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STAFF REPORT

Analysis of Efficiency Standards and Test Procedures for Commercial and Industrial Fans and Blowers

2021 Appliance Efficiency Rulemaking
Docket Number 22-AAER-01

Gavin Newsom, Governor

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California Energy Commission

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PREFACE

On May 15, 2017, California Energy Commission staff released an invitation to participate to provide interested parties the opportunity to inform the California Energy Commission about the product, market, and industry characteristics of commercial and industrial fans and blowers.

On July 19, 2017, staff reviewed the information and data received and hosted a workshop to publicly vet the information submitted for commercial and industrial fans and blowers.

On July 18, 2017, staff released an invitation to submit proposals to seek proposals for standards, test procedures, labeling requirements.

On August 1, 2017, staff hosted a public webinar to explain the participation process for anyone interested in submitting a proposal.

On October 24, 2017, staff hosted a public webinar to present the results of the invitation to submit proposals.

On January 19, 2018, the California Energy Commission formally issued an order instituting rulemaking proceeding for commercial and industrial fans and blowers. The order directs staff to consider efficiency standards, test procedures, and marking and labeling requirements.

On June 11, 2018, California Energy Commission staff published a draft staff report proposing standards for commercial and industrial fans and blowers that included stand-alone and embedded fans. Staff published a notice of staff workshop to discuss the proposed appliance efficiency regulations for commercial and industrial fans and blowers.

On July 11, 2018, staff hosted a workshop to discuss the draft staff report for commercial and industrial fans and blowers.

On July 23, 2018, California Energy Commission staff published a notice extending the public comment period to September 28, 2018, for the draft staff report for commercial and industrial fans and blowers.

On July 27, 2020, California Energy Commission staff recalculated the energy savings in the staff report for commercial and industrial fans and blowers using recent electricity rates for the State of California.

Staff reviewed all the information received. This report contains the proposed regulations for commercial and industrial fans and blowers, based on comments received at the workshop and in writing through the California Energy Commission docket.

ABSTRACT

This report discusses proposed test procedures, efficiency standards, reporting requirements, and marking and labeling requirements for commercial and industrial fans and blowers found in the *Appliance Efficiency Regulations* (California Code of Regulations, Title 20, Sections 1601 to 1609). These proposed updates are part of the 2017 Appliance Efficiency Rulemaking Phase II (Docket 17-AAER-06). California Energy Commission staff analyzed the cost-effectiveness and technical feasibility of the proposed efficiency standards for commercial and industrial fans and blowers and determined these standards would save electricity and provide related environmental benefits.

Staff proposes standards for stand-alone commercial and industrial fans and blowers, which would take effect one year after the California Energy Commission adopts the standards. The standards would apply to all stand-alone commercial and industrial fans and blowers greater than or equal to 1 horsepower, or for fans without a rated shaft input power, an electrical input power greater than or equal to 1 kilowatt, but no more than 150 air horsepower.

The proposed standard would save about 61 gigawatt-hours the first year the standard is in effect. In 2052, when all existing fans are replaced with fans that meet the proposed efficiency standards (full stock turnover), the proposed standards would save about 1,755 gigawatt-hours per year. These savings equate to about $303 million in savings per year after full stock turnover for an approximately total life-cycle net benefit of over $5 billion for California businesses and industries.

Staff analyzed available market data and concluded that the standards for commercial and industrial fans and blowers would significantly reduce energy consumption and are technically feasible and cost-effective.

Keywords: Appliance Efficiency Regulations, appliance regulations, energy efficiency, commercial and industrial fans and blowers, fans, blowers

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EXECUTIVE SUMMARY

This report presents the California Energy Commission (CEC) staff analysis of proposed efficiency standards, defined test procedure, and marking and labeling requirements for commercial and industrial fans and blowers.

Staff proposes new standards for commercial and industrial fans and blowers. The efficiency standards for commercial and industrial fans and blowers would apply to stand-alone fans manufactured on or after one year from the date of adoption by the CEC. The proposed standards cover stand-alone commercial and industrial fans and blowers used in building applications. Rather than specifying a particular flow rate or pressure point, staff proposes using the fan energy index metric, which considers the motor, transmission, and control efficiencies as part of the calculation. This metric provides a standardized and consistent basis to compare fan energy performance across fan types and sizes at a given fan duty point. The metric also allows the consumer to pick the most efficient fan for the application, based on an energy index.

The proposed regulations for stand-alone commercial and industrial fans and blowers will also require that the unit be marked and/or labeled with the FEI compliant information. The regulation also proposes, as part of the labeling and marking requirements, that all marketing information provided in California only reflects the FEI compliant performance information at the point of sale. By implementing this standard, manufacturers will be able to provide FEI compliant options to air movement designers and engineers for commercial and industrial applications where these fans are used.

