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Fan Systems Market Characterization

Prepared For NEEA:
Chris Cardiel, Sr. MRE Scientist

Prepared by:
Christopher Dyson, Principal Consultant
Ari Michelson, Principal Consultant
Clare Fitzgerald, Technical Editor

DNV Energy Insights, Inc.
621 SW Morrison Street, Suite 500
Portland, OR 97205

Northwest Energy Efficiency Alliance
PHONE
503-688-5400
EMAIL
info@neea.org

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EXECUTIVE SUMMARY

Background

Fans are commonplace in all building types and, while they represent a small portion of a building's energy use, account for a total regional load of 839 average megawatts. By partnering with market actors to overcome identified barriers to efficient fan selection (e.g., lack of familiarity with efficient products, prioritization of factors other than efficiency), the region could see an estimated energy savings of 176 aMW from the commercial & industrial sectors. NEEA's Efficient Fans Program (the "Program") is initially partnering with manufacturers and industry associations to increase awareness, visibility, and adoption of more efficient fan products, specifically those that are not embedded in larger equipment with additional operating functions such as HVAC, Make-Up Air, or Outdoor-Air unit systems ("non-embedded fan systems").[1] By developing and promoting reliable energy metrics that allow manufacturers to differentiate products and making those metrics more visible in the fan selection process, NEEA believes the overall market efficiency of fans will improve. By prioritizing upstream market actor engagement and program interventions, NEEA hopes to shift manufacturers' product mix toward more efficient products that will diffuse across the market, with the ultimate goal being that manufacturers and downstream market actors will produce and/or promote efficient fan systems, resulting in an overall increase in fan efficiency of 20–25% above baseline values.[2] The primary purpose of this study is to provide information to help the Program influence the commercial and industrial (C&I) fan system market in the Northwest (Idaho, Montana, Oregon, and Washington) by addressing the following research objectives:

- Reviewing and confirming or recommending changes to the NEEA definition of stand-alone fan system products as articulated through the 2021 C&I Stand-Alone Fans Market Research Study,[3]
- Providing a working estimate of the size of the stand-alone C&I fan systems market in the Northwest,
- Providing segmentation of regional fan system sales to support future energy savings estimation, and
- Characterizing fan system market processes and channels.

The study team analyzed the findings from this current study alongside prior research results. Previously, the study team had conducted two other fan market studies: the 2021 Commercial & Industrial Stand-Alone Fans Market Research study and the 2022 NEEA Fan Manufacturer Regional Market Share Research study.[4] The Commercial & Industrial Stand-Alone Fans Market Research study informed the fans market through 27 in-depth interviews with market actors that manufacture, sell, select, and install non-embedded fans. The NEEA Fan Manufacturer Regional Market Share Research study conducted interviews with six manufacturers of non-embedded fans, with these manufacturers preliminarily identified as likely to represent a substantial portion of the Northwest fan market.

This report sometimes compares the responses of the manufacturers interviewed for the current study to those interviewed for the 2022 NEEA Fan Manufacturer Regional Market Share Research study. Preliminary assessments conducted in that earlier study indicated that the manufacturers interviewed for the current study (hereinafter referred to as "Cohort 2") are likely to represent a lower average individual share of the regional C&I stand-alone fan market than those interviewed in 2022 (hereinafter referred to as "Cohort 1"). Therefore,

[1] It should be noted there is likely some degree of subjectivity in market actor responses to these definitions, and therefore some of the manufacturers represented may sell fans that are embedded in HVAC equipment downstream from the initial point of sale.

[2] These baseline values for fan system efficiency have not been established at the time of this report's publication.

[3] DNV. December 9, 2021. *Commercial & Industrial Stand-Alone Fans Market Research* (Report #E21-432). Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://neea.org/resources/commercial-industrial-stand-alone-fans-market-research.

[4] DNV, April 3, 2023, *Fan Manufacturer Regional Market Research*, (Report #E23-460) retrieved from Northwest Energy Efficiency Alliance (NEEA) | Fan Manufacturer…

the study team sought to enrich the findings generated through Cohort 1 manufacturer interviews through engagement with Cohort 2 manufacturers likely to represent different market roles and perspectives.

Methodology

The primary sources of information for this study were in-depth interviews with 31 fan market actors. This population included six manufacturers, eight manufacturers' representatives, seven specifiers/installers, eight building maintenance managers, and two system integrators.

In addition, the study team conducted a literature review including prior NEEA reports, conference papers, publications from research laboratories, published energy efficiency reports, AMCA publications, and other relevant conference and white papers. This literature review was used to refine the interview guides.

Key findings

Market size and characteristics

The key findings concerning market size and characteristics are as follows; additional detail regarding each of these findings is provided in the main body of this report.

- Based on manufacturer interpretations of the definition of "non-embedded fans" noted above, the size of the non-embedded sales market in the Northwest is close to $50 million, representing a conservative unit market sizing estimate of roughly 27,000 fans of all horsepower levels sold annually.
- For the manufacturers' representatives, sales of non-embedded fans were more evenly distributed across the four Northwest states than the manufacturers had reported.
- On average, the Cohort 2 manufacturers reported that 52% of their non-embedded fan sales in the Northwest were in the commercial sector, 43% of their NEEA regional sales were in the industrial sector, 3% were in the agricultural sector, and 2% in the "other" category.
- Most manufacturers and manufacturers' reps reported selling non-embedded fans under 3 horsepower.

Market dynamics

- Consistent with prior research, the study found that most non-embedded fans are sold as custom products and are not stocked or available off-the-shelf.
- The majority of non-embedded fan sales are in the new construction market.
- Most fans classified by manufacturer respondents as "non-embedded" per this study's definition are being sold with controls, most commonly with variable frequency drives (VFDs).
- The various market actors involved in fan selection and installation interact with each other in specific ways throughout the specification and purchasing process, with these relationships and interactions varying somewhat by project type.

The fan selection and specification process

- The full replacement of non-embedded fans is relatively rare, with legacy equipment often being maintained through routine replacement of components.
- Generally, fan specifiers/installers have the most influence on choosing fans to include in building designs.
- The influence of building owners on the fan selection process beyond establishing relevant budgetary restrictions is typically low, although this is not always the case for retrofit projects.
- Some contractors/installers are engaged in selection, but other interviewees reported little to no influence on the design for these actors.

- Building maintenance managers most valued reliability, energy efficiency, and ease of maintenance when selecting new fans.

Barriers to efficient fans

- Unwillingness to replace operable fans in early replacement scenarios was identified as the most significant barrier, followed by high first costs, prioritization of other factors (e.g., physical size), and preference for like-for-like replacements.
- Less than half of respondents were aware of the fan energy index (FEI) metric, with awareness highest among specifiers/installers and lowest among building maintenance managers and systems integrators.
- Market actors lack information on cost savings and return on investment of newer fans.

Recommendations

The study team identified the following opportunities for programs to influence fan selection:

1. **Code requirements can drive use of the FEI metric in fan selection**. Recent versions of both the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 90.1-2019, 90.1-2022 and the International Energy Conservation Code (IECC 2021) energy codes have incorporated the FEI metric, replacing the legacy Fan Efficiency Grade (FEG). While three states in the four-state region have adopted building codes which reference FEI, the fan market actors only mentioned the Washington building code as a driver of FEI as a consideration in fan selection. This suggests there are opportunities for more fan market actor education about recent code changes.
2. **Support market education both broadly for fan efficiency and for the FEI metric specifically**. Primary and secondary research identified a lack of awareness of fan efficiency and the FEI metric across all but one of the market actor groups. Further, first cost is one of the most influential factors reported in fan selection, and this is a metric that does not account for the lifetime benefits of efficient fans. Education targeted at market actors throughout the distribution channel provides an opportunity to highlight total cost of ownership and how to use efficiency metrics such as FEI to compare performance across products.
3. **Engage with key manufacturers to showcase FEI in fan selection software**. These software products are used by manufacturers themselves, manufacturer representatives, and other market actors who select fans such as engineers and installers. While some manufacturers indicated FEI is a metric available in the software, others indicated that FEI is not included or indicated that it is not highlighted by default.
4. **Assess the possibility of downstream rebates for energy-efficient fans as a strategy for mitigating barriers associated with low awareness and high first cost of efficient products, potentially in collaboration with utilities or other agencies.** Several building maintenance managers and other market actors recommended rebates for encouraging sales of high efficiency fans. These interviewees also cited examples where rebates from Energy Trust of Oregon or other utilities had encouraged them to select higher efficiency fans as well as more efficient versions of other types of equipment.
5. **For retrofit scenarios, consider promoting the non-energy benefits of efficient fans such as noise reduction.** Some market actors mentioned that noise reduction benefits were a selling point for new fans, especially in certain subsectors such as commercial kitchens or libraries. While promoting the energy saving benefits of new efficient fans should still be the primary focus, it may be helpful to cite additional non-energy benefits for these products.
6. **Highlight the benefits of integrating fans with controls.** While the market penetration of controls is growing, and fan market actors generally believe they provide many benefits, there are still opportunities for increasing the prevalence of controls, particularly in replacement or retrofit scenarios.

1 INTRODUCTION

1.1 Study purpose and objectives

Fans are commonplace in all building types and, while they represent a small portion of a building's energy use, account for a total regional load of 839 average megawatts. By partnering with market actors to overcome identified barriers to efficient fan selection (e.g., lack of familiarity with efficient products, prioritization of factors other than efficiency), the Northwest region of Idaho, Montana, Oregon, and Washington could see an estimated energy savings of 176 aMW from the commercial & industrial sectors. NEEA's Efficient Fans Program (the "Program") is initially partnering with manufacturers and industry associations to increase awareness, visibility, and adoption of more efficient fan products, specifically those that are not embedded in larger equipment with additional operating functions such as HVAC, Make-Up Air, or Outdoor-Air unit systems ("non-embedded fan systems").[5] By developing and promoting reliable energy metrics that allow manufacturers to differentiate products and making those metrics more visible in the fan selection process, NEEA believes the overall market efficiency of fans will improve. By targeting interventions as far upstream as appropriate, NEEA hopes to shift manufacturers' product mix toward more efficient products that will diffuse across the market. The primary purpose of this study is to provide information that will help the Program influence the commercial and industrial (C&I) fan system market in the Northwest. Specific paths of market influence for the Program will likely include:

- Engagement with Air Movement and Control Association International (AMCA) to increase market awareness and enable product differentiation through raising awareness of the Fan Energy Index (FEI).
- Engagement with fan manufacturers and their representatives to encourage them to produce and promote more efficient fans, increase the visibility of the FEI in their specification software, increase the regional sales of fan system products that are AMCA-certified, and share their sales data.

The specific information that this study will provide to aid the implementation of Program will include:

- *Profiling and sizing the regional fan market:* This includes information useful for describing the approximate size and nature of the regional market for non-embedded C&I fan systems. It also includes information describing the relationships between different fan market actor groups.
- *Identifying and prioritizing market barriers:* This includes information helpful for assessing the nature, magnitude, and tenacity of market barriers that may impact the update and diffusion of efficient fan system technologies targeted by the Efficient Fans Program.
- *Documenting market actor motivations and fan system paths-to-purchase:* This includes information concerning the process of efficient fan system selection including the perspective, motivations, and pain points of relevant market actor groups.

[5] It should be noted there is likely some degree of subjectivity in market actor responses to these definitions, and therefore some of the manufacturers represented may sell fans that are embedded in HVAC equipment downstream from the initial point of sale.

1.2 Study background

The study kicked off in March 2023, with the study work plan, interview guide development, sample design, and the literature review occurring through May. The study team conducted its first interview in June with interviews continuing through September. The team presented preliminary findings to NEEA staff in late August 2023 and issued multiple iterations of the draft report in November and December. Figure 1 provides more details on the project timeline.

Figure 1. Project Timeline

Study Activities/Deliverables	2023																			
	Mar		Apr		May		June		July		Aug		Sep		Oct		Nov		Dec	
Project kickoff																				
Work plans, interview guides, sample designs																				
Literature review																				
Data collection																				
Preliminary findings presentation																				
Analysis																				
Draft reports																				

2 METHODOLOGY

This section describes the methodology for the primary activities conducted during the 2023 Fan Systems Market Characterization study.

2.1 Literature review

The study team conducted a literature review to provide foundational information on the regional fan market to inform later data collection efforts through market actor interviews. This review included prior reports developed for NEEA, conference papers, publications from research laboratories, published energy efficiency reports, AMCA publications, and other relevant conference and white papers. The study team used the literature review results to refine the interview guides for primary data collection.

2.2 Sample design and market actor lists

The study team developed a sampling approach to target the following market actors: fan manufacturers, manufacturers' representatives, fan specifiers (e.g., designers, engineers, architects), contractors/installers, end users/building service providers, and system integrators. The study team developed market actor lists, leveraging prior work with NEEA that identified regionally active manufacturers and other market actors, and supplemented this list with additional market actor targets from the Zoominfo B2B database of market actors, publicly available reports and data, and NEEA staff referrals.

2.3 Interview guides and data collection

The study team developed in-depth interview guides for each of the fan system market actor groups for NEEA review. These interviews were designed to gather market actor perspectives on profiling and sizing the regional fan system market, identifying, and prioritizing market barriers, and documenting market actor motivations and fan system purchase practices. These interview guides contained both direct and open-ended questions, designed to confirm or modify prior study findings, as well as to identify additional market barriers and insights from the market actors. Following interview guide approval, DNV recruited market actors and completed in-depth interviews, offering financial incentives for market actors who complete interviews. The study team assured market actors that the confidentiality of any sensitive market information provided during the interviews would be protected. Table 1 summarizes the interviews completed with each market actor group for the study as well as the target number of completed interviews for each group.

Table 1. 2023 fan systems market characterization interview completes

Market Actor	Target Number of Completes	Interview Completes
Manufacturers	15	6
Manufacturers' representatives	20	8
Specifiers/installers	33	7
Building maintenance managers	27	8
System integrators	5	2
Total	**100**	**31**

It is important to note that the target numbers of completed interviews were developed before the study team had compiled their sample frames, and they later discovered that some sample frames were much smaller than anticipated. For example, the sample frames for the manufacturers and manufacturers' representatives turned out to be only 36 and 39 companies respectively. This information would have resulted in reduced sampling targets for these groups, since completion rates of near 50% are very rare for these types of nonparticipant interviews.

