nuance and experience of design professionals in different procurement models, NEEA sought to understand contacts' experience with and understanding of the elements of NEEA's VHE DOAS product definition. Specific research questions included:

1. How do architects and engineers define or describe DOAS?
2. What is clear or unclear about different types of equipment that accompany DOAS?
3. Would architects and engineers need to adjust their customary approaches and partnerships to use VHE DOAS?

To explore these topics, we asked respondents to describe their overall familiarity with DOAS, opinions on the most efficient HVAC equipment being installed, strategies for maximizing the efficiency of DOAS and other questions designed to illuminate the overall level of understanding among design professionals.

Level of familiarity

We found a mixed level of familiarity with the term DOAS among architects. Three architects, all of whom reported working with clients who had sustainability goals, had no familiarity with the term or associated equipment. All three of these contacts associated efficiency with reduced mechanicals, natural ventilation, and simple systems. Other architects reported more familiarity with decoupled systems, even mentioning heat recovery as part of the overall system. These architects tended to have more experience with public buildings, particularly schools, or projects in Washington State. Their descriptions included:

- *"Really, the codes are getting quite strict depending on the area. We are having to do that (DOAS) anyway. We'll talk with the owner about their options, we'll look at payback and longevity. Public entities have long time horizons. They will use a system until they have to replace it."*
- *"We do that (include heat recovery) a lot. Especially government buildings. They care about efficient systems and maintenance requirements, not just first cost."*
- *"[The most efficient system] is a decoupled ventilation strategy where we are using hydronic systems to deliver heating and cooling separate from the ventilation. We will sometimes combine that with natural ventilation strategies."*

In general, architect responses to the technical equipment questions were less specific than their engineer counterparts.

Engineers were consistently familiar with the term and willing to discuss specific equipment options they associated with both decoupled systems and efficient systems. All of the engineers reported familiarity with DOAS (decoupled ventilation systems, not necessarily the full NEEA-defined system). They were then asked to describe equipment that they associated with a DOAS system. Responses to this question varied somewhat but overall included most of the elements NEEA is focused on: energy recovery (ERV) or heat recovery (HRV), variable refrigerant flow (VRF), chilled beams, smaller air handlers, and decoupled ventilation.

Energy/Heat Recovery Ventilation (ERV/HRV). Adding energy recovery, even when it is not required, and including it to enhance the performance of a decoupled system emerged as a commonly associated DOAS strategy. As one engineer noted, *"Anecdotally, I can say that [Washington] code has pushed everyone into a very efficient system with DOAS and heat recovery."*

Responses indicated that some engineers were referring to adding heat recovery to a typical RTU system (typically 30% outside air) as opposed to adding heat recovery to a DOAS (100% outside air). One consulting engineer, who often works in renovation projects within existing buildings explained: "*Normally with DOAS you use heat recovery to capture as much heat as you can to pre-heat outside air… the problem is commercial building standards don't require a lot of ventilation air. It's hard to make heat recovery (with a heat wheel or air to air or split system) pay for itself, there's just not enough outside air to recover heat for. But if you have a central DOAS then heat recovery makes sense and we will typically do that. Moral of the story: if you are going to do DOAS, heat recovery makes sense. If you aren't, heat recovery doesn't make sense."*

Variable refrigerant flow (VRF). VRF equipment was most frequently mentioned as an efficient heating and cooling system to pair with DOAS among the interviewed engineers, particularly when prompted to think about buildings under 50,000 square feet. One engineer reported associating DOAS with VRF, "almost entirely," while another stated that VRF systems were the most efficient options for smaller buildings. According to him, *"they can recover heat from parts of the building that have too much, run it through the refrigerant loop to other parts of the building that need heat, it's a pretty efficient way to do things."*

Other comments from engineers on pairing VRF and DOAS included:

- *"With VRF you will have a system with energy recovery units. We've done both decoupled and non-decoupled DOAS."*
- *"ERV is probably the primary equipment. If we are talking about the mechanical system that it's used with, then I would say VRF."*
- *"DOAS has become more and more in vogue. We have figured out how to make it more cost effective (in smaller commercial buildings). It's a viable way to heat and cool a building. It has become more viable. [In Oregon] there is Energy Trust money available. Half of the commercial buildings we design include DOAS systems."*

Chilled Beams. Both active and passive chilled beam systems emerged in our interviews with engineers when asked about the highest efficiency systems being installed with DOAS right now. In a chilled beam system, a small amount of conditioned primary air is supplied through high velocity air nozzles in each zone. The high velocity air induces air from the space to flow over the heating and cooling coils housed within the active chilled beam. A central hydronic heating and cooling plant, such as a boiler and chiller, supply hot and chilled water to the coils to meet the heating and cooling demands of the space. Chilled beam systems tend to be appropriate for larger buildings and are typically paired with DOAS equipment to achieve high efficiency HVAC.

One engineer discussed the lack of chilled beam system in the health care industry, noting that a chilled beam system that meets the healthcare ventilation requirements for zoned systems is consistently priced very high in the United States because contractors will price it out of the job due to their lack of experience. With chilled beams the cooling is done with a water temperature that will never generate moisture, which is important for healthcare applications due to filtration requirements, but the system "just has not caught on."

Two additional engineers and the design builder we interviewed described chilled beams as the most efficient HVAC systems currently installed, including one who called it the "hot system of the year."

We then asked engineers about their experience specifying efficient HVAC including DOAS. Discussions revealed the effects of code as well as barriers associated with cost, complexity, and contractor capability. Washington and California building codes are expected to affect standard practice, which could, ultimately, affect cost as DOAS and heat pump systems become more familiar.

Code

- *"Heat pumps are becoming more popular due to energy code, which is favoring electric systems, especially in Seattle."*
- *"California is going to push us there [to use DOAS in small buildings]. It's not very common today. Don't see it very often right now but it will continue to get more common. Give it a year."*

Cost

- *"Switching to a VRF system with DOAS is usually the biggest win, but a harder sell, especially if the customer isn't paying that much for their energy."*
- *"When the owner says I want a really cheap option, we start trying to eliminate the DOAS."*

Complexity

- *"Cost and complexity are the top two things. Primarily cost. Secondly, it's just nice to keep it as simple as you can. Our principal engineer has been in the business for 50 years and he's seen a lot. He's found that eventually the system gets simplified down to the level of whoever is maintaining it."*

Contractor Capability

- *"It's not that the equipment isn't available, it's more if a contractor or installer isn't familiar with the technology, they aren't going to make it the first time they install it. VRF is an example – when it first started, I wasn't going to recommend it if contractors hadn't installed it before. Everybody knows what it is now. Early days it was different. The contractor needs to know what they are doing, we were burned by VRF early on."*

Small Commercial Applicability

Given the diversity of project type and size respondents worked on, we asked them to specifically comment on the application of a DOAS system in smaller commercial buildings.

When asked to consider the applicability for smaller buildings, nearly all respondents provided positive assessments. Architects that reported a basic level of familiarity with these systems noted that they saw DOAS as a good solution for a variety of reasons, including code compliance. One firm with substantial work in the public sector noted that some of their education projects are smaller (for example a 17,000 square foot science building addition) and DOAS allows them to achieve energy efficiency and ventilation air goals. Another valued the improved control, noting that *"it would be great, you have the ability to better control your ventilation and better control your heating and cooling."* Still another saw DOAS as a potential solution for supporting a building designed with night flushing, stating that in this scenario *"the ventilation fresh air is there, the outside temperatures are within range. So heating and cooling is not an issue. The air side can then turn off for periods of time."*

Engineers provided substantial discussion on the applicability of DOAS for smaller commercial buildings—considering both the positive attributes of the system as well as the competitive "standard," an RTU. On the positive side, engineers noted that smaller commercial buildings are often overventilated, which means that minimizing the outside air is a big energy saver. In this case, the DOAS could mean having smaller equipment that still meets performance requirements. Noting that these systems are more appropriate for smaller buildings, one engineer explained that they might not require much additional maintenance and provide the added benefit of better zonal control for thermal performance.