The proposal is derived from the Appliance Standards and Rulemaking Federal Advisory Committee term sheet and the U.S. Department of Energy's (DOE) third notice of data availability for efficiency standards and test procedures for commercial and industrial fans and blowers. The committee negotiations resulted in a term sheet that included scope, test procedures, marking and labeling requirements, and standards for fans. The DOE released a third notice of data availability to support the recommendations in the term sheet on November 1, 2016. CEC staff analyzed the types of fans listed in DOE's analyses (Life-Cycle Cost Analysis and National Impact Analysis). Although the DOE analysis includes stand-alone and embedded fans, this staff proposal includes only stand-alone fan types within the scope of the proposed standard.

The estimated net benefit for end users of stand–alone commercial and industrial fans and blowers is between $407 to $6,117 per unit, depending on fan type. The first year the standards take effect, California will save approximately 61 gigawatt-hours (GWh) and about 1,755 GWh per year after full stock turnover in 2052. The estimated savings for stand–alone commercial and industrial fans and blowers after complete stock turnover are roughly $303 million in annual savings.

The benefit-to cost-ratio ranges from 4.6:1 to 42:1 depending on the fan type, indicating that this proposal is cost-effective.

Staff analysis demonstrates that the proposed standards for stand-alone commercial and industrial fans and blowers are feasible because there are a large number of existing commercial and industrial fans and blowers available that operate at or above the proposed standard and can achieve the desired operating airflow.

CHAPTER 1: Legislative Criteria

Section 25402(c)(1) of the California Public Resources Code mandates that the California Energy Commission (CEC) reduce the inefficient consumption of energy and water on a statewide basis. The CEC must accomplish the mandate prescribing efficiency standards and other cost-effective measures for appliances that require a significant amount of energy or water to operate. Such standards must be feasible and attainable and must not result in any added total cost to the consumer over the designed life of the appliance.

In determining cost-effectiveness, the CEC considers the value of the water or energy saved, the effect on product efficacy for the consumer, and the life-cycle cost to the consumer of complying with the standard. The CEC also considers other relevant factors, including the effect on housing costs, the statewide costs and benefits of the standard over the lifetime of the standard, the economic impact on California businesses, and alternative approaches and the associated costs.

CHAPTER 2: Efficiency Policy

For nearly four decades, California has regularly increased the energy efficiency requirements for new appliances sold and new buildings constructed in the state. Through the Appliance Efficiency Program, appliance standards have shifted the marketplace toward more efficient products and practices, reaping significant benefits for California's consumers. California's Title 20 Appliance Efficiency Regulations, along with Federal appliance standards, encompass a variety of appliance types and have saved an estimated 34,707 gigawatt-hours (GWh) of electricity and 1,775 million therms in 2017 alone, resulting in about $8.26 billion in savings[1] to California consumers.[2] In the 1990s, the California Public Utilities Commission (CPUC) decoupled the utilities' financial results from their direct energy sales, promoting utility support for efficiency programs. These efforts have reduced peak electric load needs by more than 8,645 megawatts (MW) and continue to save about 32,594 GWh per year of electricity.[3] The potential for additional savings remains by increasing the energy efficiency of appliances.

Reducing Electrical Energy Consumption to Address Climate Change

Governor Gavin Newsom highlighted the importance of addressing climate change in his third state-of-the-state address March 9, 2021. Increases in extreme weather and severity of wildfires are evidence that climate change impacts to California are not in the future but here now, and the cost of inaction

[1] Using current average electric power and natural gas rates of residential electrical rate of $0.182 per kilowatt-hour, commercial electric rate of $0.159 per kilowatt-hour, residential natural gas rate of $1.206 per therm, commercial natural gas rate of $0.846 per therm. This estimate does not incorporate any costs associated with developing or complying with appliance standards.

[2] California Energy Commission. 2017 IEPR Workshops, Notices and Documents, Docket # 17-IEPR-01, https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2017-integrated-energy-policy-report/2017-iepr.