Other reasons for the lower-than-planned completion rates included:

- *An inherently difficult market to reach:* In contrast to other energy-consuming end uses, such as lighting or heating/cooling equipment, fans are often overlooked by both market actors and energy efficiency programs. The literature review conducted for this study found few conference or white papers on fan energy efficiency compared to what might be expected for lighting or HVAC. This lack of market attention makes it more difficult to find market actors with experience designing, installing, or purchasing fans.

  Other studies of the Northwestern fan market have encountered similar data collection challenges. For example, a 2022 BPA-sponsored study of the industrial pump, fan and adjustable speed market was able to collect data from only 10 market actors including only two fan manufacturers.[6]

- *For some market actor categories, it was difficult to find specific North American Industry Classification System (NAICS) codes that matched well with the target market actor groups:* This was a significant barrier for identifying the fan specifiers, system integrators, and building service providers. In all three cases, there were no NAICS codes that could reliably identify companies who performed these functions. Therefore, we had to rely on NAICS codes that were more tangential to these functions, which inevitably led to many calls with people who simply did not have any interaction with non-embedded fans.

- *Blind recruiting:* NEEA had requested that the study team not identify NEEA in the recruiting emails or phone calls. While this was well-intentioned for reducing possible bias, it likely reduced the chances of recruiting market actors who were familiar with NEEA and had positive attitudes toward the organization. In addition, even in cases where the target interviewees are not familiar with NEEA, explaining that the research is sponsored by a non-profit organization will likely reduce market actor concerns about sharing information (vs. sharing information with a private company such as DNV).

- *Seasonality:* Much of the recruiting efforts occurred in late July and August, which are peak vacation times for many market actors.

2.4 Analysis and integration of prior study findings

The study team analyzed the interview results alongside prior research results and findings to develop findings and recommendations for the fan market. Previously, the study team had conducted two other fan market studies: the 2021 Commercial & Industrial Stand-Alone Fans Market Research[7] (the C&I Fans Market Research study) and the 2022 NEEA Fan Manufacturer Regional Market Share Research[8] (the Fan Manufacturer Regional Market Share Research study). The C&I Fans Market Research study informed the fans market through 27 in-depth interviews with market actors that manufacture, sell, select, and install non-embedded fans. The Fan Manufacturer Regional Market Share Research study conducted interviews with six of the largest manufacturers of non-embedded fans. The current study incorporated components of both prior research efforts, engaging a wide range of market actors similar to the C&I Fans Market Research study but focusing on smaller manufacturers to supplement the large manufacturer market data gathered during the Fan Manufacturer Regional Market Share Research study. The current study also interviewed building maintenance managers for the first time.

[6] Memorandum from Jonah Hessels, Nate Baker, Elizabeth Daykin, Sarah Widder, Cadeo Group to Joan Wang, Bonneville Power Administration, March 24, 2022, Industrial Pump, Fan, and Adjustable Speed Drive Sales Data Collection Summary Memo.

[7] DNV. December 9, 2021. *Commercial & Industrial Stand-Alone Fans Market Research* (Report #E21-432). Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://neea.org/resources/commercial-industrial-stand-alone-fans-market-research.

[8] DNV, April 3, 2023, Fan Manufacturer Regional Market Research, (Report #E23-460) retrieved from Northwest Energy Efficiency Alliance (NEEA) | Fan Manufacturer…

3 DETAILED FINDINGS

This section of the report describes the detailed findings of the fan systems market characterization study.

3.1 Market size and characteristics

The study team asked manufacturers and manufacturers' representatives to characterize their sales across the Northwest, both by state and by market sector, size, and other characteristics. These prompts were similar to those investigated by DNV in the Fan Manufacturer Regional Market Share Research study, although the earlier study focused solely on manufacturer sales patterns. This prior study focused primarily on the largest manufacturers, while the current study interviewed smaller manufacturers as well as a variety of manufacturers' representatives active in the region. The study team incorporated results from both studies in the discussion below, aggregating data where possible and differentiating between the Fan Manufacturer Regional Market Share Research (hereinafter referred to as "Cohort 1") and the current study research (hereinafter referred to as "Cohort 2") where applicable.

3.1.1 Market sizing analysis

The study team asked fan manufacturers to estimate both the volume of their sales of non-embedded fans (as defined for the purposes of this study; see Section 1.1) in the Northwest and what percentage of their total U.S. sales of non-embedded fans occurred in the four-state region. Seven manufacturers provided estimates of their annual sales of non-embedded fans in the Northwest, and an eighth manufacturer provided actual sales data. The total reported sales of these eight manufacturers were $45.6 million, representing approximately 27,000 fans sold.

Figure 2 shows the estimated sales revenue from each of the eight manufacturers with their names redacted for confidentiality reasons. It shows that four of the manufacturers reported sales revenues that were much higher than those of their counterparts. Figure 3 shows sales estimates based on the number of fans. It should be noted that all the estimates in this chart are extrapolations based on a method described below except for Manufacture 6 which provided actual sales data and Manufacturer 5 which provided an estimate of the number of fans sold.

It is also important to observe that both figures combine sales data from two different reporting periods. Six of the fan manufacturers (manufacturers 1–6 in the figures, from Cohort 1) estimated their annual sales revenue for 2021 when the study team interviewed them for the Fan Manufacturer Regional Market Share Research study. The two remaining manufacturers in the figures—manufacturers 10 and 11, from Cohort 2—were interviewed for the current study, and they estimated their annual sales revenue for 2022.

Figure 2. Annual revenue from sales of non-embedded fans in the Northwest

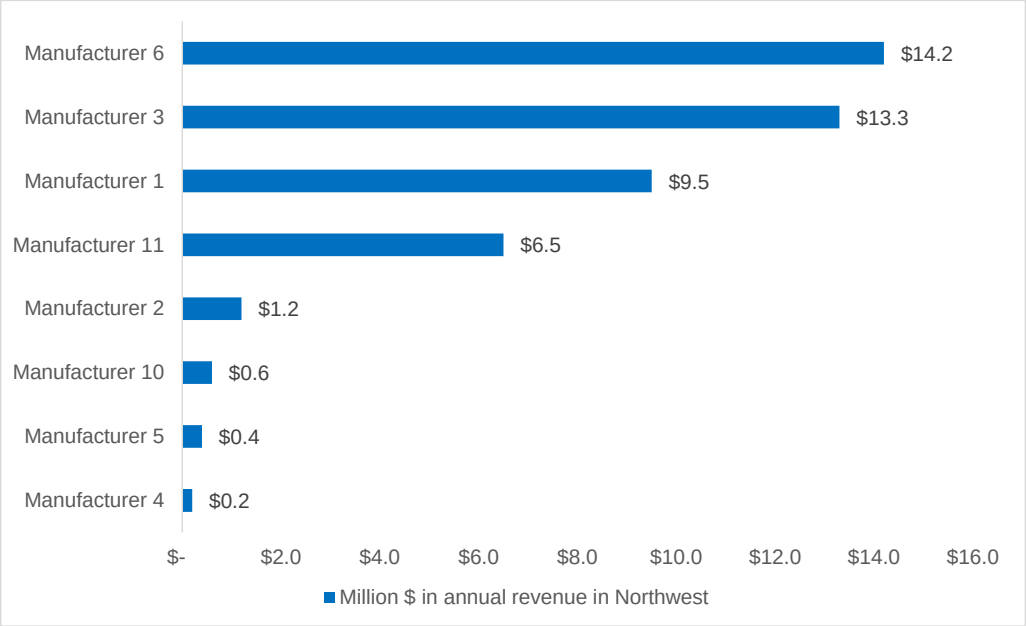
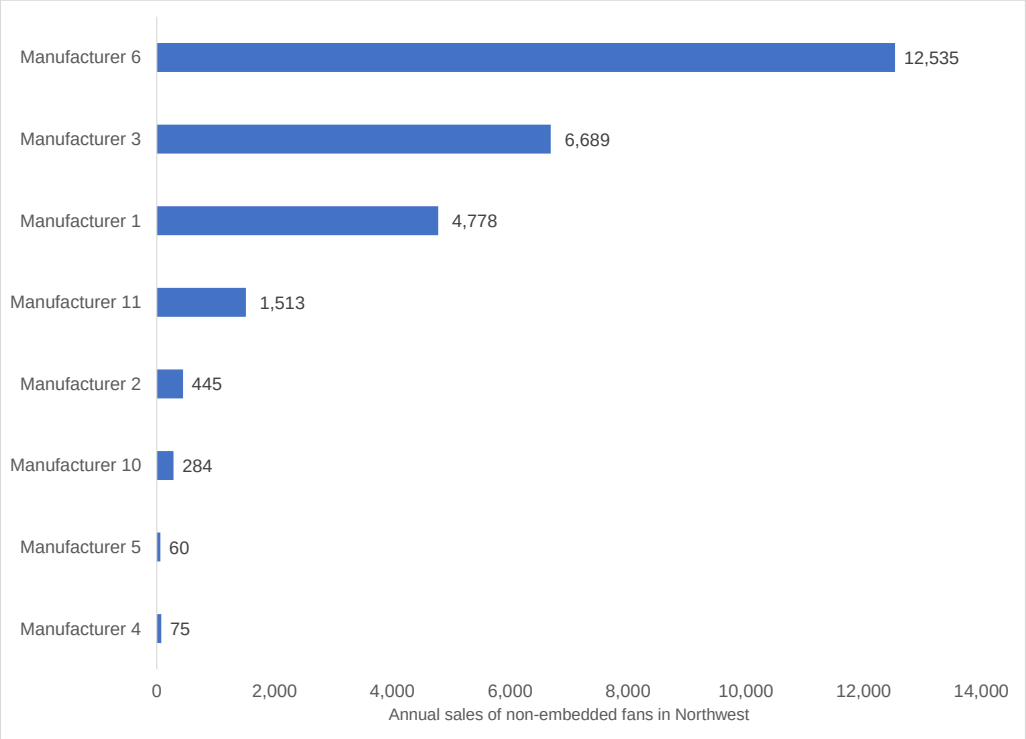


Figure 3 Annual Sales of Non-Embedded Fans in the Northwest



Only two manufacturers provided estimates of the number of non-embedded fans they sold in the four-state region, even after follow-up queries from the study team. Since estimates of sales volume in terms of unit sales

are important for forecasting purposes, the study team estimated the number of non-embedded fans sold using extrapolations and simplifying assumptions which included:

- *Revenue distribution:* The manufacturers had provided estimates of how their sales of non-embedded fans in the Northwest were distributed across different horsepower bins. The study team made the simplifying assumption that their total revenue was also distributed among these horsepower bins in similar proportions. For example, if a manufacturer estimated $600,000 in annual revenue and that 65% of their fans were in the 0.9-1.8 hp bin, we assumed that $390,000 (65% x $600,000) in revenue was coming from this bin.
- *Average fan price per horsepower bin:* Since one manufacturer had provided us with actual sales data, the study team was able to calculate their average sales price for a fan in each horsepower bin. The team made the simplifying assumption that these average sales prices would be the same for the other manufacturers.

Based on these two assumptions, the team was able to estimate the number of non-embedded fans sold by dividing the sales revenue in a given horsepower bin by the average sales price of a fan in that bin. The total number of non-embedded fans sold was 26,378. This included two manufacturers who have provided data on the number of fans sold and five manufacturers whose numbers of fans sold were estimated based on the method described above.

Because the other manufacturers who the team interviewed in the current study did not provide estimates of the volume of their sales, the study team views this market size estimate as a "floor." However, the study team does not view the remaining non-estimated portion of the Northwest non-embedded fan sales market as being very large. This is based on information from the market actor interviews—such as which fan brands they use—as well as evidence about the frequency with which fan manufacturers were mentioned in the sample frames in recent Northwest fan market studies.[9] These secondary sources of information indicated that the largest fan manufacturers are represented among the manufacturers who were willing to provide sales estimates.

To benchmark this market size estimate, we reviewed a March 2022 findings memorandum produced by Cadeo for the Bonneville Power Administration (BPA). That study focused on the subset of stand-alone fans that were greater than one horsepower in size and used some 2012–2016 DOE national fan sales data to estimate the size of this Northwest stand-alone market to be 23,000 fans.[10] It is important to note that this is an estimate of the fans larger than one horsepower and so it is not directly comparable with the 26,378 sales estimate described above which encompassed non-embedded fans of all sizes. However, as noted, this 26,378 represents a floor on the total market volume because not all fan manufacturers were able or willing to provide sales estimates.

Since the manufacturers interviewed for the Fan Manufacturer Regional Market Share Research study and the current study provided estimates for all their regional stand-alone fan sales, not just fans that were greater than one horsepower, in order to make the comparisons of these market size estimates more "apples-to-apples" the team first had to estimate what proportion of the 2022–2023 fan market sales were greater than one horsepower. While the Fan Manufacturer Regional Market Share Research study did provide estimates of market share by

[9] The 2022 fan market study provides more details on the study team's analysis of the frequency with which fan manufacturers were mentioned in the sample frames in recent Northwest fan market studies.

[10] The appendix of this memo mentioned three sources of information for this market size estimate including: 1) DOE's 2016 Fans and Blowers NODA 3 Life Cycle Cost Assessment, 2) DOE's 2016 Fans and Blowers NODA 3 National Impact Analysis, and 3) confidential anonymized information on 2012 fan shipments. The memo's appendix also mentioned that the market size estimate relied on three assumptions: 1) that the distribution of embedded vs. standalone fans covered by DOE's regulation (within the industrial & commercial) is representative of the industrial market, 2) that DOE's 2012 NODA distribution of fan shipments to the NW is representative of the current fan market, and 3) that the shipments of industrial fans to the NW can be reliably estimated using the ratio of manufacturing output in the region to the national manufacturing output.

horsepower bin, the challenge was that the smallest horsepower bin (Power Bin 1) included fans in the 0.9 to 1.8 horsepower range, thus straddling the desired one horsepower breakpoint.

