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Ceiling Fan Standard Evaluation Report

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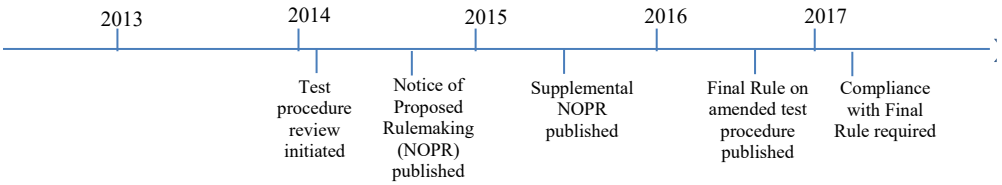
1 EXECUTIVE SUMMARY CEILIN FANS

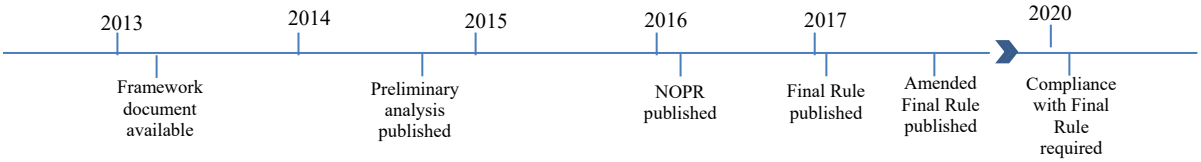
NEEA contracted with TRC to conduct an independent evaluation to qualitatively assess NEEA's influence in the establishment of the Ceiling Fan standard, and to quantitatively assess the savings from the standard due to the combined efforts of NEEA and energy efficiency organizations participating in the process. An efficiency organization is one whose goal is to seek policies that promote energy efficiency in buildings and appliances.

As part of its codes and standards program, NEEA supported this standard's development and adoption. NEEA and other efficiency organizations provided comments on the 2017 standard and 2016 test procedure that affected the analysis and the ultimate DOE Final Rule. Below are depictions of the rulemaking and test procedure timelines.

Ceiling Fan (CF) Standard Test Procedure Timeline



Ceiling Fan (CF) Standard Rulemaking Timeline



To conduct its evaluation, TRC reviewed the DOE docket for the 2017 standard and 2016 test procedure, including the Notice of Proposed Rulemakings, Final Rules, Technical Support Documents, and submitted comments. TRC also interviewed ten stakeholders active in the adoption of the process: four staff members from efficiency organizations, five manufacturers, and one independent research organization. All interviewees were involved in the 2017 Ceiling Fans standards rulemaking and/or the 2016 Ceiling Fans test procedure rulemaking

For the qualitative assessment, TRC found that NEEA engaged in most of the activities identified in NEEA's Codes and Standards logic model of its codes and standards program for this evaluation, focusing particularly submitting comments in the public review process and participating in public meetings. TRC found that these activities along with the those engaged in by the efficiency organizations are responsible for 9% of the total energy savings from the standard.

2 INTRODUCTION

On March 15, 2013, DOE published a notice announcing the availability of the framework document for Ceiling Fans and Ceiling Fan Light Kits, which described the analyses DOE planned to conduct during the rulemaking and sought comments. These products are typically installed in residential applications. On September 29, 2014, DOE published the preliminary analysis for the Ceiling Fan energy conservation standards rulemaking. On January 13, 2016, DOE published a notice of proposed rulemaking (NOPR) for the Ceiling Fans energy conservation standards rulemaking.

On January 19, 2017, DOE published the Final Rule. Some key changes compared with the NOPR included: (1) DOE updated the engineering analysis based on additional test data and (2) DOE updated the efficiency distribution in the no-new-standards case for the standard and hugger product classes with significantly more market share at the lower efficiency levels based on comments from manufacturers. Hugger fans are set flush to the ceiling (e.g., mounted without a down rod). See Figure 1 for an example. DOE conducted a review of the Final Rule in early 2017, which delayed the effective date to September 30, 2017. Compliance with the Final Rule will be required beginning January 21, 2020.

Figure 1. Hugger Fan. Photo Credit: Lawrence Berkeley National Laboratory (https://ees.lbl.gov/product/ceiling-fans)

The test procedure rulemaking happened in parallel with the standards rulemaking and was initiated in 2014. On October 17, 2014, DOE published a test procedure NOPR in which they proposed to reinterpret the statutory definition of a Ceiling Fan to include Hugger Ceiling Fans, and to amend the current test procedure through clarifying existing provisions and adding provisions for different types of Ceiling Fans (including high-volume, multi-mount, multi-headed, and ceiling fans where the airflow is not directed vertically). On June 3, 2015, after consideration of comments received on the NOPR, DOE published a supplemental NOPR (SNOPR) in which DOE revised the proposed test procedure. On July 25, 2016 DOE published the Final Rule to amend the test procedures for Ceiling Fans, in which DOE adopted amendments proposed in the test procedure SNOPR.

As part of its codes and standards program, NEEA supported the development and adoption of the Ceiling Fan standard by submitting comments at various stages of the standard development and by participating in public meetings.