[3] California Energy Commission, *California Energy Demand 2016-2026 Revised Electricity Forecast*, January 2016, https://efiling.energy.ca.gov/GetDocument.aspx?tn=207439&DocumentContentId=21362.

would be high. Appliance energy efficiency is a key to achieving the greenhouse gas (GHG) emission reduction goals set 15 years ago with the passage of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006)[4] and then followed by Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016).[5] Recommendations to increase energy efficiency were contained in the California Air Resources Board's (CARB) *Climate Change Scoping Plan*.[6] Energy efficiency regulations are also identified as key components in reducing electrical energy consumption in the CEC's *2020 Integrated Energy Policy Report (IEPR)*[7] and the 2011 update to the CPUC's *Energy Efficiency Strategic Plan.*[8] California has identified appliance efficiency standards as a key to doubling the energy efficiency savings necessary to put California on a path to reducing its GHG emissions to 80 percent below 1990 levels by 2050.[9] Such a commitment was made under the Subnational Global Climate Leadership Memorandum of Understanding agreement, along with 167 jurisdictions representing 33 countries.[10]

California passed the Clean Energy and Pollution Reduction Act of 2015 or Senate Bill 350 (De León, Chapter 547, Statutes of 2015), requiring the CEC to establish annual targets for statewide energy efficiency savings and demand reduction that will achieve a doubling of energy savings from buildings and retail end uses by 2030.[11] Appliance efficiency standards are critical to meeting this goal. In

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[4] AB 32, California Global Warming Solutions Act of 2006, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32.

[5] SB 32, California Global Warming Solutions Act of 2006, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB32.

[6] *Climate Change Scoping Plan*, http://www.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf.

[7] California CEC, 2019 Integrated Energy Policy Report, 2019, https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report

[8] CPUC, *Energy Efficiency Strategic Plan,* updated January 2011, https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5303.

[9] Gov. Edmund G. Brown Jr., 2015 Inaugural Address, https://www.ca.gov/archive/gov39/2015/01/05/news18828/index.html.

[10] Subnational Global Climate Leadership Memorandum of Understanding, https://www.theclimategroup.org/sites/default/files/under2-mou-with-addendum-english-us-letter.pdf.

11 *2018 Integrated Energy Policy Report Update*, https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2018-integrated-energy-policy-report-update.

addition, the CEC adopted the *2019 California Energy Efficiency Action Plan,*[12] which combined the *Existing Building Energy Efficiency Action Plan* and the *Doubling of Energy Efficiency Savings by 2030 Report.* The 2019 action plan update reflects a renewed promise of and commitment to efficiency as a traditional, common-sense energy management strategy and as a dynamic grid resource to transform existing residential, commercial, and public buildings into energy-efficient structures. Appliance efficiency standards are essential to strategies that reduce plug-load energy consumption in existing buildings.

Loading Order for Meeting the State's Energy Needs

California's loading order places energy efficiency as the top priority for meeting energy needs. The CPUC's *Energy Action Plan 2008 Update*[13] strongly supports the loading order, which describes the priority sequence for actions to address increasing energy needs. Energy efficiency and demand response are the preferred means of meeting the state's growing energy needs.

For the past 30 years, while per capita electricity consumption in the United States has increased by nearly 50 percent, California electricity use per capita has been nearly flat. Continued progress in cost-effective buildings and appliance standards and ongoing enhancements to efficiency programs implemented by investor-owned utilities (IOUs), publicly owned utilities, and other entities have contributed significantly to this achievement.

Clean Energy Jobs Plan

On June 15, 2010 former Governor Edmund G. Brown Jr. proposed the *Clean Energy Jobs Plan*,[14] which directed the CEC to strengthen appliance efficiency standards for lighting, consumer electronics, and other products. This plan noted that energy efficiency is the cheapest, fastest, and most reliable way to create jobs, save consumers money, and cut pollution from the power sector. It is also clear that California's efficiency standards and programs have triggered innovation and creativity in the market. Today's appliances are more efficient,

[12] 2019 California Energy Efficiency Action Plan, https://www.energy.ca.gov/programs-and-topics/programs/energy-efficiency-existing-buildings.

[13] Energy Action Plan 2008 update, https://www.cpuc.ca.gov/eaps/.

[14] Office of Edmund G. Brown Jr., *Clean Energy Jobs Plan*, http://www.jerrybrown.org/brown_announces_clean_energy_jobs_plan.

and they are less expensive and more versatile than ever, due, in part, to California's leadership in this area.

CHAPTER 3:
Product Description

There are an estimated 2 million commercial and industrial fans and blowers in California, with an energy use of nearly 69,000 GWh per year. Efficiency improvements in fans can drive down the energy use in the desired applications. This chapter describes fans in terms of airflow, construction, auxiliary parts, application, and utility.

Stand-Alone and Embedded Fans

Fans can be sold as stand-alone products, can be sold to an original equipment manufacturer (OEM) of a product that requires a fan be incorporated or embedded (such as a unitary air conditioner), or can be manufactured by an OEM and sold with the product that requires a fan be embedded.