Prior research and NEEA's direct experience have identified confusion in the terminology associated with DOAS, and this effort also found evidence of this. We heard this in two scenarios. First, in existing buildings with RTUs, engineers reported leveraging the outside air ventilation components of those units, even if they are not fully decoupled. Second, engineers discussed a variety of strategies for ensuring outside air delivery including some that are not consistent with NEEA's design guidelines. For example, one engineer offered *"instead of ducting outside air from DOAS all over the building, you might just dump it into the core and let it exfiltrate to the zones… that makes it less expensive to put a DOAS in."* Another discussed challenges of adding the complexity of DOAS to existing buildings, noting *"it doesn't come up much in these scenarios because of the added complexity, even though a supply fan with an electric heater is 'kind of' a DOAS in that it's a dedicated outdoor air system and it's decoupled."*

System Label or Shorthand

We asked each interviewee to respond to a description of the DOAS system consistent with NEEA's definition: a high-efficiency HVAC system that includes dedicated ventilation air (decoupled from primary heating and cooling air) with high-efficiency heat recovery and a high-efficiency, down-sized heating and cooling system. While all the engineers and several of the architects had heard of the term DOAS, they did not have a simple label or short-hand description for a system consistent with NEEA's definition.

Most architects offered no suggestions for what a system consistent with this definition would be called. The two offering comments noted that mechanical systems were typically described by their components in a way that's easy for clients to understand and descriptive of what will be purchased. For example, this might be "an HRV ventilation system coupled with VRF heating."

Engineers provided a similar assessment, noting that because there are so many ways to achieve high performance, there is not a single term or single technology to describe a high performance DOAS system. Instead, they label the systems by their components: HVAC with DOAS, ASHP with a DOAS, VRF or a 4-pipe fan coil system with DOAS with heat recovery, WSHP with DOAS, even chilled beam systems.

Conclusions and Recommendations

This study built on NEEA's prior research and program experience to better understand the dynamics in Heating, Ventilation, and Air Conditioning (HVAC) system design and installation, with a focus on the points of influence for new construction and major renovation projects in smaller commercial buildings, defined as 50,000 square feet or smaller. This work emerged from NEEA's High-Performance HVAC program, as part of the efforts on its first area focus- Very High Efficiency Dedicated Outside Air System (VHE DOAS). NEEA's definition of VHE DOAS is a high-efficiency HVAC system that includes dedicated ventilation air (decoupled from the primary heating and cooling system) with high-efficiency heat recovery and a high-efficiency heating and cooling system sized appropriately to reflect expected performance. The program requirements also include key design principles necessary to achieve optimum energy savings.

Conclusions

Overall, we found the design process to be diverse and dynamic, with many exceptions for building type, owner priorities, and financial constraints. Mechanical engineers are considered experts by their design counterparts, who expect them to design systems that meet the heating and cooling requirements for the building while being mindful of the cost.

The key findings related to these areas of inquiry are described below.

Procurement models affect communication flow and influence of construction pricing

NEEA sought to understand the extent to which architect and engineer influence might vary within different procurement models, expecting a more discernable split in the type of projects respondents reported working on, assuming that these professionals tended to work in either plan & specify or design+build projects. We found that this dichotomy was overly simplistic—in reality nearly everyone we spoke with had experience in multiple types of procurement models, including hybrid approaches that do not fit neatly into either the traditional plan & specify approach or the classic design+build.