2.1 Study Purpose

The scope of TRC's evaluation was to investigate the barriers to adoption for the Ceiling Fan standard, the activities that NEEA conducted, the activities that other energy efficiency organizations conducted, and the effectiveness of these activities. Based on the results, TRC provided two assessments:

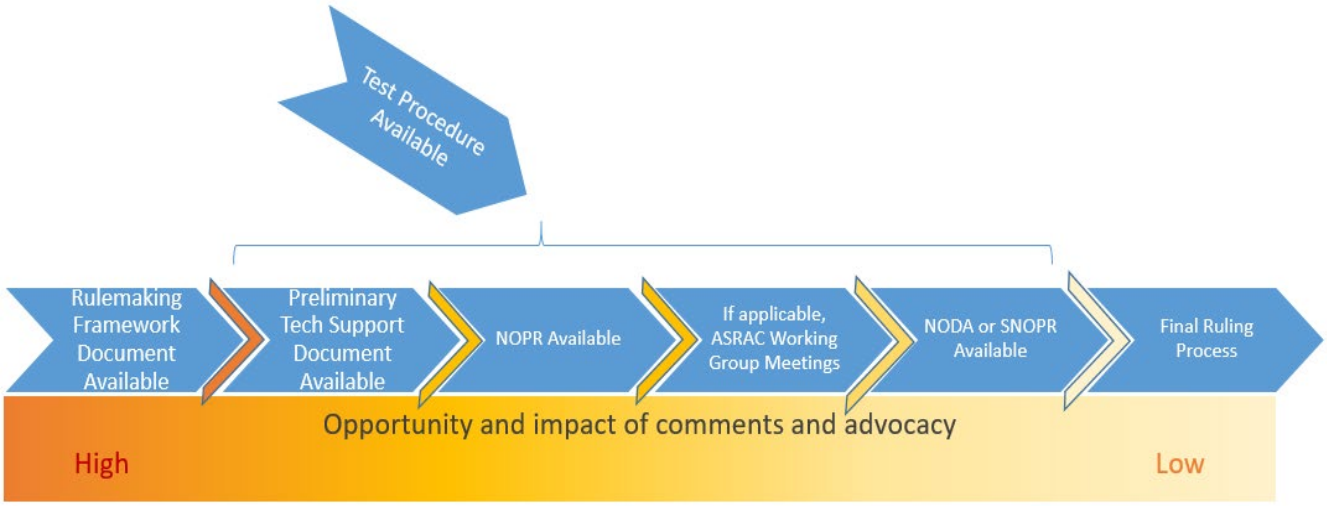
1. A qualitative assessment of NEEA's influence in the establishment of the Ceiling Fan standards, which TRC developed based on the NEEA Standards Development Logic Model; and

2. A quantitative assessment of the savings from the standards due to all energy efficiency organizations, including NEEA.

2.2 Description of DOE Adoption Process

As background, TRC provides the following description of the DOE federal standard adoption process. The DOE is the government agency responsible for developing and adopting national appliance energy standards. During the standard development process, the DOE seeks input from stakeholders, including comments regarding the feasibility of the proposed standard and its impact on consumers, manufacturers, and other stakeholders. Stakeholders can provide input during public meetings and comment periods, both of which occur after the public release of rulemaking documents. The DOE must address stakeholder comments and demonstrate that the benefit of a new or revised standard will exceed any burden that it may impose – e.g., that the energy savings (in dollars) from the new standard will exceed costs for implementation. TRC developed Figure 2 to illustrate the general DOE standard development process and opportunities for stakeholder input.

Figure 2. DOE Standard Development Process and Opportunities for Stakeholders' Influence



There are multiple opportunities for stakeholders to influence the final standard and supporting documents that impact energy savings, including providing comments and data on the:

1. Test procedure, which details how a product must be tested for compliance with the standard
2. Inputs and analysis methodologies used to evaluate each efficiency level considered for the standard, including engineering analysis to determine cost effectiveness, market availability and pricing data, and design options that could affect efficiency
3. Efficiency levels proposed for each product class

For some standards, a working group formed by the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) provides recommendations to DOE. This often occurs when a standard requires significant negotiations to identify acceptable terms, such as product classes, definitions, or required efficiency level, and the working group typically includes efficiency organizations. In the case of the Ceiling Fan, there was not an ASRAC working group.

3 METHODOLOGY

This section provides an overview of the data collection activities and analysis methodology for this evaluation.

3.1 Data Collection Approach

To collect data for this evaluation, TRC:

1. Reviewed literature – primarily from the DOE docket for this appliance standard
2. Gathered feedback from stakeholders involved in the rulemaking process for this standard, primarily through telephone interviews.

TRC's literature review included:

- DOE docketed comments from stakeholders, including manufacturers, energy efficiency organizations, and other interested parties
- DOE Framework document for the energy conservation standard
- DOE Notice of Proposed Rulemaking (NOPR) for the energy conservation standard
- DOE Final Rule for the energy conservation standard
- DOE NOPR for the test procedure
- DOE Supplemental NOPR for the test procedure
- DOE Final Rule for the test procedure
- DOE Preliminary, NOPR and Final Technical Support Documents (TSDs) for the energy conservation standard
- Public meeting transcripts

TRC conducted phone interviews with staff at various organizations that were active in the adoption of this standard. This included:

- Staff members from energy efficiency organizations that played a prominent role in supporting this standard's development. TRC interviewed staff from four of the efficiency organizations, one of which is a representative from a utility that TRC categorizes as an efficiency organization, because they consistently provided comments in support of high efficiency levels;
- Five manufacturers in phone interviews
- One organization which conducts independent research

Figure 3 summarizes the interview dispositions. As shown in this figure, TRC met the total number of target interviews. TRC contacted DOE to request an interview, but DOE staff declined the request, instead citing the docket.