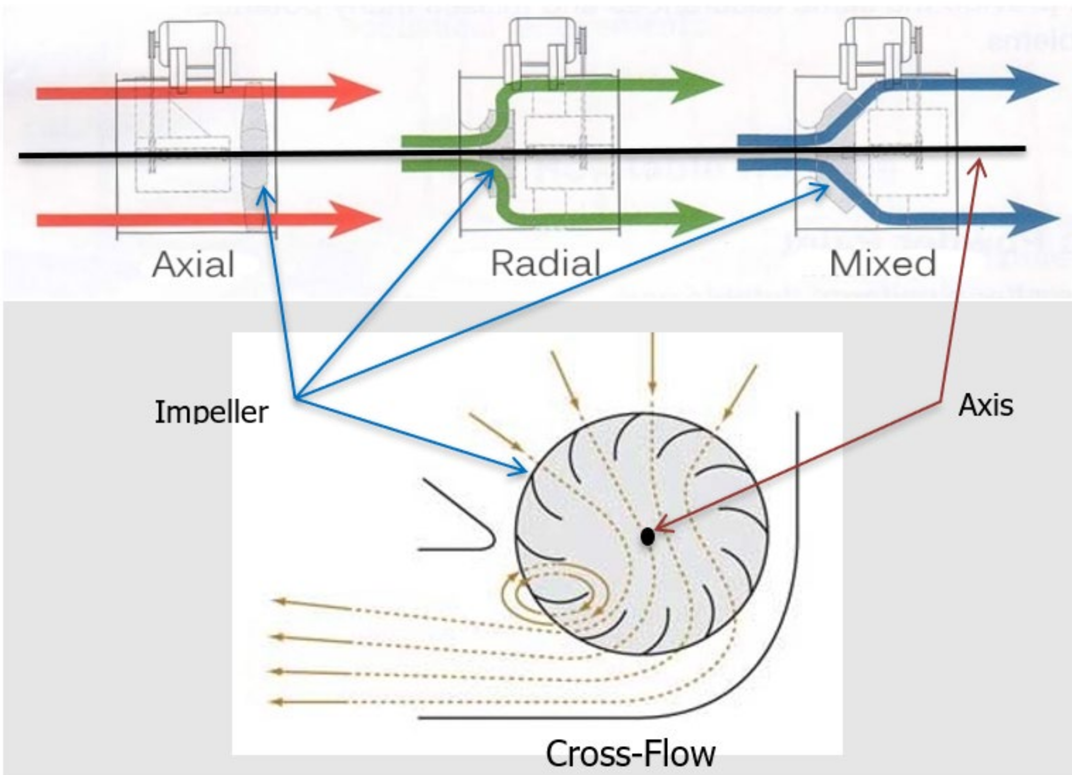
A stand-alone fan moves air through a system and is installed as an independent piece of equipment. A stand-alone fan will do work, or move air, through a system of vents.

Embedded fans are exempt from the proposed regulations because the fan is either manufactured by an OEM who embeds the fan in a piece of equipment where the main function is something other than the movement of air, or because it is manufactured for the purpose of being embedded into an appliance after market. This proposal excludes fans embedded in regulated and nonregulated equipment where the main function is other than the movement of air, as long as the fan is not sold or offered for sale as a standalone product.

Overview of Fans and Blowers

A fan, or blower, is a device that produces a current of air (airflow). Commercial and industrial fans and blowers are used in a wide variety of applications such as commercial building ventilation, commercial kitchen exhaust systems, industrial processes, and agricultural ventilation. One of the characteristics by which fans are classified is the nature of air movement through the impeller. Axial flow, radial flow, mixed-flow, and cross-flow are all possible characteristics for fan impellers. (See **Figure 3-1.**) These flow characteristics often define the type of fan, although other fan characteristics may be used to delineate the type of fan, for example, induction fans, propeller fans, vane-axial, centrifugal unhoused, and so forth.

Figure 3-1: Axial-Flow, Radial-Flow, Mixed-Flow, and Cross-Flow



Airflow Characteristics

Axial-Inline Fans

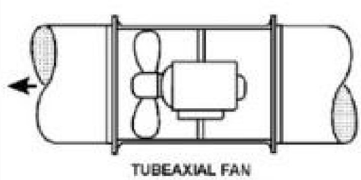
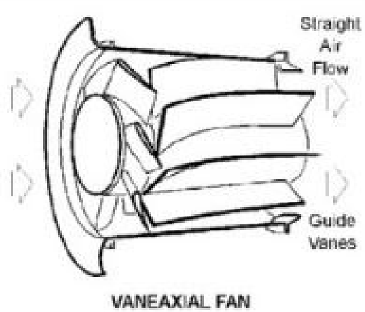
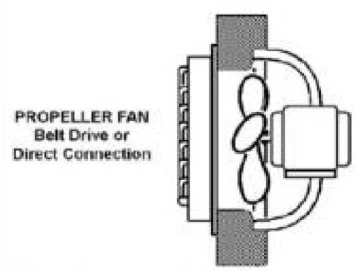
Axial-inline fans, as shown in **Figure 3-2,** are also known as *axial-cylindrical housed fans.* Examples of axial-inline fans are shown in **Figure 3-3** and include tube-axial fans, vane-axial fans, and some propeller fans that use an axial-flow impeller, where the air enters and exits the fan in the same direction as that of the axis or fan axle, as shown in **Figure 3-1** above. In addition to the axial impeller, axial-inline fans have cylindrical housing, may or may not have turning vanes, and may or may not have ducted inlets and outlets. These fans are used in applications such as general ventilation and industrial processes.