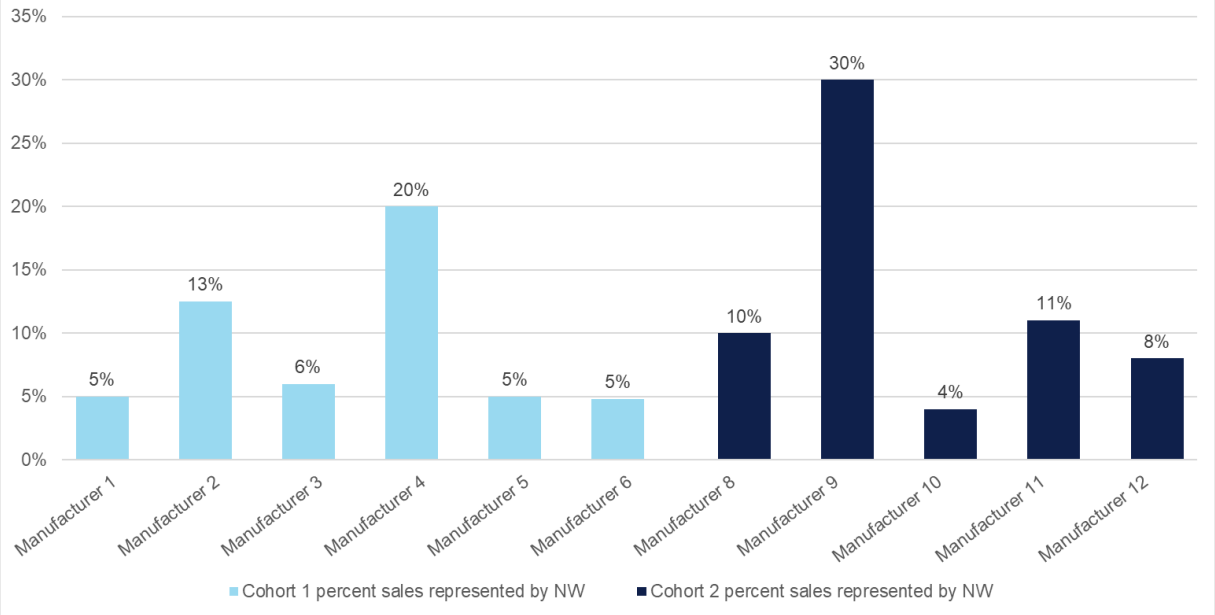
While the study team could try to make the simplifying assumption that the sales of fans within Power Bin 1's 0.9 to 1.8 horsepower range were equal in volume for each 0.1 horsepower increment, there were two concerns with this assumption. The first was that qualitative information from the manufacturer interviews for the Fan Manufacturer Regional Market Share Research study indicated that the smaller the fans, the more they sold. In addition, the one fan manufacturer from this study who provided actual sales data (vs. sales estimates) sold over 12,000 fans in the four-state region in 2021, but the large majority of these were less than one horsepower.

The second concern was that the Fan Manufacturer Regional Market Share Research study found that the share of non-embedded fan sales in the four-state region that were in Power Bin 1 was significant: 36% of total market share based on a straight average of the market share estimates from the six manufacturers and 72% of total market share based on a sales-weighted average of the market share estimates from these manufacturers. Because this Power Bin 1 accounted for such large slices of overall market sales, any attempts to make simplifying assumptions about the proportion of fans in Power Bin 1 that were above or below one horsepower would be especially consequential.

Due to these two concerns, the study team did not feel comfortable making simplifying assumptions about the distribution of sales within Power Bin 1. And without these simplifying assumptions, it is not possible to compare the DNV and Cadeo market size estimates.

The team for the current study also asked manufacturers to estimate what percentage of their 2022 total U.S. sales of non-embedded fans occurred in the Northwest. Five of the six Cohort 2 manufacturers (dark blue bars) were able to estimate this. Figure 4 shows their responses in comparison with the Cohort 1 manufacturer responses (light blue bars). The chart shows that the percentage of each manufacturer's overall non-embedded fan sales represented by the Northwest market were similar (4%–11% Northwest market shares) across Cohort 1 and Cohort 2. The exception was a single Cohort 2 manufacturer who estimated that 30% of their non-embedded sales were in the four-state region.

Figure 4. Percentage of Non-Embedded Fan Sales Represented by Northwest Region



The study team also asked manufacturers and manufacturers' representatives about the distribution of sales within the four-state region. Figure 5 presents these results for manufacturers across both studies, and Figure 6 show the results from the manufacturers' representatives. Manufacturer responses were similarly distributed in both studies, with higher average sales in Washington and Oregon. For the manufacturers' representatives, sales of non-embedded fans were more evenly distributed across the four states. This is likely a function of the regional nature of these representatives, as these interviewees were not specifically selected by size or geography, and some were entirely focused on a single state.

Figure 5. Distribution of manufacturer Northwest non-embedded fan sales by state

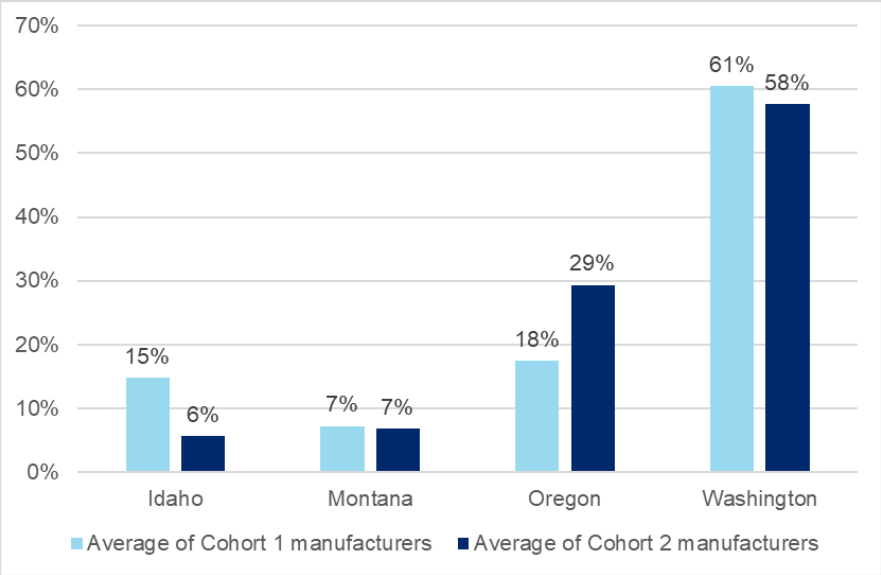
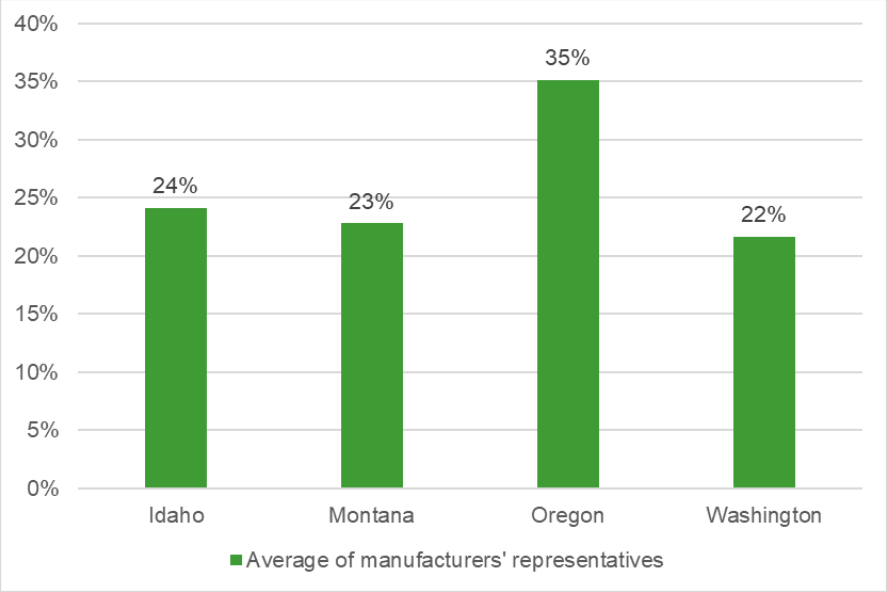


Figure 6. Distribution of manufacturers' representatives Northwest non-embedded fan sales by state

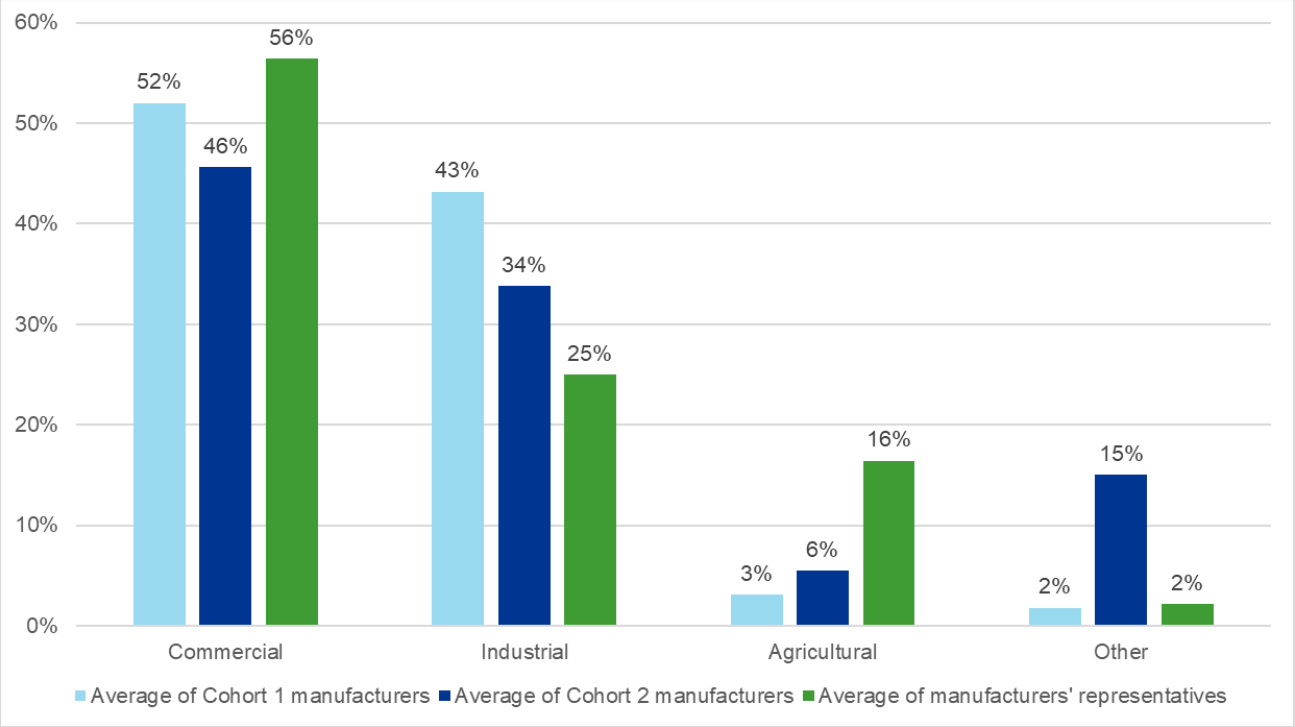


3.1.2 Distribution of fans by market sector

The study team investigated the distribution of non-embedded fan sales by sector. Figure 7 presents these results for both the manufacturers and the manufacturers' representatives. Consistently, respondents estimated that

most sales were in the commercial sector, followed by industrial and agricultural applications respectively. Consistent with the Fan Manufacturer Regional Market Share Research study, most manufacturers and representatives interviewed for the current study indicated that most of their sales occur in a single sector; these firms focus on either commercial, industrial, or agricultural applications for the majority of their sales.

Figure 7. Average Northwest non-embedded fan sales by market sector



3.1.3 Distribution by fan size

The study team asked manufacturers and manufacturers' representatives to estimate the distribution of non-embedded fans by size. Respondents in the current study were largely unable to provide detailed sales data across the distribution of fan sizes during the interviews and follow up efforts by the study team did not yield additional data. However, respondents were able to provide general perspectives regarding the fan sizes they offer, summarized below:

- The majority of manufacturers and manufacturers' representatives selling non-embedded fans primarily sell small fans under 3 horsepower. This is consistent with study team findings from the Fan Manufacturer Regional Market Share Research study.
- The Cohort 2 manufacturers were generally smaller manufacturers, and some respondents indicated that their companies sell fans for specific applications that may require larger fans, up to 500 hp. Examples of these applications for larger fans include data centers, health care, and agricultural uses.

3.2 Market dynamics

This section first describes how the Northwest fan market is segmented by product mix and project type. Then it provides more information on the roles of two less-well-understood groups of fan market actors: specifiers/installers and system integrators.

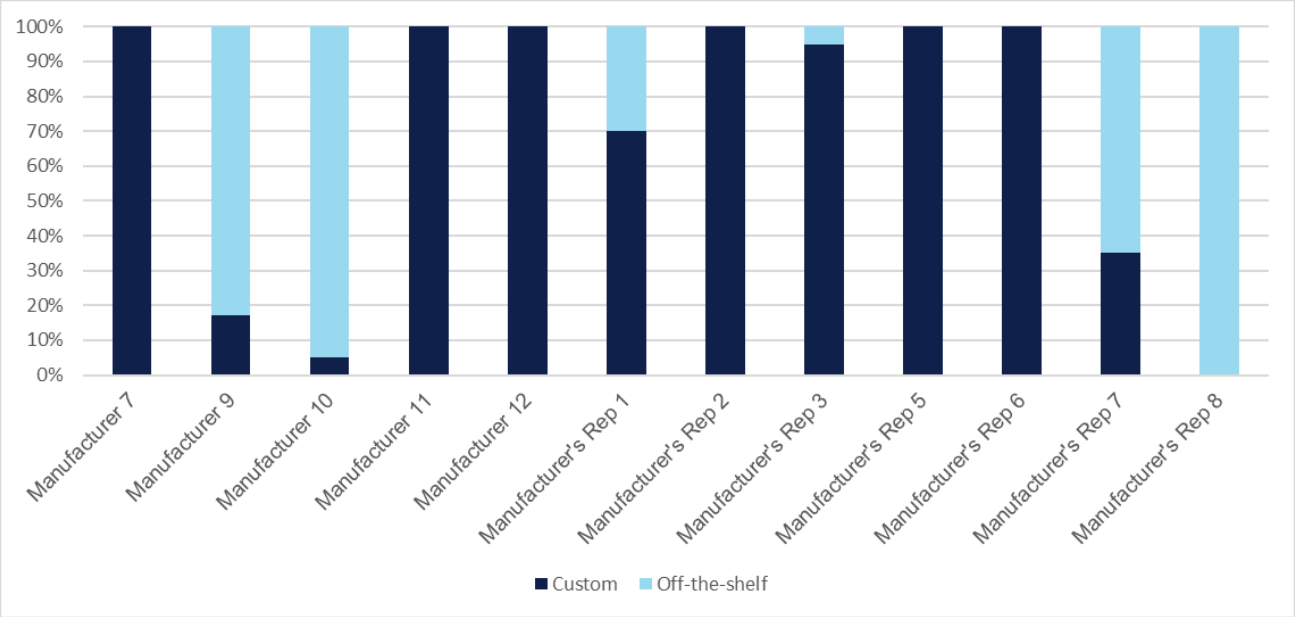
3.2.1 Market segmentation

The study team was able to further segment the manufacturers and manufacturers' representatives responses to provide insights into the types of projects and fan sales practices employed in the market.