Figure 3. Number of Targeted and Completed Interviews by Stakeholder Category

Stakeholder Category	Target Interviews	Candidates Contacted	Completed Interviews
NEEA C&S Staff	1	1	0
Energy Efficiency Organizations and Utility Representative	3 – 5	6	4
Manufacturers and Trade Organizations	3 – 5	11	5
(OPTIONAL - Pending need) Other Stakeholders	1 – 2	1	1
Total	**7 – 11**	**19**	**10**

3.2 Limitations of Data Collection Efforts and Analysis

One overarching limitation was that the DOE began development of the Ceiling Fan standard years ago, with stakeholder comments submitted as early as March 2013. To help address recall issues, TRC sent interviewees their organization's docketed comments and a summary of the adoption timeline prior to the interview. TRC acknowledges that this may have introduced some bias into interviewees' responses. Several stakeholders interviewed also reported difficulty recalling aspects of the standard development, given the time lag.

Based on TRC's review of the dockets and from information collected through interviews with participants in the process, we believe that our quantitative and qualitative assessments accurately portray the proceedings and that the conclusions regarding efficiency organizations' influence are reasonable.

3.3 Methodology to Assess NEEA's Influence

To assess NEEA's influence on the development and adoption of this standard, TRC compared the proposed activities from NEEA Standards Development Logic Model (provided in Appendix: NEEA Logic Model for Standards Rulemaking Process) with activities that NEEA conducted, based on interviews and the literature review. TRC identified barriers to the adoption of this standard, and then identified influential activities that addressed the barrier in which NEEA participated. Finally, TRC identified NEEA's role and contribution for each activity and output.

3.4 Methodology to Estimate Energy Savings from All Efficiency Stakeholders

To estimate savings from all energy efficiency organizations' efforts in support of the standard, TRC first developed a qualitative assessment of the impact of energy efficiency organizations' efforts. Specifically, TRC:

1. Used the docketed literature to identify all barriers to the adoption of the standard, including comments raised by all stakeholders.
2. Used the docketed literature to identify the outcome of each issue where the efficiency organizations provided comments and identified those for which DOE made a change based on the comment – such as a revision in product classes, definitions, analysis, or proposed efficiency level.
3. Used the docketed literature and interviews with stakeholders to understand:
    a. The relative significance of the issues where efficiency organizations provided comments compared to all issues raised for the standards
    b. For each issue affected by the efficiency organizations, the relative impact of the efficiency organizations' comments on the final outcome.

TRC then translated this qualitative assessment into a quantitative framework to approximate the significance of energy efficiency organizations' activities as a percentage of energy savings resulting from activities during the development and rulemaking process. Section 5.1 provides detail on TRC's methodology for the quantitative analysis.

4 NEEA EFFECTIVENESS ASSESSMENT RESULTS

Figure 4 summarizes the results of TRC's assessment of NEEA's efforts. TRC developed this figure using the NEEA logic model as an assessment framework. Note that NEEA has one logic model for all codes and standards activities. NEEA adapts its activities to suit the specific needs for each particular standard; therefore, not all barriers or activities are relevant for every standard.

Using the assessment criteria from the NEEA logic model, TRC used information from the analysis to identify whether NEEA met each relevant criterion. TRC identified logic model activities and outputs with a "Y" if NEEA undertook the activity or output and "N" if NEEA did not. The figure provides a rationale for whether NEEA accomplished each objective and describes where some activities may not have been relevant or necessary for this standard.

NEEA's primary influence came from submitting comments to DOE during the standard development process. Comments and recommendations from NEEA and other energy efficiency included the following:

1. Supported DOE's proposed efficiency level
2. Supported DOE's proposal that on a national level, ceiling fan energy use and air conditioning energy use interaction is negligible and provided a supporting reference
3. Supported the inclusion of brushless direct current (DC) motor technology design option for all product classes
4. Recommended narrowly defining belt-driven ceiling fans to include fans that have one or more motors located outside of the fan head

DOE adopted the recommendation on belt-driven ceiling fans and utilized support from the efficiency organizations' other comments to adopt their own proposals.

Overall, NEEA engaged in most of activities found in the logic model. There were three activities that NEEA did not conduct for this standard: negotiation with manufacturers, conducting primary research and providing savings, and economic analysis based on Northwest data. In general, TRC found that this standard did not necessitate these activities. There was no direct negotiation because this was not a negotiated rulemaking and did not have an ASRAC working group (described in section 2.2) formed by DOE. There was not a high need for NEEA to provide these data or conduct savings analysis for this standard, since manufacturers or other efficiency organizations (including the CA IOUs) were generally able to provide data.

Figure 4 compares NEEA's activities to the C&S logic model. The white cells show the logic model inputs. The blue cells show TRC's assessment of NEEA's activities for this standard.