Tube-axial and vane-axial fans use a tubular casing. Unlike tube-axial fans, a vane-axial fan has stationary guides (vanes). A great deal of energy transferred to the air in axial-flow fans is kinetic. This kinetic energy can be transformed into pressure energy by straightening the swirl of air by using vanes or reducing the exit velocity with the use of a diffuser. Vane-axial fans can be equipped for maximum transformation, as well as high transfer of energy, and have a high-pressure-producing potential depending on tip speed and blade angles.

Figure 3-2: Axial-Inline Fan

Source: Greenheck

Figure 3-3: Tube-Axial, Vane-Axial, and Propeller Fans

Tube Axial	Vane Axial	Propeller
		
		

Source: Mechanical Galaxy, blogspot.com

Axial-Panel Fans

Axial-panel fans, also known as *propeller fans* or *panel fans*, are fans with an axial impeller mounted in a short housing that can be a panel, ring, or orifice plate. The housing is typically mounted to a wall separating two spaces, and the fans are used to increase the pressure across the wall, when inlets and outlets are not ducted. Panel fans achieve little transformation and, for this reason, have low pressure-producing capability. Panel fans transport air from one space to another, such as for ventilation through a wall in factories and warehouses. An axial-panel fan is shown in **Figure 3-4**.

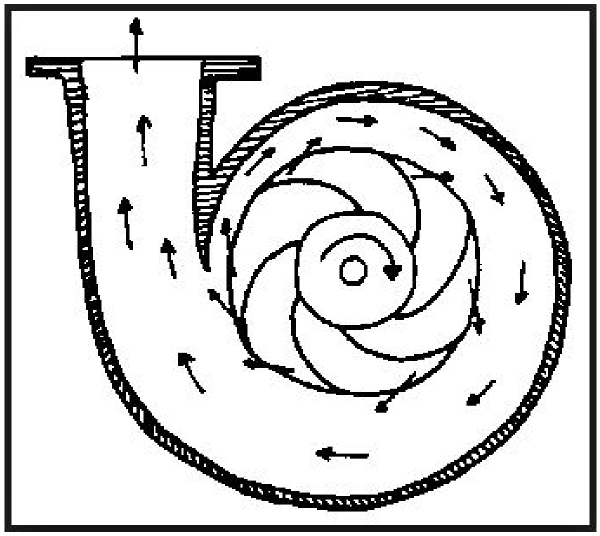
Figure 3-4: Axial-Panel Fan

Source: Loren Cook Company

Centrifugal Housed and Unhoused Fans

Centrifugal fans move air from an axial to a radial flow because of centrifugal action by the impeller. Centrifugal fans usually use a scroll-type casing or housing (**Figure 3-5**), where the flow enters at the middle of the case in an axial direction and leaves the impeller in a tangential direction from the axle of the impeller.

Figure 3-5: Scroll-Type Casing



Source: Wells Construction

Centrifugal fans can come without a casing, also known as a *centrifugal-unhoused fan* (**Figure 3-6**), or with a scroll-type casing, also known as *centrifugal-housed fans* (**Figure 3-7**). Tubular centrifugal fans use a tubular casing so that the flow enters and leaves axially. (See **Figure 3-8**). The pressure-producing capability of radial flow fans varies depending on blade depth, tip velocity, and blade angles. (See **Figure 3-9**).

A centrifugal-housed fan (with casing) has a centrifugal or radial impeller in which airflow exits into a housing that is generally scroll-shaped to direct the air through an outlet. Inlets and outlets can be ducted. Centrifugal-housed fans include forward-curved, backward-curved, backward-incline, and airfoil impellers (**Figure 3-9)**. Forward-curved, backward-curved, and backward-incline impellers have blades of a single thickness, while airfoil fans have a backward-incline airfoil blade. An *airfoil* is the shape of a wing that produces an aerodynamic force when it moves through a fluid. Centrifugal-housed fans are used to supply ventilation air and are used in industrial process applications.