3.2.1.1 Custom vs. off-the-shelf products

Consistent with prior research, most non-embedded fans are sold as custom products and are not stocked or available off the shelf. Figure 8 shows this distribution across all the respondents who were able to provide this data; note that this question was not asked of manufacturers interviewed during the Regional Market Share study, only of manufacturers and representatives interviewed during the Market Characterization. Four of the twelve respondents had mostly off-the-shelf products, while the remaining eight were either all or majority custom products.

Figure 8. Non-embedded fan sales of custom vs. off-the-shelf products.



3.2.1.2 Fan selection project types

The study team asked respondents to estimate the sales of their company's product by project type between new construction, planned replacements, early replacements, and other projects. Figure 9 shows the results for the 12 respondents who could provide the detail, and Table 2 shows the average responses for each category. New construction was the most-cited project type, representing on average 67% of sales, and is the best opportunity to influence the market, as fan selection for new construction is typically not bound by space constraints commonly encountered in replacement projects. The preference of maintenance managers to repair rather than replace older legacy fans, as discussed elsewhere in this report, helps explain the smaller share of fan sales accounted for by planned replacements. There was one manufacturer who cited a large percentage of other projects, clarifying that those are primarily tenant improvement projects, specifically opportunities to retrofit buildings to incorporate fans in commercial settings.

Figure 9. Respondent non-embedded fan sales by project type

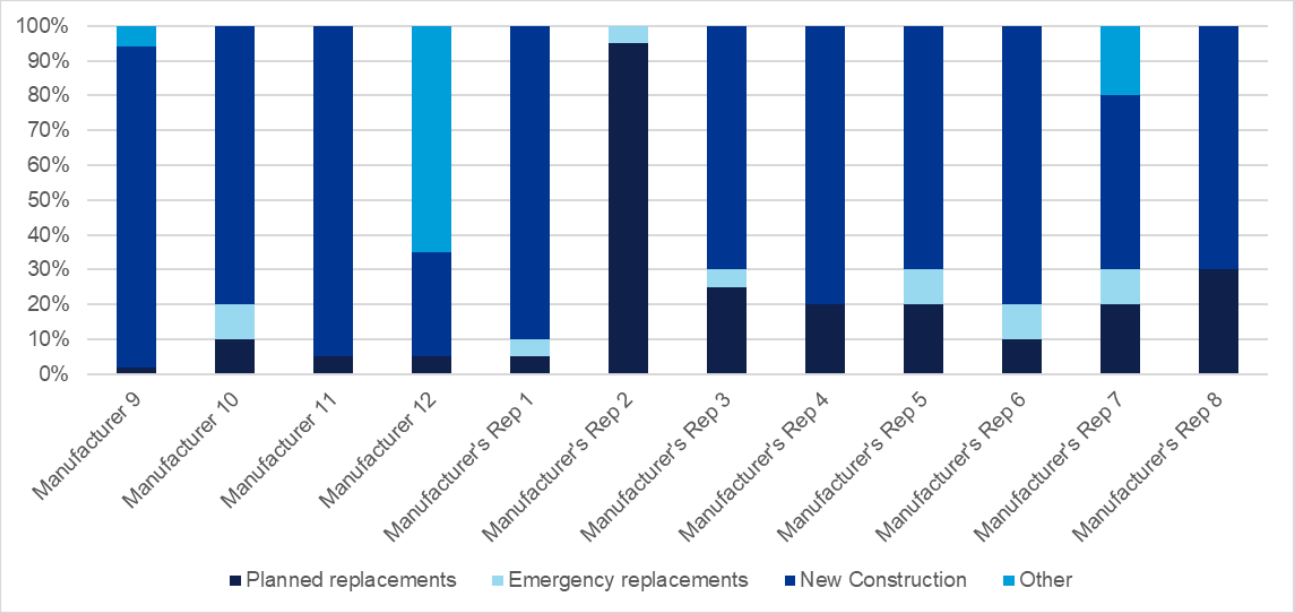


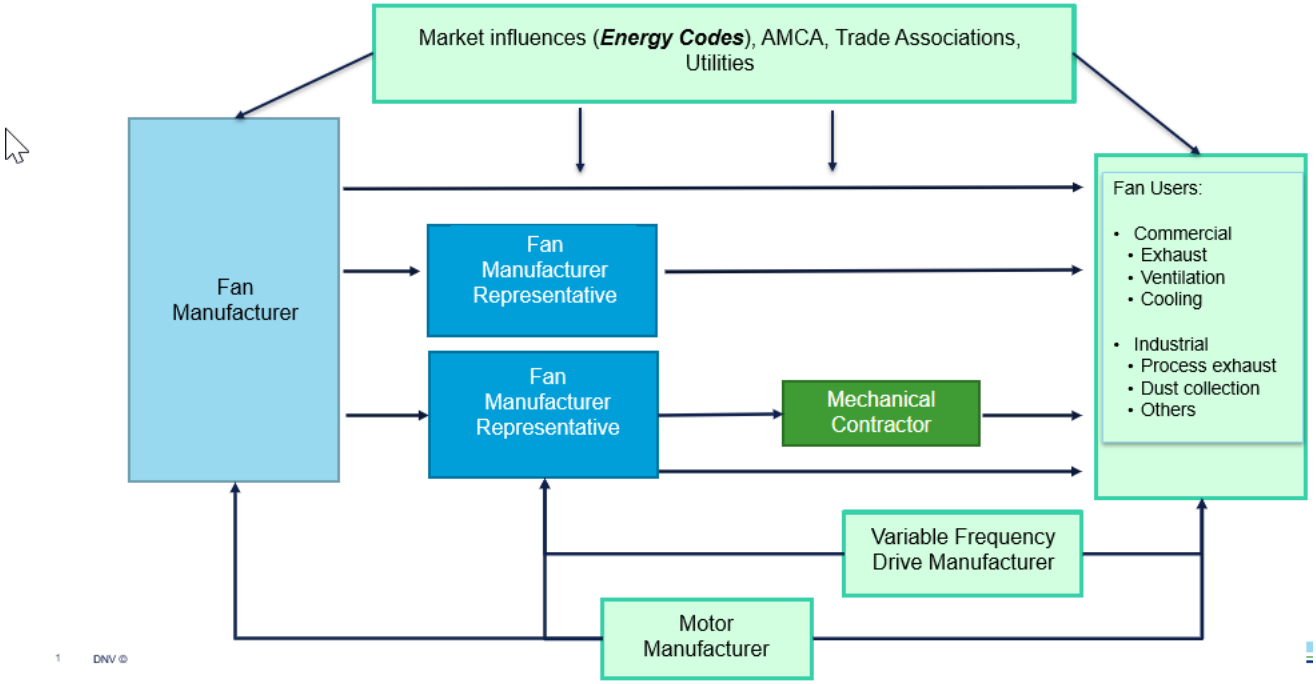
Table 2. Average sales by project type for manufacturers and manufacturers' representatives

Project Type	Average Percentage of Projects (n=12)
New construction	67%
Planned replacements	21%
Emergency replacements	5%
Other project types	8%

3.2.2 Market structure

In the 2021 fan market study, DNV developed a graphic to illustrate the fan market product flow. The 2023 round of fan market actor interviews did not reveal any changes in this product flow structure. The graphic is reproduced in Figure 10 as a reference.

Figure 10. Fan market product flow



It is important to note that while product flow is an important component of market structure, the fan specification and selection process is another dimension of market structure. This market dimension is covered in Section 3.2.3 (intermediate market actors) and Section 3.3 (the fan selection and specification process).

3.2.3 Intermediate market actors

While the previous two DNV fan market studies for NEEA defined the roles of the manufacturers and the manufacturers' representatives in the Northwest non-embedded fan market, the roles of other fan market actors—such as the fan specifiers and system integrators—remained somewhat vague. The current study attempted to better understand the roles of these intermediate market actors.

3.2.3.1 Specifiers/installers

The current study drew the specifiers/installers from two different lists. One list included engineering firms and the other included HVAC installation contractors. The fan specifiers/installers said that they were all engaged in the design and specification of mechanical systems, and they all worked with architects who were mostly outside their firm. They differed as to how much regular interaction they had with end use customers such as building owners. Five of the seven specifiers/installers said that they interact regularly with end use customers while two said they only interact rarely with these customers.

The fan specifiers/installers described the different type of projects they typically work on:

- *Design and specification:* For these kinds of new construction projects, the fan specifier/installer would be designing and specifying the mechanical systems for an architectural firm that would be leading a design team responsible for producing construction documents. With design and specification projects, the fan specifier/installer would not be involved in the actual installation of the mechanical equipment, which would be done by a separate construction team.

- *Design/build:* For these kinds of new construction projects, the fan specifier/installer would not only be designing and specifying the mechanical systems but also installing them. The C&I Fans Market Research study observed that design/build projects offer greater opportunities to consider the total cost of ownership than other types of new construction projects.
- *Facilities engineering:* For these kinds of projects, customers who owned buildings – such as hospitals or school systems – would contract the specifier/installer firms for engineering consulting services for existing buildings. These services might include monitoring current systems to optimize efficiency, troubleshooting any problems with the mechanical systems, scheduling routine maintenance of building systems, and recommending system improvements.

Three of the seven interviewees said they conducted fan installations in addition to fan specification.

3.2.3.2 System integrators

The current study completed interviews with two system integrators, limiting the study team's ability to draw broad assumptions about typical roles and services from such a small sample. Therefore, the responses of each system integrator are summarized separately.

- *System integrator #1:* This company reported doing about 60% of its business in new construction and the remaining 40% with existing buildings. It only installed new energy management systems in these buildings and did not deal with legacy energy management systems. While they mostly worked with large corporate end users, they occasionally did equipment installation work for general contractors.

  The company had a team of in-house building engineers who would specify mechanical systems such as fan systems and this group did most of their fan selection, although occasionally an architect or a general contractor would come to them with a request for a particular type of mechanical system. The company reported that its customers often asked for energy-efficient equipment. It identified the key factors that influenced fan selection as upfront cost most important, efficiency and durability next in importance, and noise reduction as a tertiary consideration.

- *System integrator #2:* This company reported doing a lot of work in the multifamily sector and working with building owners frequently and in some cases with developers and architects. It said it helped clients select fans, install fans, integrate these fans into existing systems, and service the fans. However, unlike the other system integrator, they did not get involved with the installation of energy management systems.

3.2.4 Fan Energy Index and general energy efficiency

This subsection focuses on the awareness and use of the Fan Energy Index (FEI) metric as well as the general role of energy efficiency in fan selection.

3.2.4.1 Fan Energy Index awareness and use in fan selection

The study team asked all market actors about their familiarity with the FEI metric, as well as the frequency with which the metric is used in fan selection for non-embedded fans. The interview guide first asked them: "Have you heard of the Fan Energy Index or FEI metric?" If they said "no" to this question, the team provided them a brief description of the FEI metric[11] and then asked again if they were familiar with it.

[11] The description of the FEI index provided was: "The Fan Energy Index or "FEI" is a measure of the relative energy efficiency of a fan compared to baseline equipment. It can be expressed as either: FEI = Fan Efficiency/ Baseline Fan Efficiency or FEI = Baseline Fan Electrical Input Power/Fan Electrical Input Power."

Table 3 shows FEI awareness across market actors. The study team asked all market actors about their familiarity with the FEI metric, as well as the frequency that the metric is used in fan selection for non-embedded fans. Fifteen of the 31 (48%) fan market actors claimed awareness of the FEI metric. In all but one case, they cited familiarity based on the first question (e.g., they did not need the follow-up description to recognize the FEI index).

Self-reported FEI awareness was highest among the fan specifiers/installers (86%) and lowest among the building maintenance managers (25%) and system integrators (0%). While all the larger Cohort 1 manufacturers had reported being aware of FEI and using this metric extensively in fan selection, market actors interviewed for the current study were not as familiar. For manufacturers, this is likely due to the smaller sized companies; half of the interviewees were aware of the metric, but only one reported any use of the metric in selection, while another was in the process of certifying its fans.

Table 3. Awareness of the FEI metric across fan market actors

	Manufacturers	Manufacturers' Representatives	Building Maintenance Managers	Specifiers/ Installers	System integrators	Total
Aware of FEI	3	4	2	6	0	15
Not aware of FEI	3	4	6	1	2	16
Total responses	**6**	**8**	**8**	**7**	**2**	**31**

For manufacturers' representatives, half were aware of FEI, but many of these interviewees were not able to estimate how often it is used in the fan selection process. Several respondents indicated that their engineering departments conduct the fan sizing and estimation of efficiency metrics.

The market actor group with the highest awareness was the fan specifier/installer group where five of the seven interviewees claimed initial FEI awareness and a sixth claimed FEI awareness after having received a description of the index. However, when asked how frequently they use the FEI metric when helping clients select a fan, most specifier/installers said none of the time and one said only 5% of the time. One specifier/installer observed that the brand of fans that they often work with for commercial kitchen design do not even show the FEI metric in their data. The interviewee said that in commercial kitchen design, efficiency is rarely considered and that more attention is paid to noise levels and fan performance curves. Two of the specifier/installers who did a lot of business in Washington state observed that the state building code does require that fans satisfy FEI requirements and therefore the metrics are included in their fan selection considerations.

None of the specifiers/installers, with one exception, said that their customers bring up the FEI metric on their own accord. The one specifier/installer who has experienced customer-initiated FEI discussion said that this happens "rarely." When asked why their clients do not mention the FEI metric, most of the fan specifiers/installers said it was due to simple unawareness. Fan specifier/installer perspectives on the barriers to wider adoption of the FEI index appear in the barriers section below. Neither of the two system integrators were aware of the FEI metric.