Figure 4. Assessment of NEEA's Activities on the Ceiling Fan Standard

Barrier (NEEA logic model)	Manufacturer opposition			Lack of data with which to conduct the necessary analyses in a rulemaking		Lack of common interest among certain stakeholders	Insufficient funding/staff for US DOE to run standards processes
Proposed Activity (NEEA logic model)	Negotiation with manufacturers.	Attend public meetings held by DOE.	Analyze and critique organizations, manufacturers and rulemaking documents.	Conduct primary research to create data for standards and test procedures.	Provide savings and economic analyses based on Northwest data.	Collaboration with other organizations under the umbrella of ASAP.	Encourage utilities to provide data and political support for standards.
Undertaken by NEEA? (TRC)	N	Y	Y	N	N	Y	Y
Rationale/ explanation (TRC)	TRC did not find evidence that NEEA negotiated with manufacturers during the RFF standard process.	NEEA attended public meetings at all stages of rulemakings.	NEEA submitted sole comments and joint comments on standard development. NEEA attended and actively participated in all public DOE hearings.	NEEA did not collect or provide primary data.	NEEA did not provide savings data for the Northwest.	NEEA submitted joint comments and held on-going communication and meetings.	NEEA worked jointly with CA IOUs, who provided data in the support of the standard.
Outputs (NEEA logic model)	Consensus-based proposals to submit to DOE or better general understanding of manufacturer positions and concerns	NEEA adds valuable information at each stage of the rulemaking process.		NEEA adds valuable information at each stage of the rulemaking process.	NEEA information/ analysis referenced in rulemaking proceedings/ documentation	NEEA adds valuable information at each stage of the rulemaking process. NEEA information/ analysis referenced in rulemaking proceedings/ documentation	Utilities are present at hearings/ publicly support new standards.
Accomplished by NEEA? (TRC)	N/A	Y		N/A	N/A	Y	Y
Rationale/ explanation (TRC)	N/A, because NEEA did not complete negotiations with manufacturers.	NEEA provided comments in support of DOE and other efficiency organizations that influence the test procedure and efficiency level adopted.		N/A, because NEEA did not complete any primary research for this standard.	N/A, because NEEA did not provide any research for the docket.	DOE rulemaking documentation references NEEA joint comments. NEEA was active during public stakeholder hearings.	NEEA collaborated with the California Investor Owned Utilities (IOUs), which submitted comments that generally aligned with NEEA's.

5 INFLUENCE OF EFFICIENCY ORANIZATION S

5.1 Description of Calculation of Energy Savings

TRC estimated the energy efficiency organizations' influence using an analysis framework described below. Sections 5.3 and 5.4 provide descriptions of TRC's rationale for our rankings and estimates of percentages. This section includes an example calculation to demonstrate how we arrived at our estimates in the following sections 5.3 and 5.4.

In this example, we estimate the impact of removing one barrier (lack of adequate definitions of equipment classes). We do this by first estimating how important the removal of this barrier is compared to all others present in this particular standards process. We then estimate how important and how effective energy efficiency work was in removing the barrier. Below we lay out the steps more explicitly, including the estimated input we used (shown in *italics*).

a. **Identified and estimated the relative significance of the barriers** to adoption of the standard. TRC identified three barriers that were significant for standard development. Within each barrier, TRC identified sub-barriers. Based on the importance of each sub-barrier, TRC assigned a weighting factor to each so that their sum would total 100%:
   i. *Manufacturer Opposition to More Stringent Standard: 45%*
   ii. Lack of Data Availability and Accuracy: 55% total
      i. Interaction between ceiling fan energy use and air conditioning energy use to assume in the analysis: 35%
      ii. Inclusion of brushless direct current (DC) motor as a technology design option: 20%
   iii. Lack of Representative Test Procedure: 0%

b. **Identified and estimated the significance of each efficiency organization activity to overcome each barrier.** As one example activity the energy efficiency organizations supported DOE's proposal to adopt trial standard level[1] (TSL) 4. TRC found that this activity had a high significance in reducing the barrier, "Manufacturer Opposition to More Stringent Standard". TRC estimated the significance as 40% for addressing this barrier, based on the following scale:

   Negligible = ~0%; Low = 10%, Medium = 20%, and *High = 40%*

c. **Estimated the effectiveness of each efficiency organization activity relative to all efficiency organization activities to overcome all barriers**. Following our example activity, TRC rated the barrier, "Manufacturer Opposition to More Stringent Standard" as 40% of significance across all barriers. Consequently, TRC estimated that the

[1] The Trial Standard Level (TSL) combines specific efficiency levels for each product class. In the NOPR, DOE analyzed the benefits and burdens of six TSLs, which includes five product classes.

significance of this energy efficiency organizations activity relative to all activities was 45% x 40% = 18%.

d. **Estimated the role of efficiency organizations in each activity relative to all participants to support DOE (i.e. all, primary, major contributor, minor).** TRC estimated efficiency organizations' role to support DOE and address each barrier and applied a weighting to the significance of their activities. Because DOE (including its consultants) did the majority of the work to develop the test procedure, standards, and supporting analyses, TRC assumed that the maximum role played by the energy efficiency organizations for comments affecting these documents and analysis was 50%, as described below:

   Primary Support (50%): Led efforts to provide comments to DOE.

   Major Support (30%): Did not lead efforts but contributed significantly.

   Minor Support (10%): Did not contribute significantly.

   Using the example activity of comments adopt TSL 4, efficiency organizations provided Major Support to the DOE. For this example, activity, the final estimated significance for this energy efficiency activity is 18% (calculated in step c) x 30% = 5.4%.

e. **Estimated the total impact of efficiency organizations' activities.** For each activity, TRC estimated the significance of each activity to overcome all barriers (step c) and multiplied this by the relative role of the organizations (step d). TRC then summed the significance of all activities.

5.2 Efficiency Organizations' Contribution to Energy Savings

TRC estimates the efficiency organizations' influence for this part of the standard development process is 9%. Figure 5 presents the detailed results. TRC provides a supporting rationale for each input in the sections below the figure. Note that this figure only lists barriers for which TRC found that the efficiency organizations impacted the final standard.