A centrifugal-unhoused fan (without a casing) has a centrifugal or radial impeller (**Figure 3-10)** in which airflow enters through a panel and discharges into free space, and the inlet and outlet are not ducted. Centrifugal-unhoused fans include fans designed for use in fan arrays that have partition walls separating the fan from other fans in the array. Centrifugal-unhoused fans are also known as "plenum fans."

Figure 3-6: Centrifugal-Unhoused Fan

Source: peerless blowers.com

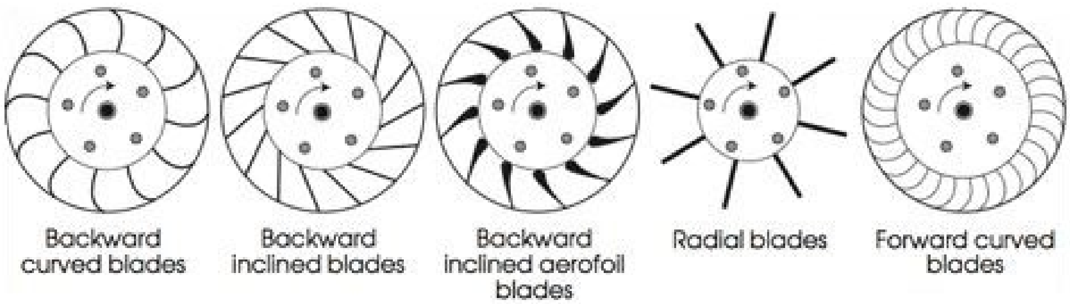
Figure 3-7: Centrifugal-Housed Fan

Source: The New York Blower Company

Figure 3-8: Centrifugal-Inline and Inline Mixed-Flow Fan

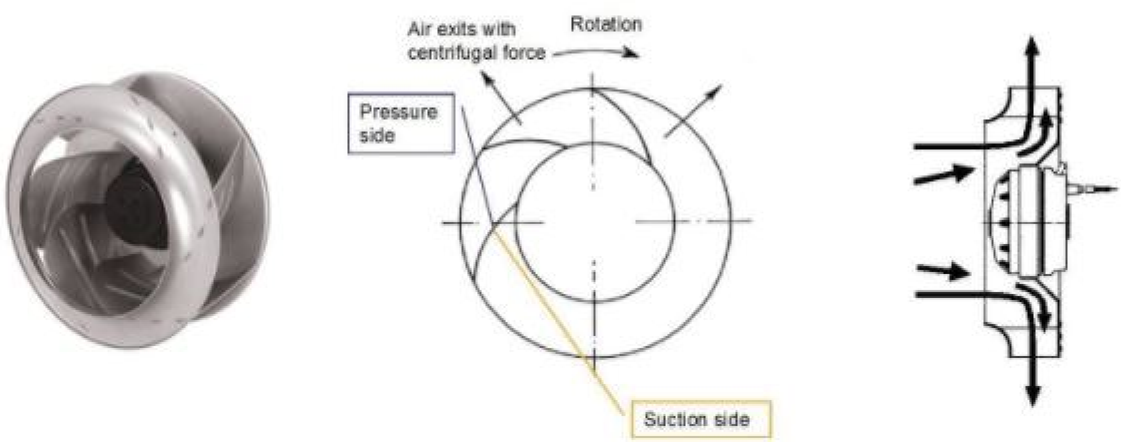
Source: Aerovent.com

Figure 3-9: Centrifugal Impellers



Source: cibsejournal.com

Figure 3-10: Radial Impeller



Source: Design Spark

Centrifugal-Inline and Mixed-Flow Fans

Centrifugal-inline and *inline mixed-flow fans* (**Figure 3-8)** often have cylindrical housing similar to axial-inline fans but have either a centrifugal or a mixed-flow impeller design. Airflow enters axially at the fan inlet, and the housing redirects radial airflow from the impeller to exit the fan in an axial direction. The inlets and outlets may be ducted. Centrifugal-flow impellers will discharge the air in a radial direction (**Figure 3-1)**, but the cylindrical housing will redirect the air to exit in an axial direction. Centrifugal-inline fans can also have square or rectangular housings. Inline mixed-flow fans are characterized by an axial and radial airflow taking place on the blades of the impeller. Mixed-flow impellers used in axial-flow casings have a hub similar to an axial-flow impeller, but the inlet portion of the blade extends down over the face of the hub, guiding air radially (**Figure 3-1**). Centrifugal and mixed inline-flow fans are typically used for general ventilation applications.

Radial-Housed Fans

Radial-housed fans, also known as *radial fans*, are a type of centrifugal fan that has blades that extend radially from the central hub (**Figure 3-9** and **Figure 3-10**)**.** The air enters in an axial direction and exits in a centrifugal or radial direction. Radial-housed fans are typically used in material handling (**Figure 3-11**).