The study team asked the two building maintenance managers who were familiar with the FEI metric whether they had seen the metric being referenced in any of their fan selection decision-making. One of these maintenance managers said that he had seen it referenced in only a small percentage of cases and only for the purchase of a new fan installation (vs. the replacement of an existing fan). "If it's a new installation, [energy efficiency] will factor in fairly high," the interviewee said. "We want the new stuff to be as efficient as

possible." The other maintenance manager estimated that the FEI metric has played a role in only about 10% of the cases when they were making a fan selection decision. However, in those few cases he also estimated that the FEI rating had influenced his organizations' decision-making 90% of the time. "But those instances haven't been the emergency instances either," the interviewee observed. "If it was an emergency fan replacement, you would overlook [the FEI index] a little bit more."

3.2.4.2 The role of general energy efficiency in fan specification

Although the market actors indicated that the FEI index is only rarely used in fan selection, energy efficiency in general was considered more frequently than this in fan selection. When asked to identify the types of customers or applications where energy efficiency is valued more in fan selection, the fan specifiers/installers mentioned the following:

- Pharmaceutical companies: One specifier/installer estimated that 90% of the pharmaceutical companies they serve are seeking efficient fans
- New construction
- Any operations where fans are running 24/7
- Larger, "sophisticated" customers, such as health care, precision manufacturing, data centers
- State or federal governments
- Multifamily buildings, which often request ENERGY STAR® equipment[12]

When the study team asked the fan specifiers/installers how often their customers are bringing up fan energy efficiency or fan operating conditions before the fan specifiers/installers mentioned it, one said "sometimes," four said "rarely," and two said "never." One interviewee said that the availability of rebates for variable-frequency drives (VFDs) can occasionally get customers interested in energy efficiency. Another said that interest in efficiency "always stems from carbon footprint concerns and goals."

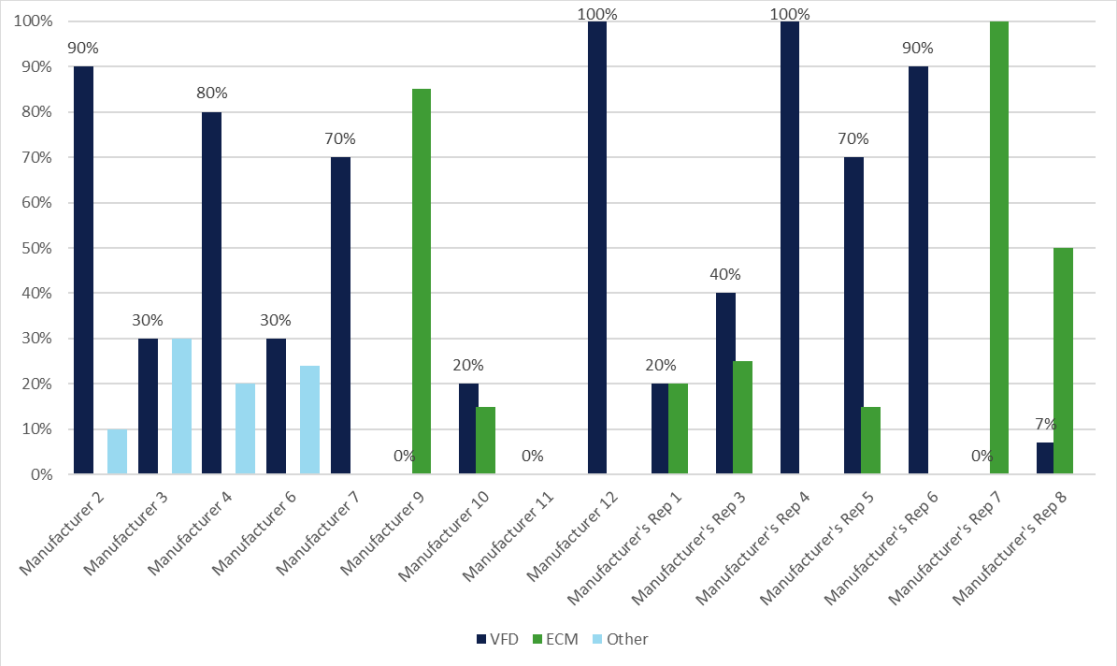
3.2.5 Fan controls

The study team asked the manufacturers and manufacturers' representatives about the frequency with which fan controls were supplied on non-embedded fans. Figure 11 shows the responses regarding fan controls for those interviewees who were able to provide estimates. In the Fan Manufacturer Regional Market Share Research study (Manufacturers 1 through 6), respondents were asked about VFDs (navy blue), as well as other controls (light blue). In the current study, respondents were asked specifically about VFDs and electronically commutated motor (ECM) controls on fans (green).

The chart shows there was wide variability in fan control use among the manufacturers' representatives. Several representatives reported that all, or nearly all, of their fans were sold with some type of fan control, while others only sold 40%–55% of their fans with controls. The chart also shows that a couple of manufacturers' representatives and one manufacturer have heavily adopted ECMs. Since ECMs work best with lower horsepower fans (e.g., less than 10 horsepower), this preference for ECM controls is likely correlated with the size of fans that they sell.

[12] While not probed in the interviews conducted for the present study, it is likely that these comments refer to ENERGY STAR certified ceiling fans and similar residential equipment that falls outside the scope of non-embedded fan products targeted by NEEA's Efficient Fans program.

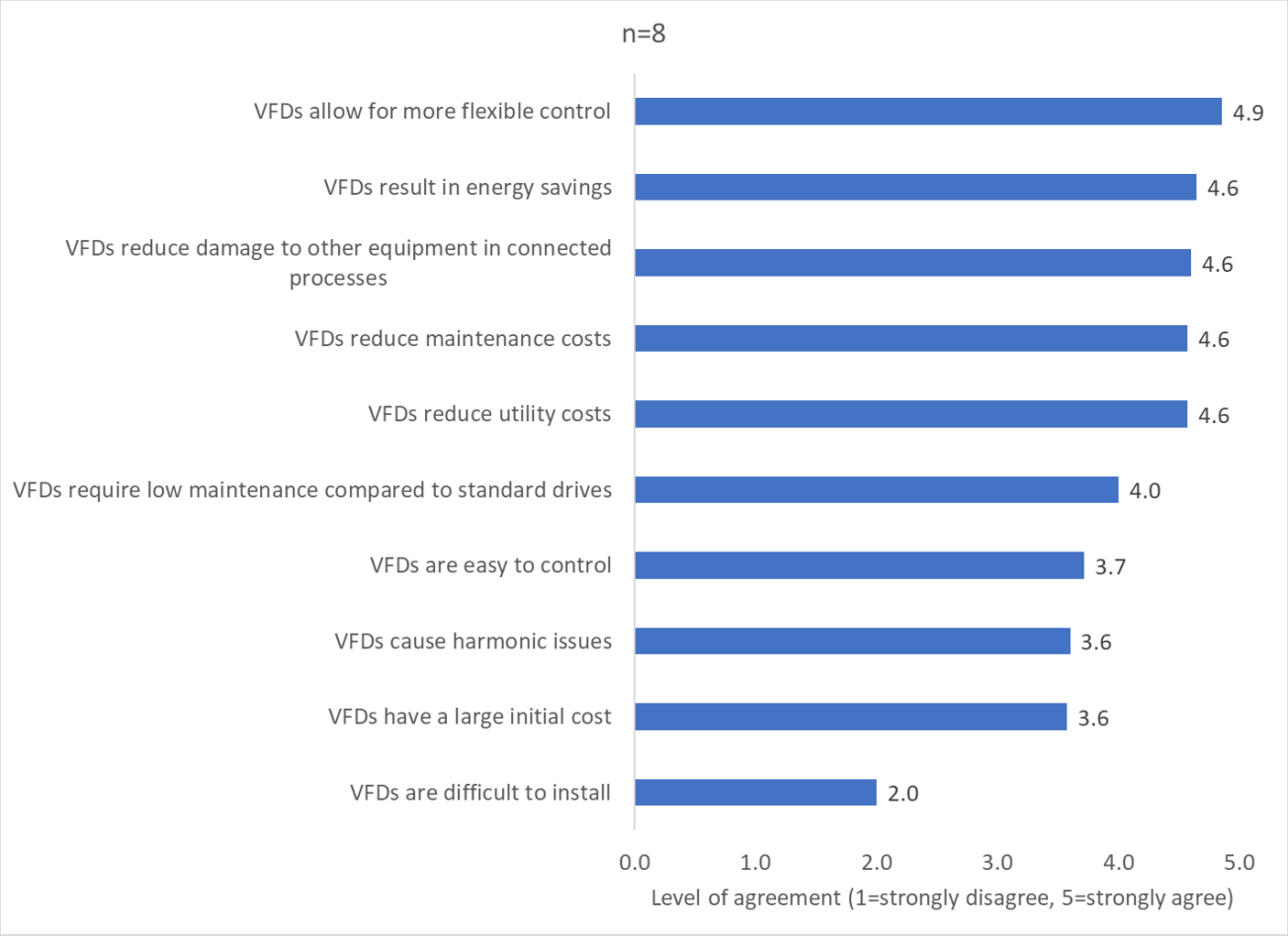
Figure 11. Percentage of non-embedded fan sales with fan controls.



Respondents reported an average of 43% of fans sold with VFDs and another 26% of fans sold with ECMs, for a total average of 69% with some fan control. Several manufacturers and representatives indicated they do not sell controls themselves but that representatives or other third parties often provide aftermarket controls.

The study team also asked the building maintenance managers whether they used VFDs. Seven of the eight maintenance managers said they have VFDs installed in their buildings, and one said they have a VFD on nearly every fan or pump they use. The study team asked the maintenance managers about their level of agreement with 10 different statements about VFDs using a scale where 5 equaled strongly agree and 1 equaled strongly disagree. Figure 12 shows that the interviewees viewed VFDs in a very positive light with five of the attributes—more flexible control, energy savings, reducing damage in other equipment in connected processes, reducing maintenance costs, and reducing utility costs—receiving average agreement levels of 4.6 or higher.

Figure 12. Level of maintenance manager agreement with VFD attributes



While the study team did not ask the maintenance managers to explain their ratings, a few of the building maintenance managers commented on their ratings, especially if they were lower:

- VFDs are easy to control:
  - *Agreement rating of 3:* "Just going through the parameters and the menu of a VFD trying to set it up is kind of cumbersome."
- VFDs result in energy savings:
  - *Agreement rating of 3:* "Depends how they're set up."
- VFDs *cause harmonic issues:*
  - *Agreement rating of 3:* "It depends how they're set up. … That they cause harm, they can. They can also avoid harm, so call it a three."

3.3 The fan selection and specification process

3.3.1 Motivations for fan replacement

One key finding of the study was that the full replacement of non-embedded fans is relatively rare. For example, one building maintenance manager said that his organization had replaced only one non-embedded fan in his seven-year tenure, and another said that no non-embedded fans had been replaced in his three-year tenure, although the building had replaced two fans embedded in an Integrated Heating Pump (IHP) system. A maintenance manager at a hospital said that only a couple of their 30 exhaust fans had been replaced in the last fifty years.

More commonly, building maintenance staff reported keeping existing fans going via the routine replacement of standalone fan components such as motors, shafts, bearings, and belts/pulleys. Some observed that replacing fan components such as bearings and belts can be purchased relatively inexpensively through auto part supply channels or general wholesalers such as Grainger's. However, one interviewee observed that the cost of purchasing a new motor was "getting pretty close to … the cost of replacing the fan." Two of the interviewees reported that they had fans manufactured in the 1970s that were still operating due to this routine maintenance. Representative quotes from building maintenance managers included:

- *Just because the cost is less, I do still replace bearings, pulleys, motors, re-bearing motors, or if I have to, purchase a new motor.*
- *We typically didn't replace [the fans]. We just rebuilt them and kept going. The ones that were there seemed to last fairly well. So, we weren't going to go with some random, off-the-shelf thing and hope that it works.*
- *That's the virtue of all this old stuff, is it was designed to be repaired, not just replaced. … most of the parts that these things need are old automotive parts, so they're just not that expensive. The last set of bearings I put in the squirrel cage [fan] upstairs cost me $22.*
- *At this building we haven't had to actually replace any fans because, … we do routine maintenance on them. Our PM [preventive maintenance] crew comes through quarterly, so they're getting looked at every three or four months. And so we replace bearings, belts, shims, as needed, hopefully to keep it going.*

According to the interviewees, total fan failure that could not be addressed via component replacement was the most common motivation for full fan replacement. Other, less commonly cited reasons included:

- Improving the efficiency of the fan via a more efficient motor or the installation of a VFD or other control system,
- Changing fan systems to address COVID-19 pandemic ventilation/exhaust requirements,[13] and
- Adding a new production area in a factory.

3.3.2 Non-embedded fan decision-making

This subsection discusses which market actors are involved in fan selection, first from the perspective of the fan specifier/installers and second from the perspectives of the building maintenance managers.

3.3.2.1 Fan specifier/installer perspectives

The fan specifiers/installers did not give a consistent description of who were the key decision-makers in fan selection. For example, some said that the building owners had little or no influence over the fan selection process while others claimed they had some influence. These differing views are likely due to inherent differences in the business practices of the specifiers/installers, which are discussed in Section 2.4.2. As

[13] During the COVID-19 pandemic both the Center for Disease Control and Prevention (CDC) and ASHRAE issued new ventilation guidelines (Ventilation in Buildings | CDC and guidance-for-re-opening-buildings.pdf (ashrae.org))

discussed there, some specifiers/installers work regularly with end users while others do not. Therefore, it would not be surprising if the specifiers/installers who often worked with end users would be more likely to credit building owners with influence over the fan selection process.

Other observations from the fan specifier/installer interviews included:

- *Generally, the fan specifiers/installers have the most influence on choosing the fans to include in building designs.* This includes engineering firms as well as manufacturers' representatives. Some engineers reported using selection software themselves, others said that they outsourced that activity directly to the manufacturers' representatives.
- *Building owners typically have little influence on the fan selection process.* They may have budgetary restrictions that affect selection but are generally not aware of the specific fan specification parameters. However, for retrofits, some fan specifiers/installers indicated that owners may be more involved if they have familiarity with the prior equipment.
- *Some contractors/installers are engaged in selection, but other interviewees reported little to no influence on the design for these actors.* However, the contractor is most often the party who is purchasing and installing the fan, so they may choose the fan or substitute with a different product.
- *Specifiers reported varying practices regarding the number of fan options they provide.* Some choose a single fan to include in the design, while others reported providing a list of options that vary by price and efficiency.
- *Specifiers reported consistent processes regardless of installation type (new construction vs. replacement).* However, some indicated that for replacements, the building owner or facilities team may have more influence if they have a brand preference/familiarity. For emergency replacements, fan availability plays a larger role, as there's a need to get the replacement fan up and running as soon as possible.
- *Architects were generally not involved in fan selection decisions:* The fan specifiers/installers reported that architects typically do not care what mechanical equipment is selected as long as it does not take up too much space or negatively impact the building aesthetics.