Figure 5. Impact Analysis of Efficiency Organizations' Contributions

Barrier, based on NEEA logic model	1. Manufacturer Opposition to More Stringent Standard	2. Lack of Data Availability and Accuracy		3. Lack of Representative Test Procedure	Total
		Interaction Between Ceiling Fans and Air Conditioners	Brushless DC Motors		
Sub-barrier specific to standard	Industry pushed back on DOE's proposed standard for Standard and Hugger Ceiling Fans (representing 96.8% of the market), commenting that DOE significantly underestimated the impacts on manufacturers and is not economically justified.	Industry commented that ceiling fans were inherently energy-saving products because they reduced air conditioning energy use. Industry commented that the proposed rule could push homeowners to not purchase ceiling fans and therefore lead to an increase in air conditioning use.	Industry opposed DOE's proposal to include brushless direct current (DC) motors as a technology design option, citing concerns about technological feasibility.	Lack of adequate definition for belt-driven ceiling fan. DOE's proposed definition left ambiguity around whether the motors must be located outside of the fan head in this product class. Since DOE did not propose efficiency standards for belt-driven ceiling fans, definition impacts which products are not subject to efficiency standards.	
Significance for energy savings	**Very High**	**High**	**Medium**	**Negligible**	
a. Significance of barrier (%)	**45%**	**35%**	**20%**	**~0%**	**100%**
Activities Conducted by all EE Organizations	**Activities to Address Barrier 1**	**Activities to Address Barrier 2**		**Activities to Address Barrier 3**	
	Efficiency organizations supported DOE's proposal for TSL 4. TSL 4 was projected to save 0.758 quads of energy and save consumers $0.81-2.76 billion over the 30-year analysis period.	Efficiency organizations supported DOE's proposal that on a national level, ceiling fan energy use and air conditioning energy use interaction would be negligible.	Efficiency organizations supported the inclusion of brushless DC motor technology design option for all product classes.	Efficiency organizations recommended narrowly defining belt-driven ceiling fans to include fans that have one or more motors located outside of the fan head.	
Results - i.e., DOE response	In the Final Rule, DOE adopted TSL 4, as proposed in the NOPR.	In the Final Rule, DOE did not account for any interaction between ceiling fans and air conditioning or heating equipment.	DOE kept brushless DC motors as a technology design option in all product classes in the Final Rule. In the Final Rule, DOE adopted	In the Final Rule, DOE modified the definition of belt-driven ceiling fans per the recommendation from the efficiency organizations to include	

			standard levels that included brushless DC motors in all product classes except the very-small diameter product class.	"located outside of the fan head" onto the proposed definition.	
Effectiveness of activity for addressing barrier	**High**	**Medium**	**Medium**	**High**	
b. Significance for each barrier (%)	**40%**	**20%**	**20%**	**40%**	
c. Significance across <u>all</u> barriers: axb (%)	**18%**	**7%**	**4%**	**0%**	
EE organizations' role	**Major**	**Major**	**Major**	**Major**	
d. EEs' Relative Role in activity (%)	**30%**	**30%**	**30%**	**30%**	
e. Significance of EE activity relative to total savings, cxd (%)	**5.4%**	**2.1%**	**1.2%**	**0%**	**8.7%**

5.3 Rationale for Weighting Significance of Barriers

To identify barriers, TRC began with the barriers in the NEEA Standards Development Logic Model. Because this is the general logic model that applies to all of NEEA's standards development efforts, TRC revised this list of barriers based on the specific challenges of this standard. TRC identified two of the barriers in the NEEA logic model for standards rulemaking as applicable to this standard – Manufacturer Opposition, and Lack of Data – and added a third barrier based on the specifics of this standard: Lack of representative test procedure.

5.3.1 Barrier 1: Manufacturer opposition to regulation or more stringent standard

Significance: Very High

Rationale and Findings: In the NOPR, DOE proposed adopting TSL 4 for Ceiling Fans, which was projected to save 0.758 quads. The docket and interviews suggested industry strongly pushed back on the proposed standard for the Standard and Hugger product classes (which represent 96.8% of the market), commenting that DOE significantly underestimated the impacts on manufacturers and are not economically justified. Though industry did not identify a particular TSL as an alternative, their comments made it appear that they would have been satisfied with TSL 1 or TSL 2.

TRC ranked this barrier as very high because the final efficiency level has a major impact on the energy savings from the standard, and because there was significant industry pushback on the proposed efficiency level.

5.3.2 Barrier 2: Lack of data availability and accuracy

DOE makes numerous assumptions in the engineering analysis that ultimately shape the energy savings values. Assumptions are wide-ranging and consist of different factors such as the product mark-up by small general contractors, individual component costs, consumer discount rates, and many other factors. In the sections below, TRC describes those engineering analysis assumptions that efficiency organizations commented on that resulted in energy savings. One reason that these engineering assumptions have a significance of Medium and Low is because there were many other assumptions and inputs that stakeholders debated than the issues listed here. (Recall that this analysis only tracks issues that the efficiency organizations impacted.) If DOE revises analysis assumptions that therefore result in lower predicted energy use in the analysis at higher efficiency levels, it may make a higher efficiency level more cost-effective, and therefore enable DOE to adopt the higher level. Figure 6 shows the number of comments that the efficiency organizations and the industry submitted on each topic in the standards Final Rule, illustrating that in the Final Rule alone, there were numerous comments from both the efficiency organizations and the industry with only a subset of the comments resulting in a change to the final outcome of the rulemaking. A comment is considered to have a 'resulting change' if it caused DOE to revise a proposal or if its support of an existing proposal allowed DOE to adopt the proposal when other stakeholders opposed it.