Figure 3-11: Radial-Housed Fan

Source: Twin City

Power Roof/Wall Ventilators

Power roof/wall ventilators (PRV) can exhaust or supply air to a building. They can be designed with an axial flow, known as an *axial power roof ventilator*, or a centrifugal flow, known as a *centrifugal power roof ventilator*. A power roof/wall ventilator has an internal driver and housing to prevent precipitation from entering the building, as well as a base designed to fit over the roof or wall opening. A centrifugal PRV exhaust fan has a centrifugal impeller that exhausts air from a building; the inlet is typically ducted, and the outlet is not. A centrifugal PRV supply fan has a centrifugal impeller that supplies air to a building; the inlet is typically not ducted, and the outlet is typically ducted. An axial PRV has an axial impeller that either supplies or exhausts air to a building; the inlet and outlets of an axial PRV are typically not ducted. See **Figure 3-12** for an example of an exhaust PRV.

Figure 3-12: Exhaust Power Roof/Wall Ventilator

Source: Captive Air

Characteristics of Excluded Fans

Embedded fans, induction fans, and jet fans are excluded from the scope of this proposal. This proposal excludes fans embedded in regulated and nonregulated equipment with a main function other than the movement of air, as long as the fan is not sold or offered for sale as a standalone product. Embedded fans are discussed above at the beginning of Chapter 3, induction and jet fans are discussed below.

Induction Fans

An induction fan (**Figure 3-13**) is a fan designed specifically for exhausting contaminated air vertically away from a building. An induction fan is a housed fan where the outlet airflow is greater than the associated inlet airflow due to induced airflow through an outlet nozzle and a windband. The design of the outlet nozzle creates a high-velocity jet from the inlet airflow that, when combined with a windband, induces ambient air to create a larger volume of diluted air that is discharged out the top of the windband. These fans are generally installed in laboratory or hazardous exhaust air systems and are used as an alternative to a traditional centrifugal or axial fan that exhausts into a tall stack. Inlets can be ducted, and outlets are not ducted.

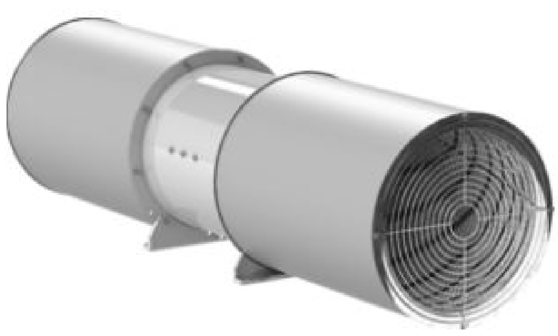
Figure 3-13: Induction Fan

Source: Twin City Fan Blower

Jet Fan

A jet fan, also known as *jet tunnel fan,* is used for producing high-velocity flow of air in a space. Jet fans are tested using either International Organization for Standardization (ISO) standard 13350:2015 Fans – Performance Testing of Jet Fans or Air Movement and Control Association (AMCA) 250 – Laboratory Methods of Testing Jet Tunnel Fans for Performance. The typical function of a jet fan is to add momentum to the air within a tunnel. Inlets and outlets are not ducted. (See **Figure 3-14**).