3.3.2.2 Building maintenance manager perspectives

The building maintenance managers identified themselves as important decision-makers in fan selection. Seven of the eight interviewees said they play a role in the fan selection process at their companies or organizations. In general, the smaller the fan project, the more influence the building maintenance managers reported having over the selection process. For example, they reported near total freedom over decisions to replace fan components since these costs were relatively low and most could pay for the components out of their building maintenance budgets.

The next step up in project size, according to the interviewees, was the replacement of a fan with one of similar size and function using in-house labor with no additions such as VFDs. With projects of this size, the building maintenance managers would still have significant influence over the fan selection, but because of the higher cost they would typically share the decision with others in their organization. Usually, these people were other facility managers (such as the interviewee's boss) who had approval authority for larger project expenditures.

One interviewee described how he interacted with his managers on equipment replacement decisions:

> *It's obvious … that management relies on my judgment. But, on the other hand, my boss is smart enough to insist that I defend things logically rather than just saying: 'Because I said so.' And this requirement that you develop a logical case process to do anything keeps everybody honest. It keeps me honest. And so as far as this decision-making matrix … in these environments, it's a cooperative*

> *decision-making process. They rely on me to state the problem and mitigate the problem, but they also rely on themselves to look at long-term solutions based on my input.*

Still larger fan projects might involve the installation of new fans in an existing or new space, the replacement of an existing fan with one of a different size or function, or the addition of VFDs or other controls to existing fans. For roof-mounted fans, the installation of a VFD typically involves roof penetration and then ducting over. Due to the increased complexity of such projects, most interviewees said that they could not complete these projects with in-house resources but had to involve outside contractors.

Most interviewees said such larger projects involved bid solicitations and sometimes a wider group of company decision-makers than had been the case for the one-to-one fan replacements. In some cases, these additional decision-makers might be technical resources. For example, one interviewee observed that a new fan required the involvement of company electricians so they could provide specs for the voltage and electrical current. In other cases, they might be an entity required to approve expenditures above a certain dollar threshold such as a capital expenditures committee for a company, a board for a non-profit organization, or a property management committee for a commercial building.

One maintenance manager in a commercial building described the typical process:

> *So, typically, we would bring [a proposal for a new fan installation] to property management. If they have any concerns about the cost of it, they might ask us to get additional bids. But, generally, for larger items, we present them multiple bids and let them choose. But for smaller things, if it's a few thousand dollars and we need to replace a fan motor or something like that, typically, we present that to them, and there usually isn't too much pushback.*

There was a mixed response from the building maintenance managers as to how much involvement their companies/organizations had in specifying the types of fans for these larger projects. Some deferred to the vendors beyond providing some performance specifications, as one interviewee explained:

> *"For the [fans] that I am replacing, I have a little bit of input [on the fan type]. We do a lot of research and see what suits the situation. But if we contract it out, we kind of let [the vendors] do all their research on the fan. … We come up with the air requirements needed for the fan and then they just build that fan based on those statistics. … [Then] they provide us with a bid, and we accept it or not.*

However, other interviewees reported that their organizations had requirements in their bid solicitations such as energy efficiency that went beyond the minimum performance requirements.

After the presentation of preliminary results from this study in late August, NEEA staff expressed interest in knowing whether bidding fan vendors typically offer end users multiple options in their bid submissions or push a particular solution. One building maintenance manager suggested that it varied with the vendors:

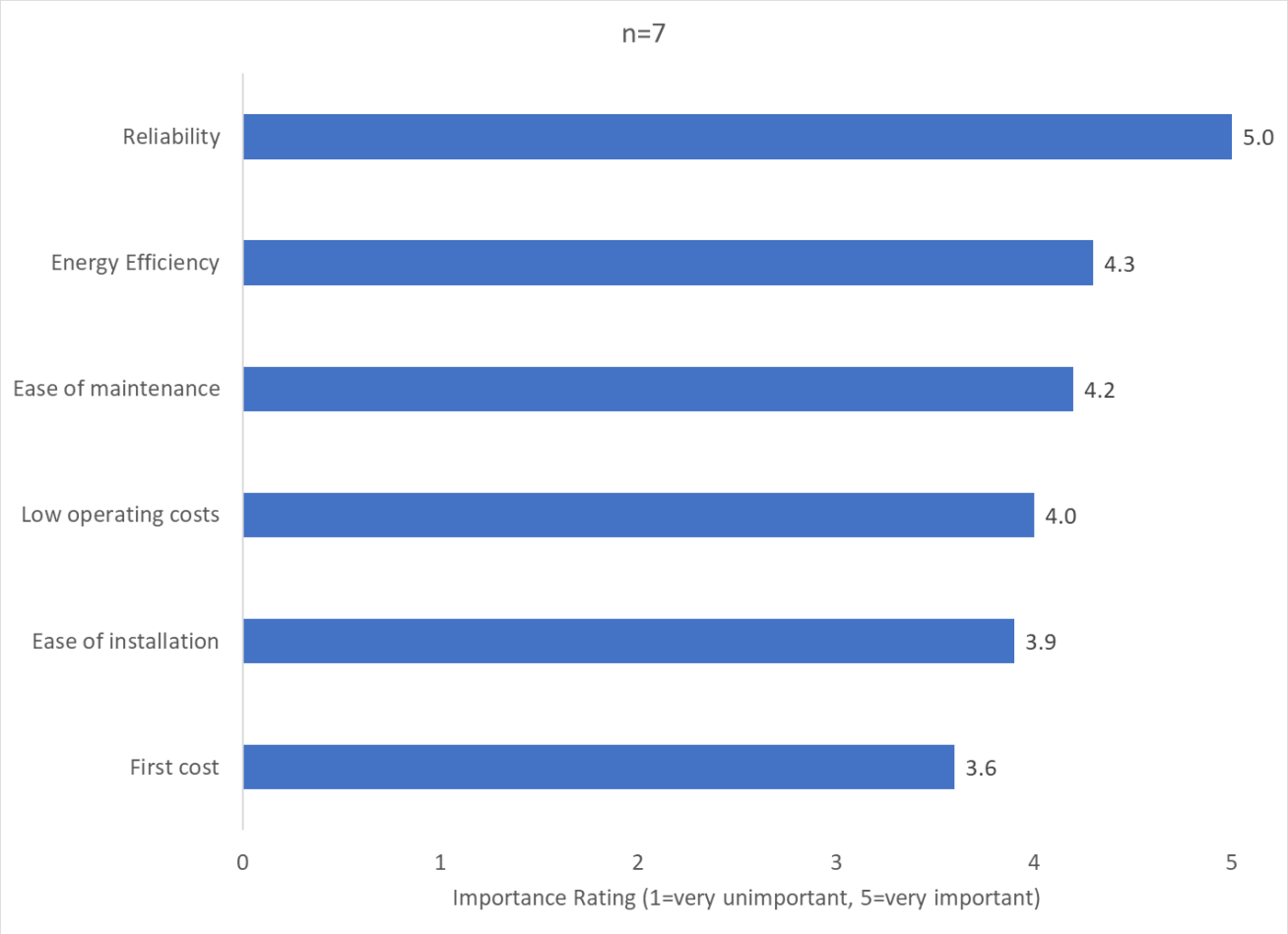
> *Some vendors come back and say: 'Hey, this is the greatest thing since sliced bread.' Other vendors come back and say: "Hey, these are three options." Maybe this one is more efficient, this one costs less, and this one is no maintenance since everything is sealed, and you don't have to touch it for 30 years. So different vendors come back in different ways.*

3.3.3 Key factors influencing fan selection and installation

The study team asked the building maintenance managers to weigh the relative importance of various factors that might influence the selection of non-embedded fans using a five-point scale where a one equals

"very unimportant" and five equals "very important." Seven of the eight interviewees provided these importance scores (one interviewee said that he was not involved enough in the fan selection process to rate these, although he did provide qualitative information about his company's selection criteria). Figure 13 shows that building maintenance managers gave reliability their highest average importance score followed by energy efficiency and ease of maintenance.

Figure 13. The relative importance of fan selection criteria



The following subsections provide more details on why the maintenance managers assigned these levels of importance to their fan selection criteria.

3.3.3.1 Reliability

The reliability of the new fans was the most important consideration for fan selection among the building maintenance managers (average importance rating of 5 out of 5). The fact that several interviewees reported successfully maintaining fans that dated to the 1970s likely reinforced their stated belief that the older fans had better quality manufacturing and that newer fans might not prove as reliable. "*Stuff nowadays really isn't made that well*," one of the maintenance managers claimed. Fan reliability, or lack thereof, can also impact other important fan selection criteria such as operating costs and ease of maintenance. Some representative quotes from the maintenance managers concerning the importance of fan reliability included:

- "Our *current fans, … which are … from the 1970s, are old, inefficient, but they've been running for 50 years. Stuff nowadays really isn't made that well. [So necessary information for new fans is] information on quality."*
- *"If I was to say a barrier for purchasing new [fans], they either have to have an extremely long warranty or be designed so that they're easy to repair."*
- *"In the medical [sector], … It can literally be life or death type situations [that are relying on fan performance]."*

3.3.3.2 Energy efficiency

The building maintenance managers gave energy efficiency the second highest average importance rating among the fan selection criteria (average importance rating of 4.3 out of 5). Two interviewees observed that their interest in energy efficiency would depend on the size and operating hours of the fans in question. One maintenance manager noted that the fan requirements for metal casting were orders of magnitude greater than for simple ventilation functions. "If you look at the [fan] load of a steel arc furnace compared to ceiling fans, [the latter] is less than a rounding error," the interviewee said. For similar reasons, another maintenance manager did not see the value of adding VFDs to their small bathroom exhaust fans:

> *We won't throw a bunch of money at these bathroom fans because they just don't draw that much juice. I mean, think about it. You got a half horse motor. You got three of them. They run 12 hours a day. For us, it looks like the tempest in a teapot*.

One interviewee observed that in a factory expansion scenario they would be more likely to value energy efficiency in fan selection. "I might not be able to get as efficient a fan for the existing layout," the interviewee said, "but when installing something new I could look into getting, as part of the process of designing a new space, the design of a more efficient [fan] system."

Two of the maintenance managers said that they would value energy efficiency in fan selection because of broader company policies. "We would definitely try to look at energy efficiency," said one interviewee. "[Our company] is pretty big on sustainability and efficiency … so that would definitely be a huge consideration." "The new push towards energy conservation … that's one of the big things that we're doing," said another.

Some other representative quotes from the maintenance managers concerning the importance of fan energy efficiency included:

- *"I like saving money or just energy as much as I can."*
- *"We specifically ask for [fan efficiency in our bid solicitations] because we can get incentive programs for an ultra-efficiency fan. The state of Oregon has energy-efficiency programs that sometimes give you rebates back on putting in more efficient equipment than what was there before."*
- *"We'd be far more likely to get the high-efficiency fan for two reasons. Number one, it costs as much money. But number two, that is just the sort of thing that we can get incentive moneys from Energy Trust of Oregon or our electric cooperative. They both worked very well with me, especially ETO, with subsidies for upgrading our stuff to more efficient equipment."*

3.3.3.3 Ease of maintenance

The building maintenance managers gave ease of maintenance the third highest average importance rating among the fan selection criteria (average importance rating of 4.2 out of 5). "Ease of maintenance always comes into play because the more replaceable parts you have on a fan, the more money it's going to end up costing the

organization," said one interviewee. "I want very little [fan] maintenance because getting up on the roof is a pain in the ass," said another. "If I don't have to have guys up on the roof, that's a lot of man-hours saved."

As noted, many of the maintenance managers had successfully kept very old fans operating for many years and therefore they hoped for similar ease of maintenance in any new fans they purchased. "The other thing I like about the old [fan systems] is that all the bearings have grease inserts on them," said one interviewee. "The new ones are all sealed, so you can't grease them and when they go bad, they're done. The old ones, when they start to howl, you just grease them up, and they keep going."

3.3.3.4 Low operating costs

The building maintenance managers gave low operating costs the fourth highest average importance rating among the fan selection criteria (average importance rating of 4.0 out of 5). A couple of the interviewees made the point that long-term fan operating costs were greater than first costs. "The up-front cost is only a small portion of total ownership cost of those things," said one of the maintenance managers. Two of the interviewees also observed that the importance of operating costs varied with the fan system's hours of operation. "If [the fan] is going to be run 24/7, [operating cost] is much more important, but if [fan operation] is intermittent, it's less important," one of them said.

The average importance rating for low operating costs would have been higher if not for one interviewee giving it only an importance rating of two. He gave it this low rating because his company was in a transition period where they were moving into a large fabricating facility. "That transition is kind of slow for us and so I don't know that we think ahead that much," the interviewee said. "We'll worry about [operating costs] five years down the road."

3.3.3.5 Ease of installation

The building maintenance managers gave ease of installation the fifth highest average importance rating among the fan selection criteria (average importance rating of 3.9 out of 5). One maintenance manager observed that the importance of ease of installation depends on the fan type and location. While he could replace some fans himself, if the new fan required roof penetration or ducting, he would have the fan contractor do the install. Another maintenance manager observed that while ease of fan installation is helpful, if there was a trade-off between the energy efficiency of a fan and its ease of installation, he would choose the efficiency. "We don't want [the fan system] to be a nightmare to get in there," the interviewee said. "But if it's going to be twice as efficient as something else, then I don't mind staying late."

3.3.3.6 First costs

The building maintenance managers gave first costs the lowest average importance rating among the fan selection criteria (average importance rating of 3.6 out of 5). The point made earlier—that the long-term operating costs of the fans were larger than the first costs—was one reason for the low importance rating. One maintenance manager also said that his company had encountered many problems with cheaper equipment:

> *I was bawled out by overhead for not looking at less expensive motors, fans, and fan assemblies … Then I watched a Taiwan fan motor seize, stop the pulley, break the belt, then the carcass of the belt beating a hole in a condenser matrix. … I replaced our entire heating array in 2021. The hot water circ pump was replaced by our vendor with two different models from India. These both were a problem. They did not pump as hard as the spec stated, but the worst part was that these brand-new pumps seized as well, burned them up real sweet. …. Labor is the biggest cost. My labor to chunk through second tier, imported, low-cost junk has cost me and my clients money, time, and stress.*

Maintenance managers who worked in hospitals also said that the importance of having reliable fan systems to serve critical hospital spaces, such as operating rooms, meant that fan cost was not an important consideration. "Patient safety is the primary goal, that supersedes any budgetary concerns," said one of these hospital maintenance managers. "So, I've found that in medical our pockets are deep and if I can frame it into a safety type concern, then you don't get much pushback. If you say it's a life safety issue, they don't argue."