Figure 6. Final Rule Comments

	Efficiency Organization		Industry	
	Neutral or No Impact	**Resulting change**	**Neutral or No impact**	**Resulting change**
Energy Use Analysis	1	1	5	1
Engineering Analysis	4		5	3
Life-Cycle Cost & Payback Period Analysis	3		6	1
Manufacturer Impact Analysis				1
Market and Technology Assessment			1	1
National Impact Analysis			1	
Product classes & scope of coverage			1	
Screening Analysis	1	1	9	2
Shipments Analysis	1		3	
Total	**10**	**2**	**31**	**9**

The two comments from the efficiency organizations that resulted in a change were that there was negligible interaction between ceiling fan and air conditioning energy use, and that DOE should include brushless DC motors in the analysis. This report provides more detail on those comments and their outcomes in later sections.

Sub-barrier: Interaction Between Ceiling Fans and Air Conditioners

Significance: High

Rationale and Findings: In the NOPR, DOE did not account for any interaction between ceiling fans and air conditioning equipment. Industry strongly pushed back on this, suggesting that DOE's proposed ceiling fan standards would increase the cost of ceiling fans, causing consumers to forgo the purchase of ceiling fans and instead rely solely on air conditioning for comfort cooling, which would result in increased air conditioning use and ultimately increased overall energy use. Industry commented that ceiling fans are inherently energy-saving products and that therefore there should not be efficiency standards for ceiling fans. Starting from their response to the Framework all the way up through their response to the NOPR, industry made similar comments. Industry also commissioned a study and provided results which showed that ceiling fans are inherently energy-saving products and that an increase in cost would likely lead to overall higher energy use.

TRC ranked this barrier as high because there was significant industry pushback and also because DOE acknowledged that ceiling fans have the potential to theoretically decrease the amount of air conditioning use.

Sub-barrier: Brushless DC Motors

Significance: Medium

Rationale and Findings: In the engineering analysis, DOE selects technology design options which improve the product's energy efficiency rating. DOE suggested or proposed including brushless direct current (DC) motor technology as a technology option at every stage of the rulemaking, including the Framework, Preliminary Analysis, and the NOPR. In comments at each of these stages of the rulemaking, industry opposed the inclusion of brushless DC motors as a technology design option for any product class, citing concerns about technological feasibility.

TRC ranked this barrier as medium because industry raised the same concerns regarding DC motors at every stage of the rulemaking, making this a significant barrier.

5.3.3 Barrier 3: Lack of accurate test procedure

Significance: Negligible

Rationale and Findings: In the NOPR, DOE proposed to define belt-driven ceiling fans as ceiling fans with a series of one or more fan heads, each driven by a belt connected to one or more motors. This definition left some ambiguity around whether the motors must be located outside of the fan head in order to be considered belt-driven ceiling fans. DOE determined that the market share of belt-driven ceiling fans was about 1% and that they did not have enough data on them to analyze and set standards, so they did not propose efficiency standards for this product class. TRC notes that with an ambiguous product class definition, it would not be known exactly what the market share was, and it is possible that the 1% estimate underestimates actual market share. However, TRC believes that even if the actual market share was higher, it would still overall be very small. Since DOE did not propose efficiency standards for belt-driven ceiling fans, an ambiguous definition could unintentionally allow some products to not be subject to efficiency standards.

TRC ranked this barrier as negligible because there was no opposition to DOE's proposed definition from industry and because these fans represent a very small portion of the ceiling fan market.

5.4 Rationale for Weighting Significance of Activities

This section describes TRC's rationale for weighting the significance of each activity that the efficiency organizations conducted.

5.4.1 Activities to Address Barrier 1: Manufacturer Opposition to More Stringent Standard

Activity and Significance: In response to the NOPR, the efficiency organizations submitted comments and participated in public meetings expressing support for the proposed TSL and commenting that the economics of higher TSLs may be even better than shown in DOE's NOPR analysis, with the potential to roughly double the national energy savings relative to the proposed standard.

The efficiency organizations' support of the proposed efficiency level was useful to DOE and gave them justification to adopt their proposed efficiency level. Though industry did not recommend a particular TSL, it is likely that they would have been satisfied with TSL 1 or TSL 2.

Figure 7 gives a summary of the TSLs and associated cumulative national energy savings including full-fuel-cycle over the 30-year analysis period, as determined by DOE in the NOPR.

Figure 7. Energy Savings Projections at Each Standard Level and Supporters of Each Standard Level

Standard Level	National Energy Savings Determined by DOE in NOPR (quads)	Supporters	Relative Savings
TSL 1	0.137	Likely had industry support	-
TSL 2	0.210	Likely had industry support	-
TSL 3	0.555	-	-
TSL 4	0.758	Adopted by DOE in Final Rule. Supported by efficiency organizations.	Saves 5.5x more energy than TSL 1; Saves 3.5x more than TSL 2
TSL 5	1.362		-
TSL 6	1.802		Saves 2.3x more energy than TSL 4

Because DOE adopted TSL 4, which was the TSL that efficiency organizations supported, TRC ranked the efficiency organizations' effectiveness as High.

Role of Efficiency Organizations: TRC identified the efficiency organizations as being a major proponent to the DOE for this activity, since they supported DOE's proposal while manufacturers pushed it.

Savings from Activity: 5.4% of savings.[2]

5.4.2 Activities to Address Barrier 2: Lack of Data Availability and Accuracy

Commented on Interaction Between Ceiling Fans and Air Conditioners

[2] All savings rates referenced in this section are derived as described in section 5.1 and can be found in Figure 5.