This research identified four primary procurement paths through which new construction and major renovation typically occur:

- **Plan & specify** Plan & specify is the classic approach to designing buildings and includes a staged process that proceeds logically from early conversations to establish a "program of requirements" for the building. Pricing is not obtained until the bidding and procurement stage, which typically occurs after construction documents are submitted.
- **Design+build:** In design+build, the general contractor/design builder is hired directly by the owner or client and is expected to manage the project from design through construction. The general contractor acts as the project manager, typically selecting the rest of the design team. This model is oriented around construction and building costs, and thus installed prices are considered as each building element is designed.

- **Progressive design+build:** Similar to design+build, except the entire design and construction team is selected by the owner instead of just the general contractor. These teams will submit their qualifications without detailed information on building requirements and then work together. In these projects, construction pricing is integrated into design decision making, similar to design+build.
- **General Contractor Construction Manager (GCCM):** GCCM is a hybrid of design+build and plan & specify in which the owner or client hires both the general contractor and the architect directly and expects them to work together. The owner maintains direct communication with both professionals and expects that the general contractor will also manage the overall construction project. Advocates of this approach note that it has the potential to balance design and cost pressures by ensuring both are represented to the owner.

In each model, design occurs in a logical sequence that reflects the requirements established by the owner or client. However, the established milestone sequence associated with plan & specify can be more fluid in the alternative procurement models, as pricing and input from construction professionals are more likely to alter design decisions early in the design process.

Mechanical design responsibility does not vary by procurement model

Mechanical systems are an important part of the function of new buildings and one of the top five building costs, according to the professionals interviewed as part of this research. Mechanical system design for commercial buildings is a customized and specialized process that requires substantial expertise and encourages decisions that reduce risk. In every procurement model, the final decisions on system design rest with mechanical engineers and their mechanical contractor counterparts.

Mechanical system procurement can be bundled into a design and construction package

While it is still common to have a mechanical engineer as part of a design team, it is not required. The overall "trades package," which can include mechanical, electrical, and/or plumbing (MEP) can also be procured by selecting a construction and installation firm to design and install the overall mechanical system. These firms may have a mechanical engineer on staff, or they may subcontract with one to review their design for permitting purposes. This process was referred to as "MEP design+build." Obtaining HVAC system design through this MEP design+build approach can occur in any type of procurement model (not just in design+build projects). In this scenario, the mechanical design is likely to reflect the equipment that can be installed profitably by the MEP contractor which could reduce recommendations for innovative or super-efficient equipment. Profitability for MEP firms is driven by construction and installation, not design fees, and avoiding risk in installation costs is important for these firms.

Owner priorities affect the entire design team

Design professionals described their work as customized to reflect the requirements and priorities of their clients, the owners or developers of the property. Projects that involve owner-occupied buildings or institutional owners are more likely to have sustainability or efficiency objectives. They are also more likely to consider the operating costs (both of energy consumption and maintenance). The specific priorities for any given client or owner are more likely to affect the extent to which energy efficiency is considered than the procurement model used.

There is uneven familiarity with VHE DOAS equipment

Architects were less familiar with the term DOAS and with specific HVAC equipment in general than their engineering counterparts. Even architects able to discuss system components reported relying on mechanical engineers to make final decisions on system design. Engineers, however, were consistently familiar with the term DOAS, and able to describe specific equipment options they associated with both decoupled systems and efficient systems. In addition, they mentioned a variety of equipment options that can be part of a VHE DOAS system, including energy recovery ventilators (ERV) or heat recovery ventilators (HRV), variable refrigerant flow (VRF) systems, chilled beams, smaller air handlers, and decoupled ventilation.

Equipment discussions revealed opportunities

Interviews revealed several opportunities for aligning VHE DOAS with existing trends. These opportunities included:

- Leveraging the pressure to meet new building codes, which emerged as a major driver for DOAS systems in Washington, where DOAS is mandated by code for many new buildings.
- Capitalizing on a trend indicating that mechanical system design may be occurring earlier in the design process as systems get more complex and code requirements are harder to design around, which could enable consideration of a broader set of mechanical solutions.
- Aligning with the business model of energy service companies (ESCOs), who regularly recommend upgrades to lighting and mechanical systems in existing buildings to achieve energy savings.[4]

Recommendations

Several themes emerging from this work point to logical next steps for NEEA's VHE DOAS initiative and high-performance HVAC efforts more broadly.