3.3.3.7 Emergency replacement

The building maintenance managers acknowledged that total fan failure could narrow their fan replacement options, but there was often some flexibility in these situations. "The [fan] that I just replaced here six months ago, it actually failed, but it was a general exhaust [fan] in an area where we had a little bit more time to just do research and purchase a fan and get it installed," said one interviewee. Another interviewee observed that the urgency to replace a failed fan depended on how many fans were serving a given application. "If it's 1 of 18 [fans], then nobody is going to miss it," the interviewee said. "If it's one of three, somebody is going to miss it."

3.4 Barriers to efficient fans

This section presents the study team's assessment of the primary barriers to adoption of efficient non-embedded fans in the Northwest.

3.4.1 Perspectives of manufacturers and manufacturers' representatives

The study team asked manufacturers and manufacturers' representatives to rate their agreement with a list of barriers that inhibit sales of high-efficiency non-embedded fan sales in the Northwest (on a 1 to 5 scale where 1 equaled strongly disagree and 5 equaled strongly agree), and to also rate the difficulty in overcoming each barrier that they agreed was a challenge (where 1 equaled very difficult and 5 equaled very easy to overcome). Table 4 presents the average responses across all respondents.[14] Overall, the barriers with the highest agreement, such as customers unwilling to replace operable fans and high first costs of new fans, were also identified as the most difficult barriers to overcome.

[14] To improve the readability of this table, we flipped the scale for the difficulty in overcoming the barrier so that a 5 equals "very difficult" whereas in the interview guide a 1 equaled "very difficult."

Table 4. Perspectives on barriers from manufacturers and manufacturers' representatives

Barrier	Average Agreement (5 equals strongly agree)	Average Difficulty to Overcome (5 equals very difficult)
Customers unwilling to replace inefficient fans because they are still operable	4.4	3.3
High first costs	4.3	3.0
Preferences for like-for-like replacement	3.7	2.4
Lack of data on ROI [return on investment]	3.6	2.2
Lack of requests from end-users for high-efficiency	3.6	2.4
Prioritizing other factors such as physical size	3.3	2.6
Lack of consideration due to relatively low contribution to load	3.1	2.6
Low ROI	3.0	1.8
Fan suppliers lacking specialized knowledge to help customers optimize fan efficiency in certain applications	2.6	0.5

3.4.2 Perspectives of other market actors

This subsection describes the barriers to energy efficient fans that other fan market actors such as specifiers/installers, building maintenance managers, and system integrators identified.

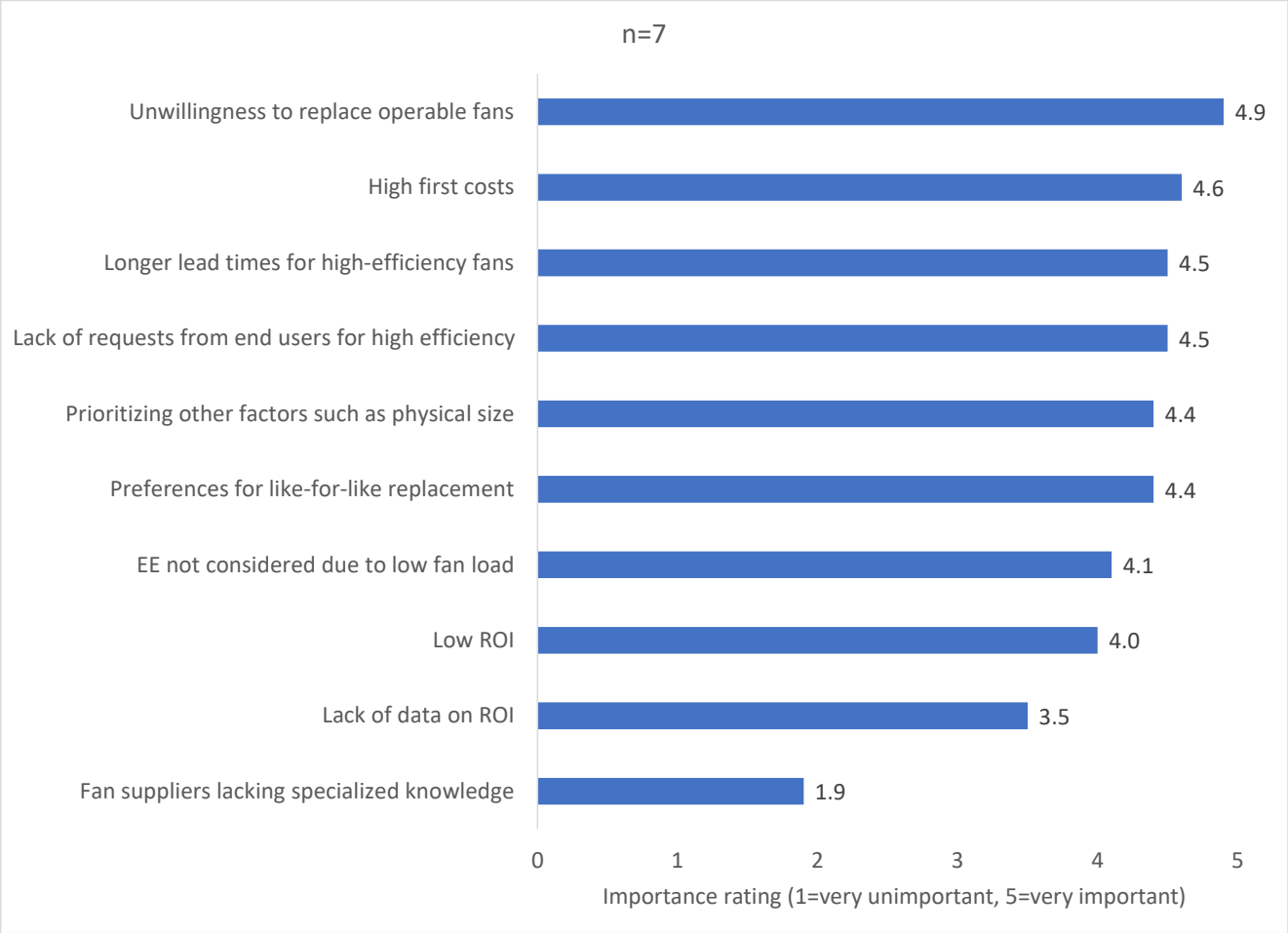
3.4.2.1 Fan specifiers/installers

The study team asked the fan specifiers/installers what barriers prevented wider use of the FEI metric. They mentioned the following:

- There is a lack of FEI and other energy efficiency information for the smaller fans often used in commercial applications.
- Specifying a certain FEI metric can increase the size and cost of the fan and motor which can result in customer pushback.
- There is a lack of FEI information from vendors in general except in Washington state where building code requirements forced the vendors to start providing this information.
- Fans used in environments with explosive atmospheres or hazardous area environments are harder to designate for the FEI index because the certification process for that equipment is so strenuous it hasn't been updated in about 50 years.

The study team also asked the fan specifiers/installers for their perspectives on barriers to the purchase of high efficiency fans. They identified the unwillingness to replace operable fans and high first costs as the two most significant barriers. Figure 14 shows all their responses.

Figure 14. Fan specifier/installer perspectives on barriers to high efficiency fans



3.4.2.2 System integrators

The study team asked the two system integrators for their perspectives on barriers to the purchase of high efficiency fans. Table 5 shows their responses. The two interviewees both agreed on high first costs, low ROI, and lack of data on ROI as barriers. However, they had differing opinions on the other barriers.

Table 5. System integrator perspectives on barriers to high efficiency fans

Barrier	System Integrator #1	System Integrator #2
High first costs	Strongly agree	Strongly agree
Low ROI	Strongly agree	Agree
Lack of data on ROI	Agree	Agree
Lack of consideration due to relatively low contribution to load	Not sure	Agree
Lack of requests from end-users for high efficiency	Disagree	Agree
Preferences for like-for-like replacement	Not sure	Disagree
Prioritizing other factors such as physical size	Neutral	Agree
Longer lead times for high-efficiency fans	Not sure	Neutral
Fan suppliers lacking specialized knowledge to help customers optimize fan efficiency in certain applications	Disagree	Agree
Customers unwilling to replace inefficient fans because they are still operable	Agree	Neutral

3.4.2.3 Building maintenance managers

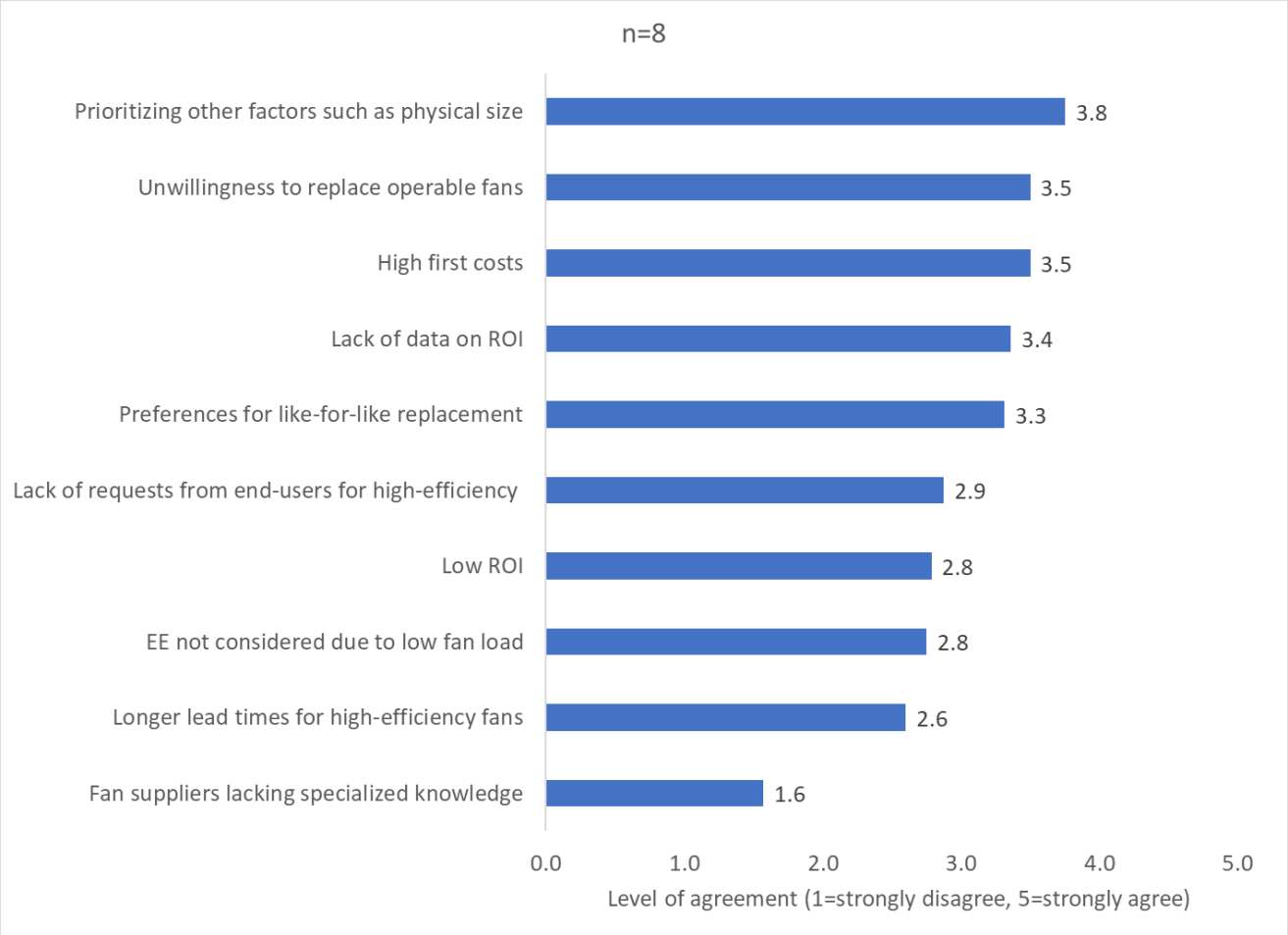
The study team asked the building maintenance managers how much they agreed with same list of barriers to the purchase of high efficiency non-embedded fans (Figure 15). Their perspectives were similar to those of the manufacturers and manufacturers' representatives in most respects. For example, four of the maintenance manager's top five barriers—preferences for like-for-like replacement, lack of data on ROI, the unwillingness to replace operable fans, and high first costs—were also among the top five barriers for the manufacturers and manufacturers' representatives, although the order was somewhat different.

There were a few differences. Interestingly, the maintenance managers, who theoretically should be most familiar with end user preferences, were less likely to think that lack of requests from end users of high efficiency was a barrier than the manufacturers and manufacturers' representatives (2.9 average agreement rating vs. 3.6 average agreement rating).

The end users were also generally less likely than the manufacturers and manufacturers' representatives to consider the barriers to be significant. For example, the most significant barrier that the maintenance managers mentioned – prioritizing other factors such as physical size -- only got a 3.8 average agreement rating. In contrast, the top barriers for the manufacturers and manufacturers' representatives had average agreement ratings of 4.4 and 4.3 respectively.

DNV asked the maintenance managers about one additional barrier: longer lead times needed for obtaining high-efficiency fans due to vendors not stocking these models. This barrier received a 2.6 average agreement rating.

Figure 15. Perspectives on barriers from building maintenance managers



Some of the maintenance managers gave explanations for their barrier ratings:

- Preferences for like for like replacements:
  - *Agreement rating of 1 (strongly disagree):* "Model, or brand name doesn't necessarily mean much. I mean we'll look at a certain brand, yes, but if I find an equivalent good brand that has a good reputation for longevity, I'll get that fan."
  - *Agreement rating of 2.*5: "I would say probably a two or a three. At this point, the stuff in here is so old that I would imagine anything that we're replacing it with … like for like is current would … be way more efficient than what we have anyway."
  - *Agreement rating of 5 (strongly agree):* "We do a lot of times replace like with like, so I would say that's very, very common here. And like I say, if there's energy incentives to go with a more efficient one, then, yeah, we'll probably go with the more efficient one. But otherwise, it's like for like."
- Longer lead teams for high efficiency fans:
  - *Agreement rating of 3:* "That all depends on need."
  - *Agreement rating of 3:* "General lead times on a lot of things has been a little bit of a barrier. It's kind of bad out here. I'd say probably about a three."