Activity and Significance: Efficiency organizations submitted comments expressing their agreement with DOE's proposal that there is negligible interaction between ceiling fan energy use and air conditioning energy use. To support their position, efficiency organizations cited a study conducted by the Florida Solar Energy Center (FSEC), which found no significant difference between thermostat settings of homeowners with ceiling fans and homeowners without ceiling fans.[3]

In interviews, efficiency organizations and manufacturers generally stated that the role of the efficiency organizations on this issue was high. However, when asked about the energy savings impact of interaction between ceiling fan energy use and air conditioner energy use, the results were mixed. While multiple efficiency organizations ranked the energy savings as medium to high, the manufacturers ranked the energy savings as low to negative and referenced the same reason for which they opposed the standard.

Because DOE received significant pushback on this proposal, support from the efficiency organizations was a key factor in getting this proposal adopted. TRC ranked the efficiency organizations' effectiveness as medium.

Role of Efficiency Organizations: TRC identified the efficiency organizations as being a major proponent to the DOE for this activity, since they supported DOE's proposal and provided a reference (though not their original research) to support the proposal.

Savings from Activity: 2.1% of savings.

Commented on Brushless DC Motors

Activity and Significance: Efficiency organizations supported the inclusion of brushless DC motor technology option for all product classes. Brushless DC motors are typically more efficient than standard alternating current (AC) motors because they have no rotor energy losses. DOE kept brushless DC motors as a technology design option in all product classes in the Final Rule. The final adopted standard level includes brushless DC motors in all product classes except for the very-small diameter (VSD) product class.

Figure 8 shows the technology design options that DOE assumed in the Final Rule.

Figure 8. Design Options from DOE Final Rule Technical Support Document

[3] James, P.W., J.K. Sonne, R.K. Vieira, D.S. Parker, and M.T. Anello. 1996. Are Energy Savings Due to Ceiling Fans Just Hot Air? Presented at the 1996 ACEEE Summer Study on Energy Efficiency in Buildings. http://www.aceee.org/sites/default/files/publications/proceedings/SS96_Panel8_Paper10.pdf.

Small-Diameter Ceiling Fans		
Standard, Hugger, and VSD Ceiling Fans	**High-Speed Small-Diameter (HSSD) Ceiling Fans**	**Large-Diameter Ceiling Fans**
• Fan optimization • Larger direct-drive single-phase induction motors • Brushless DC motors	• Fan optimization • Curved blades • Airfoil blades • Brushless DC motors	• Fan optimization • Curved blades • Airfoil blades • Premium AC motors • Geared Brushless DC motors • Gearless Brushless DC motors

DOE established Efficiency Levels (ELs) by combining various technology options and determined the resulting energy efficiency ratings achievable by product class. DOE established Trial Standard Levels (TSLs) by combining efficiency levels for each product class. Figure 9 shows the ELs that comprise each TSL. The adopted standard level (TSL 4) is comprised of EL 2 for Very Small Diameter (VSD) fans, EL 4 for High-Speed Small-Diameter (HSSD) fans, and EL 3 for Hugger fans, Standard fans, and Large-Diameter fans. Standard and Hugger fans, which comprise 97% of the market, move from EL 2 (without brushless DC motors) to EL 3 (with brushless DC motors) between TSL 2 and TSL 3.

Figure 9. Trial Standard Levels (TSL) for Ceiling Fans, from DOE Final Rule

	VSD	**Hugger**	**Standard**	**HSSD**	**Large-diameter**
TSL 1	EL 1	EL 1	EL 1	EL 1	EL 1
TSL 2	EL 1	EL 2	EL 2	EL 1	EL 1
TSL 3	EL 2	EL 3	EL 3	EL 3	EL 3
TSL 4	EL 2	EL 3	EL 3	EL 4	EL 3
TSL 5	EL 3	EL 4	EL 4	EL 4	EL 4

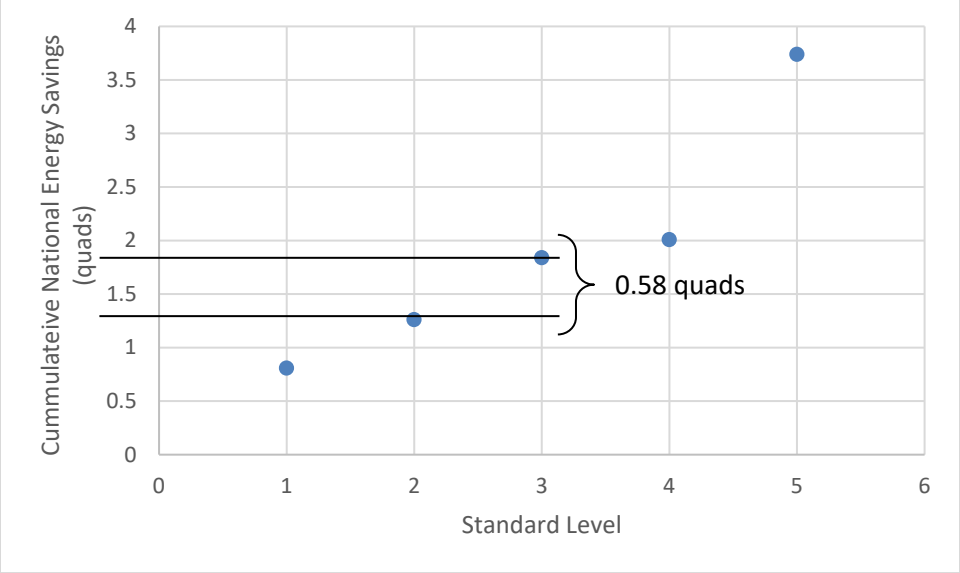
Figure 10 shows the efficiency improvements captured in each efficiency level due to the design options. Note that EL 3 includes brushless DC motors for VSD, Standard, and Hugger fans, and improves efficiency over EL 2 by 70 to 150%.