Mimic vendor strategies for system promotion. Mechanical engineers universally reported learning about new equipment and innovative products from vendors (typically manufacturers and their representatives) who reach out for that purpose. To be successful NEEA needs to engage with mechanical engineers in a similar manner—through lunch and learns, demonstrations, and road shows with "kick the tires" models available. Partnering with distributors and other vendors could help demonstrate the accessibility of equipment and increase familiarity.

Engage proactively with MEP design+build firms, ESCOs and others that are in the trenches of mechanical design for high volume smaller projects. Given the variety of design scenarios and

[4] The ESCO business model depends upon identifying cost effective upgrades in existing facilities that will lead to specific contracted energy savings. They are not traditional mechanical contractors as their scope will include multiple types of systems (lighting, controls, HVAC, etc.)

the role of the mechanical engineers in making major system recommendations, NEEA should focus on ensuring these professionals responsible for early system design have all of the information they need *before* they are engaged in a specific design process.

Leverage relationships with ASHRAE. ASHRAE, an organization mechanical engineers and MEP contractors rely on for best practice information, has already published a Design Guide for Dedicated Outside Air Systems. Enhancing that guidance with a high efficiency option would provide a credible source of information to system designers and specifiers. Expanding the information available to include cases studies, local chapter presentations, and *High-Performance Buildings* articles will also help inform these professionals and normalize DOAS design.

Identify strategies for offsetting risk. Equipment and installation costs were cited by many as the primary factor stopping DOAS installations from being paired with high efficiency heat recovery. However, another commonly cited barrier was the risks associated with soft costs, such as concerns about additional design time, performance, and realizing energy savings. NEEA should consider opportunities to subsidize design fees, provide technical assistance, or develop calculators to assist in life cycle cost analyses, in addition to the education and awareness activities discussed above.

Help design professionals meet the requirements of their clients. Identifying non energy benefits will help mechanical system designers make the case for high performance systems and ensure that they survive value engineering. Potential benefits include smaller duct work, larger windows, reduced noise, improved zonal control, improved air quality, and a smaller footprint for mechanical rooms.

Continue efforts to expand the target market and equipment set. Additional high-performance HVAC system options would likely enable NEEA to engage with a larger section of the market by having a more diverse qualifying product selection, providing more options for larger buildings or including solutions for scenarios for which the current VHE DOAS product definition is impractical.

Appendix A: List Disposition

As mentioned in the body of the report, we sought to complete interviews with a mix of architects and mechanical engineers. We also sought to include perspectives on design+build and plan & specify projects. In early December 2020, we purchased a contact list from InfoUSA based on two primary NAICS Codes:

- 5413001 Architectural Services
- 54133077 Engineering Services

The contact list contained 2,117 names, with email addresses as well as other information about the firm (location, number of employees, approximate revenue).

The SIC codes contained under the broader NAICS codes include a variety of firms unqualified for the research envisioned in this project because they focus on other forms of engineering (e.g., civil or environmental), only design residential structures, or do only architectural illustrations. The engineering category includes more diverse specialization than the architecture category. Several of the broader categories, including civil engineering and consulting engineers were found to include some firms that appeared qualified, so those categories remained in the population. Others, such as trucking, mining, nuclear, masonry, and land planning, were removed from the population frame. Ultimately, we removed 219 records in categories deemed to be unqualified.

Before we began recruitment, we further reviewed the list and performed spot quality checks, by looking up firms and contacts online to see if they were likely to be qualified, if the contact appeared accurate or if we saw evidence of list errors. We identified that list errors would likely require careful review and updating over the course of recruiting in order to be successful in reaching a representative population of qualified individuals/firms. Approximately 35 records were added to the list based on website review, personal knowledge, or to address obvious errors (for example, a firm known to have been acquired or changed its name).