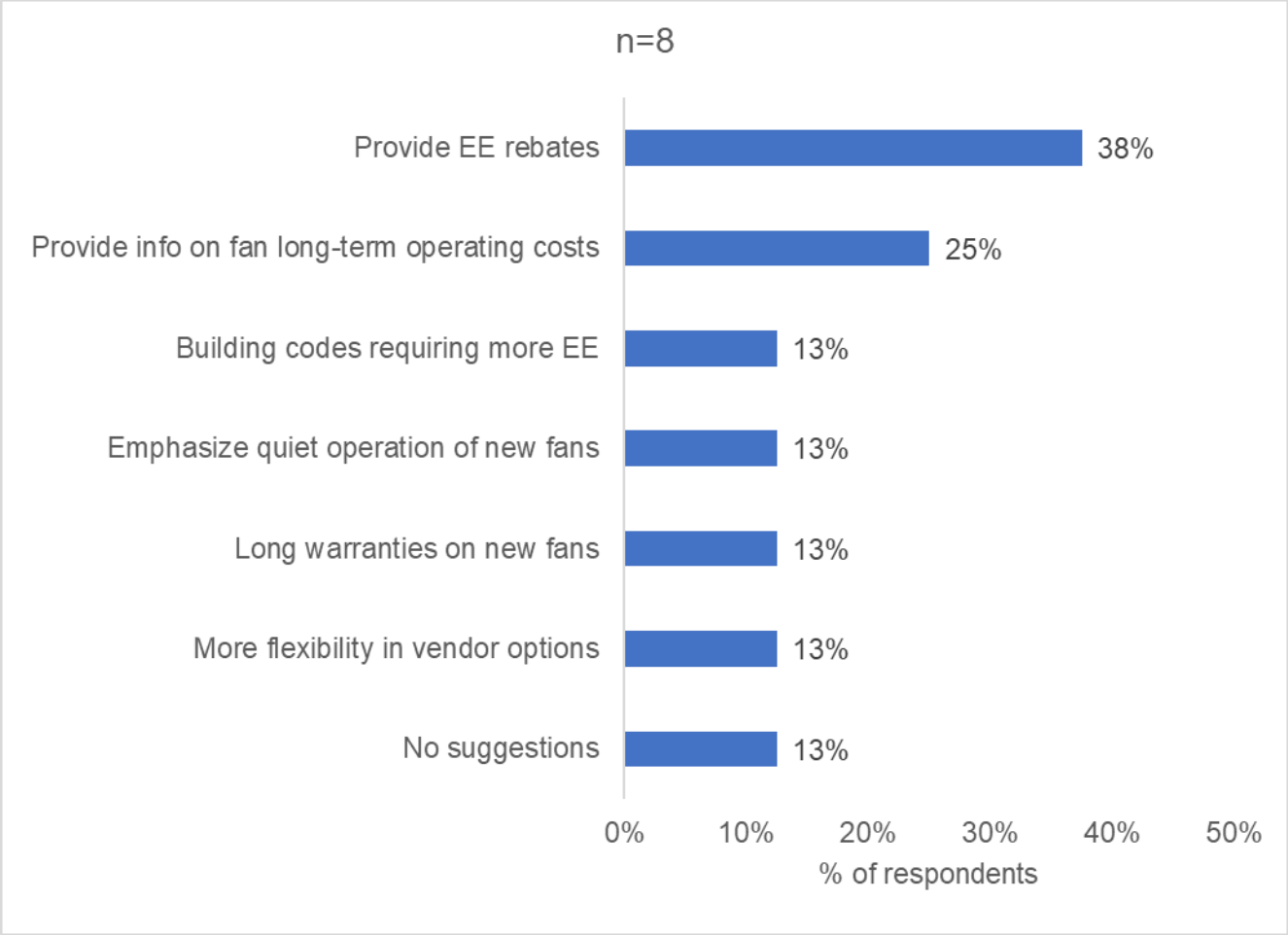
- Low ROI:
  - *Agreement rating of 1.5:* "Our ROI a lot of times isn't terribly important because it's a need to operate, so I'd say one or two."
  - *Agreement rating of 4:* "If it's got a low return on investment, we're likely not to buy it. So, I'd put that around four. "
- Prioritizing other factors such as physical size:
  - *Agreement rating of 4:* "That's quite a barrier. A lot of times, the size restricts what we can put in there."
- Unwillingness to replace operable fans:
  - *Agreement rating of 4:* "Well, ten years ago, I would have said we were extremely reluctant to replace that stuff. But, you know, lately, it's been getting a lot better."

Besides this list of standard barriers, some of the interviewees also volunteered their own barriers to the purchase of efficient fans including:

- Company policies requiring equipment purchases through a single vendor (e.g., Grainger's),
- Supply chain issues related to the COVID-19 pandemic,
- Getting financial decision-makers to spend money on fan upgrades, and
- Outdated fan equipment and controls for which it is difficult to find a replacement.

The study team also asked the building maintenance managers for suggestions to overcome these barriers to the purchase of high efficiency fans. The two most common suggestions were to provide energy-efficient rebates and to provide more information on fan long-term operating costs. Figure 16 shows all their suggestions.

Figure 16. Building maintenance manager suggestions for increasing sales of EE fans



One of the maintenance managers suggested the development of a tool that would help them compare the long-term costs of high efficiency vs. standard efficiency fans:

> *make an online calculator. So, if I go in and say: 'Alright, here's my existing fan. Here's its ratings. And here's my new fan.' And you could even do horsepower-to-efficiency ratings, and then it would pop up a little number saying hours of operation and all that stuff, and it would pop up a number on how much it would save you in kilowatt-hours.*

3.4.3 Overarching barriers to efficient fans

Table 6 summarizes the barrier rankings of the three largest groups of fan market actors. It shows that when their ratings are averaged, the three most-cited barriers were the unwillingness to replace operable fans, high first costs, and prioritizing other factors such as physical size. The table also shows that the manufacturers, manufacturers' representatives, and the fan specifiers/installers viewed the barriers to high efficiency fans as being more significant than the building maintenance managers.

Table 6. Barrier rankings for all fan market actors

Barrier	Manufacturers/ Manufacturers' Reps (n=14)	Fan Specifiers/ Installers (n=7)	Building Maintenance Managers (n=8)	Average Rating
Unwillingness to replace operable fans	4.4	4.9	3.5	**4.3**
High first costs	4.3	4.6	3.5	**4.1**
Prioritizing other factors such as physical size	3.3	4.4	2.6	**3.8**
Preferences for like-for-like replacement	3.7	4.4	2.9	**3.8**
Lack of requests from end-users for high efficiency	3.6	4.5	3.8	**3.7**
Longer lead times for high-efficiency fans	N/A	4.5	3.3	**3.6**
Lack of data on ROI	3.6	3.5	2.8	**3.5**
EE not considered due to low fan load	3.1	4.1	2.8	**3.3**
Low ROI	3	4	3.4	**3.3**
Fan suppliers lacking specialized knowledge	2.6	1.9	1.6	**2.0**

The literature review and primary research conducted by the study team suggests the following primary barriers to adoption of efficient non-embedded fans:

1. **First cost is an important barrier for the selection of energy-efficient fans, although there are some qualifiers about its importance**. Regardless of the market actor specifying the fan, concern about the first or upfront cost of the equipment influences the fan selection. Most manufacturer software and ad hoc analyses do not incorporate the total cost of ownership or other operating costs into the selection criteria. Concerns about the first cost of energy efficient fans was the second-most cited barrier by both the manufacturers/manufacturers' representatives and the building maintenance managers. In addition, many market actors mentioned that rebates for energy efficiency would influence their decision to go with a more energy efficient replacement fan.

   However, one qualifier for the importance of the first cost barrier came from the interviews with building maintenance managers. As Figure 13 shows, the maintenance managers cited first costs as the least important factor influencing fan selection at their company. One possible explanation for this contradiction has to do with the fact that for certain fan applications cost is a secondary consideration. Two of the maintenance managers worked in hospitals and three worked in industrial facilities. Both the hospital maintenance managers said that having reliable fan systems to serve critical hospital spaces, such as operating rooms, meant that fan cost was not an important consideration. A couple of the industrial maintenance managers also mentioned that finding the right fan system for facilitating a production process trumped any cost considerations. However, it is important to also point out that these companies/organizations also have many fan systems which perform more routine exhaust and ventilation functions where cost considerations would be assumed to be more significant.

   Another possible explanation for this contradiction is that while all but one of the eight building maintenance managers said they have influence over the fan selection process, they also acknowledged that when fan projects get bigger and more expensive, the pool of project decision-makers widens and often includes people in the company/organization with more of a bottom-line focus. When we asked the maintenance managers about the factors their company/organization valued in new fan selection, some drew

a distinction between what they themselves valued and what were the priorities of the "bean counters" in their company. So, it is possible that if the study team had interviewed some of these decision-makers with more of a budgetary focus, first cost would have received a higher importance ranking as fan selection consideration.

2. **There is a lack of awareness of efficiency metrics such as FEI among fan manufacturers, system integrators, and building maintenance managers**. While the large manufacturers were all familiar with FEI and indicated their sales at least in part reflect FEI certified products, more than half of the smaller manufacturers and other market actors were not familiar with the FEI metric. Additionally, some market actors had heard of it but were not actively using the metric in fan selection and/or sales processes. Only two of the eight building maintenance managers had heard of the FEI metric.

3. **Additional site considerations such as acoustics and space constraints can have large impacts on fan selection**. Market actors frequently identified acoustics and noise considerations as key decision-making criteria for fan selection. Additionally, space constraints were identified as a factor both for new construction and retrofit applications. Prioritizing other fan factors such as physical size was the market barrier to efficient fan adoption that the building maintenance managers mentioned the most. In addition, as discussed in the program opportunities section, one maintenance manager mentioned noise reduction as a promising selling point for new energy-efficient fans.

4. **There is a market preference to repair rather than replace existing fans wherever possible**. The majority of fan sales reported by manufacturers and manufacturers' representatives were for new construction, followed by planned replacements, with emergency replacements at an average of 5% of projects. End users indicated a strong preference for repairing existing broken fans with readily available parts rather than replacing with new fans. Efficiency is not often a consideration here, as getting the fan back online promptly within end user existing knowledge is the primary objective.

5. **A lack of information on cost savings and payback of newer fans.** Several maintenance managers wished they had tools they could use to explore the financial implications of purchasing standard efficiency vs. high-efficiency fans in terms of long-term operating costs. In addition, interviews with manufacturer representatives and other fans specifiers indicated that fan selection software is mostly not designed to provide this kind of information to fan decision-makers.

4 RECOMMENDATIONS

The study team identified the following opportunities for programs to influence fan selection:

1. **Code requirements can drive use of the FEI metric in fan selection**. Recent versions of both the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 90.1-2019, 90.1-2022 and the International Energy Conservation Code (IECC 2021) energy codes have incorporated the FEI metric, replacing the legacy Fan Efficiency Grade (FEG). While three states in the four-state region have adopted building codes which reference the FEI, the fan market actors only mentioned the Washington building code as a driver of the FEI as a consideration in fan selection. This may be because the Washington code changes were adopted earlier (e.g., early 2021) than those in Oregon (late 2021) or Montana (mid 2022) and therefore there has been more time for the market to become familiar with the new code changes. This suggests there are opportunities for more fan market actor education about recent code changes.

2. **Support market education both broadly for fan system efficiency and for the FEI metric specifically**. Primary and secondary research identified a lack of awareness of fan system efficiency and the FEI metric across all but one of the market actor groups. Further, first cost is one of the most influential factors reported in fan selection, and this is a metric that does not account for the lifetime benefits of efficient fans.

   Education targeted at market actors throughout the distribution channel provide an opportunity to influence the narrative and selection process for fans, highlighting total cost of ownership and how to use efficiency metrics such as FEI to compare performance across products. Furthermore, all the building maintenance managers expressed interest in learning more about fan efficiency, although their preferred methods of education did vary (YouTube video vs. website vs. in-person Building Operator Certification (BOC) training).

3. **Engage with key manufacturers to showcase FEI in fan selection software**. Most manufacturers leverage in-house or third-party fan selection software to assist in fan selection. These software products are used by manufacturers themselves, manufacturer representatives, and a variety of other market actors who select fans, such as engineers, architects, and installers. While some manufacturers indicated the FEI is a metric available in the software, others indicated that FEI is not included or indicated that it is not highlighted by default in the software. There is an opportunity to work with manufacturers to promote FEI, feature it prominently in software default settings, and encourage its use in fan selection.

4. **Assess the possibility of downstream rebates for energy-efficient fans as a strategy for mitigating barriers associated with low awareness and high first cost of efficient products, potentially in collaboration with utilities or other agencies.** Several building maintenance managers and other market actors recommended rebates for encouraging sales of high efficiency fans. These interviewees also cited examples where rebates from Energy Trust of Oregon or other utilities had encouraged them to select higher efficiency fans as well more efficient versions of other types of equipment.

   The study team recommends downstream rebates rather than midstream rebates based on recent evaluations of midstream HVAC programs, which raised questions about whether the benefits of these programs were being passed downstream. In addition, many midstream programs target distributor stocking practices, and the fan market does not stock much equipment.

5. **For retrofit scenarios, consider promoting the non-energy benefits of efficient fans such as noise reduction.** Some of the market actors mentioned that noise reduction benefits were a selling point for new fans, especially in certain subsectors such as commercial kitchens or libraries. While promoting the energy saving benefits of new efficient fans should still be the primary focus, it is often helpful to cite additional non-energy benefits for these products. A similar approach has been used recently by HVAC contractors promoting heat pump technologies where noise reduction benefits were promoted alongside energy savings benefits.

6. **Highlight the benefits of integrating fans with controls.** While the market penetration of controls is growing, and fan market actors generally believe they provide many benefits, there are still opportunities for increasing the prevalence of controls. Respondents reported an average of 43% of fans sold with VFDs and another 26% of fans sold with ECMs, for a total average of 69% with some fan control. While several manufacturer representatives reported that all, or nearly all, of their fans were sold with some type of fan control, others reported only selling 40%–55% of their fans with controls. In addition, these percentages only reflect new fan sales and the opportunities for VFDs in existing fans are much greater.

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