Figure 10. Relative Energy Performance of Efficiency Levels, from DOE Final Rule Technical Support Document

Product Class/ Representative Size	Efficiency Improvement Compared to Previous Efficiency Level (%)		
	EL 1: Baseline + Fan Optimization	EL 2: EL 1 + Larger Direct Drive Motor	EL 3: EL 1 + Brushless DC Motor
VSD/13-inch	11.1	7.7	83.4
VSD/16-inch	11.1	6.4	70.1
Standard/44-inch	11.1	8.0	86.7
Standard/52-inch	11.1	11.6	125.9
Standard/60-inch	11.1	14.2	153.7
Hugger/44-inch	11.1	8.0	86.7
Hugger/52-inch	11.1	11.6	125.9

Figure 11 shows the cumulative national energy savings at different standard levels, with 0.58 quads of national energy savings added between TSL 2 and TSL 3. As seen above, the difference between TSL 2 and TSL 3 is due to the inclusion of brushless DC motor technology.

Figure 11. National Energy Savings at Different Trial Standard Levels



Interviewed efficiency organizations and manufacturers generally stated that the efficiency organizations had a medium role in getting to this final outcome, and generally noted that the energy savings impact of this issue was around a medium. Because DOE did receive significant pushback on this proposal, support from the efficiency organizations was key in getting this proposal adopted.

TRC ranked the efficiency organizations' effectiveness as medium.

Role of Efficiency Organizations: TRC identified the efficiency organizations as being the major proponent to the DOE for this activity, since efficiency organizations led the commenting on this topic.

Savings from Activity: 1.2% of savings.

5.4.3 Activities to Address Barrier 3: Lack of Representative Test Procedure

Activity and Significance: Efficiency organizations submitted comments recommending that the definition of belt-driven ceiling fans include having "motors located outside the fan head" in the definition. Efficiency organizations noted that this was to prevent potential loopholes in the proposed definition, which was primarily defined by a mechanical feature that may be added to products not originally intended by DOE to be exempted from standard requirements (since DOE was exempting this product class from efficiency standards). Figure 12 shows an example of a belt-driven ceiling fan, as provided in a comment submitted by the American Lighting Association (ALA).

Figure 12. Belt-driven Ceiling Fan. Source: ALA comment dated January 20, 2015

Industry had suggested including belt-driven ceiling fans with highly-decorative ceiling fans, which did not have efficiency standards.

In the test procedure Final Rule, DOE took the efficiency organizations' recommendation and adopted a definition of a belt-driven ceiling fan as "a ceiling fan with a series of one or more fan heads, each driven by a belt connected to one or more motors that are located outside of the fan head."

TRC ranked the efficiency organizations' effectiveness as high.

Role of Efficiency Organizations: TRC identified the efficiency organizations as being the major proponent to the DOE for this activity, since they proposed a specific amendment to the proposed definition that DOE ultimately adopted.

Savings from Activity: Negligible. Though the efficiency organizations' activity on this issue contributed to some savings, given the market size of these products and that this comment was relatively minor, the savings are negligible.[4]

[4] It is possible that the industry would have substituted this type of system at a higher than expected rate in which case savings would have been greater than negligible. However, without additional research to determine how responsive the industry would have been, indicating savings as negligible is prudent.

6 FUTURE ENERY SAVINS AND OTHER FEEDBACK COLLECTED

TRC notes other activities that the efficiency organizations conducted during the Ceiling Fan standard development that may lead to future energy savings:

- Efficiency organizations encouraged DOE, in future rulemakings, to monitor the development of ASHRAE Standard 216P (which relates air circulation to thermal comfort) and to consider a test procedure that compares energy input to thermal comfort gains per area of occupied space.

- One manufacturer noted that they had worked with efficiency organizations to develop the "fan energy index" (FEI) metric for large-diameter ceiling fans.[5] This new metric is specified in the 2018 version of ANSI/AMCA 208 and may be adopted by DOE in future ceiling fan rulemakings.

Manufacturers interviewed provided the following comments in addition to those described in Section 5:

- One manufacturer noted that they did not believe that there would have been a ceiling fans rulemaking at all had the efficiency organizations not been involved and pushing for it.

- One manufacturer noted that having the efficiency organizations involved in the rulemaking process is helpful, and that the key is getting efficiency organizations and manufacturers to work together.

- Following the publication of the 2016 final rule, DOE determined that testing ceiling fans at different laboratories led to very different test results. Because of this, DOE is currently working with industry to conduct round robin testing at different test labs.[6]

[5] https://appliance-standards.org/sites/default/files/appliance%20DESIGN%20June%202018%20fan%20metric_0.pdf

[6] https://www.energy.gov/sites/prod/files/2018/07/f53/Round_Robin_FAQ_2018-7-09.pdf

7 CONCLUSIONS

Based on the data collection, TRC's impact assessment was that efficiency organizations had a low-to-moderate influence on the standard. The main influence of the efficiency organizations was submitting comments regarding which standard level to adopt. TRC estimates that the efficiency organizations contributed 9% of total savings from the standard.

APPENDIX: NEEA LOIC MODEL FOR STANDARDS RULEMAKIN PROCESS