Over the weeks of December 16, 2019 and January 27, 2020 we emailed interview invitations to 280 contacts, with a focus on those categorized as architects and mechanical engineers. We found that the overall population of those categorized as mechanical engineers to be small. To expand our outreach to engineers, and to find qualified contacts in larger firms we began screening records in more generic engineering categories including: Engineering/Engineers, Consulting, Professional, Structural, and Civil Engineering.

Note that design+build firms are typically found in the NAICS codes associated with general contracting. Rather than purchase and clean this list, we accessed the Design Build Institute of America's (DBIA) Northwest Chapter listings to identify promising design+build contacts.

Table 1: Interview Disposition

Contact Type	No Response	Complete	List error	Not qualified	Grand Total
ARCHITECTS	89	7	25	3	124
ARCHITECTURAL & CONSTR SPECIFICATIONS			1		1
ARCHITECTURAL SERVICES	2		1		3
BUILDING DESIGNERS				1	1
ENGINEERING	19	3	11	3	36
ENGINEERS-AIR COND HEATING VENTILATING	4		2		6
ENGINEERS-CIVIL	2		3	7	12
ENGINEERS-CONSTRUCTION				1	1
ENGINEERS-CONSULTING	18		12		30
ENGINEERS – ELECTRICAL	1		1		2
ENGINEERS-ENVIRONMENTAL			2	1	3
ENGINEERS-MECHANICAL	29	4	10	3	46
ENGINEERS-PROFESSIONAL	2		2		4
ENGINEERS-STRUCTURAL	2	1		2	5
DESIGN BUILD	5	1			6
TOTAL	**173**	**16**	**70**	**21**	**280**

**Table does not include specialties deemed unqualified early and not recruited. Only two contacts, one architect and one engineer, declined directly to us, non-response was a more common scenario.*

Ultimately, we completed interviews with contacts from the following firms:

- Mackenzie
- NAC Architecture
- SRG Partnership
- William/Kaven Architecture
- Architects West
- Ernest R Munch Architecture
- Hennebery Eddy Architects
- Lease Crutcher Lewis
- MacDonald Miller
- AEI Engineering
- Franklin Energy
- Colebreit Engineering
- McKinstry CO LLC
- Engineering System Solutions (ES2)
- BCE Engineers Inc
- Mechanical Systems Engineering

Appendix B: Documents Reviewed

Documents reviewed as part of literature review.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. 2004. *Integrated Design for Sustainable Buildings.* ASHRAE Journal, September 2004.

American Society of Heating, Refrigerating and Air-Conditioning Engineers. 2016. *Design Considerations for Dedicated OA Systems*. ASHRAE Journal, March 2016.

Cadeo Group for BPA (Bonneville Power Administration). 2015. *Commercial HVAC Market Characterization 2015 Findings*. Portland: BPA. https://www.bpa.gov/EE/Utility/research-archive/Documents/Momentum-Savings-Resources/2015_Momentum_Savings_HVAC_Market_Overview.pdf

Energy 350. 2019. Internal VHE DOAS Memos.

Evergreen Economics. 2017. Rooftop HVAC Market Characterization Study. Prepared for: Northwest Energy Efficiency Alliance. https://neea.org/resources/rooftop-hvac-market-characterization-study

Navigant Consulting for BPA (Bonneville Power Administration). 2016. HVAC Market Intelligence Report. Portland: BPA. https://www.bpa.gov/EE/Utility/research-archive/Documents/Momentum-Savings-Resources/2016_HVAC_Market_Intelligence_Booklet.pdf

NMR Group. 2019. Commercial Code Enhancement Audience Research. Prepared for: Northwest Energy Efficiency Alliance. https://neea.org/resources/commercial-code-enhancement-audience-research

Opinion Dynamics. 2019. Commercial High-Performance HVAC Market Characterization. Prepared for Northwest Energy Efficiency Alliance.