Figure 3-14 Jet Fan

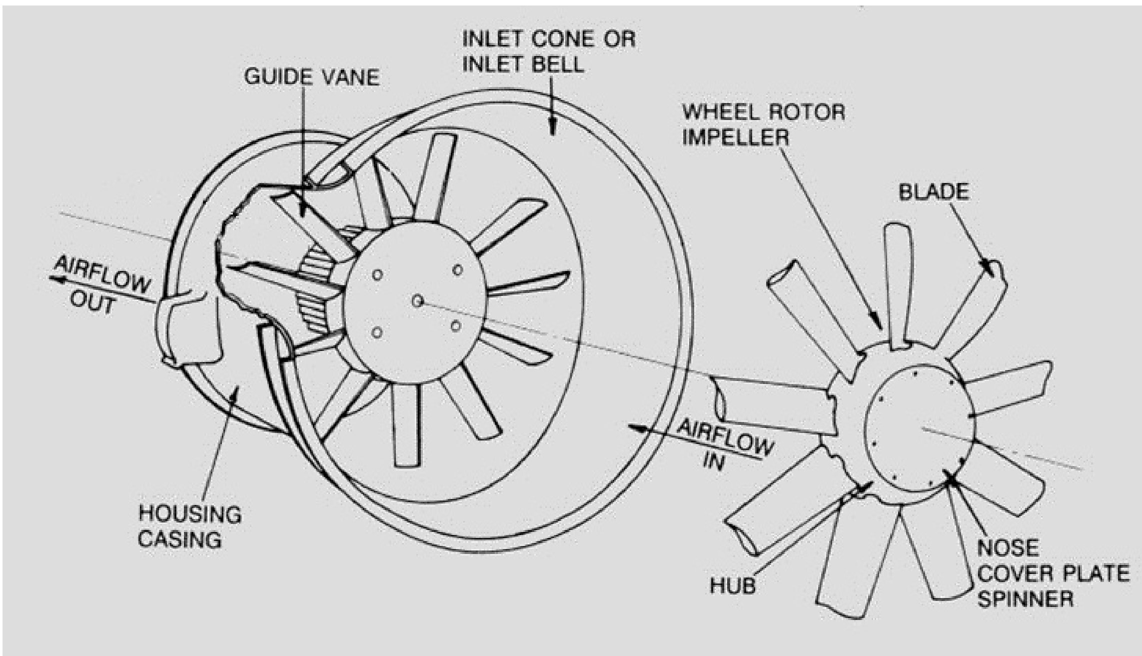


Source: Kruger Fan

Fan Construction

Axial fans (**Figure 3-15**) may use blades shaped to airfoil sections (shape of a wing) or blades of uniform thickness that can be fixed, adjustable at standstill, or variable in operation. The design of these fans takes in air and discharges it in a direction that is generally parallel to the shaft of the impeller. The larger the hub, the more important it is to have an inner cylinder roughly the size of the hub located downstream of the impeller. The guide vanes of a vane-axial fan are in the annular space between the casing and the inner cylinder and are used or designed to straighten the airflow.

Figure 3-15: Vane-Axial Fan, Exploded View

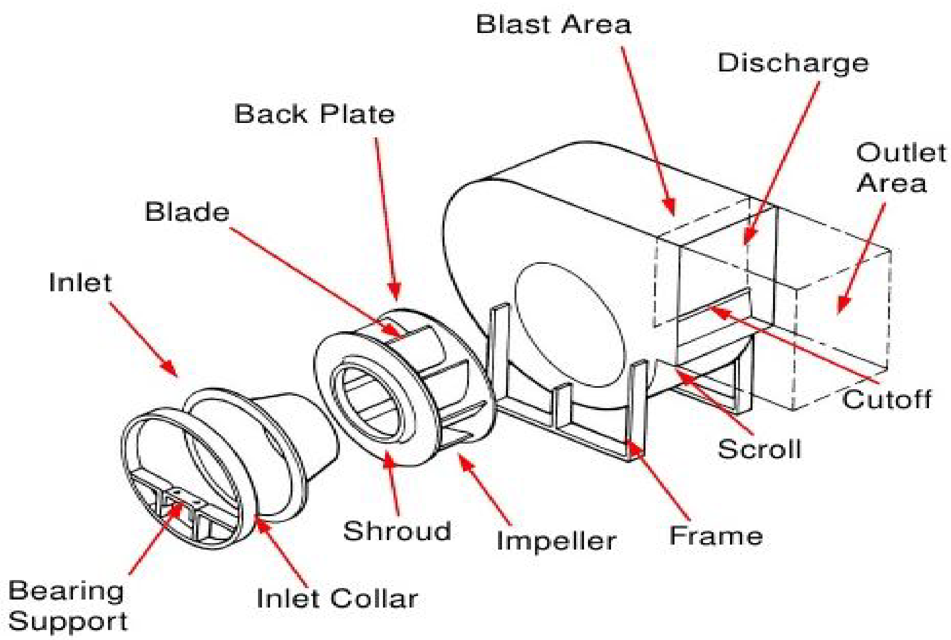


Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Handbook

Centrifugal fans (**Figure 3-16**) use forward-curved blades; radial and radial-tip blades; backward-curved, backward-incline blades; and airfoil blades. Forward-curved blades are shallow and curved so that the tip and the heel point in the direction of rotation. Radial and radial-tip blades have fins that are straight or perpendicular to the hub; however, radial-tip blades are curved at the heel to point in the direction of rotation. Backward-curved and backward-incline blades point in the direction opposite rotation at the tip and in the direction of rotation at the heel. All the blades mentioned above are of uniform thickness and are designed for radial flow.

Airfoil blades have backward-curved chord lines so that the leading edge of the airfoil is pointing forward at the heel, and the trailing edge is pointing backward at the tip with respect to rotation. Impellers for all blade shapes are usually shrouded and may have single or double inlets. Blade widths are related to the inlet-to-tip-diameter ratio. Tubular centrifugal fans may be designed for backward-curve, airfoil, or mixed-flow impellers. An inlet bell and discharge guide vanes are required for good performance.

Figure 3-16: Centrifugal Fan Parts



Source: Loren Cook Company

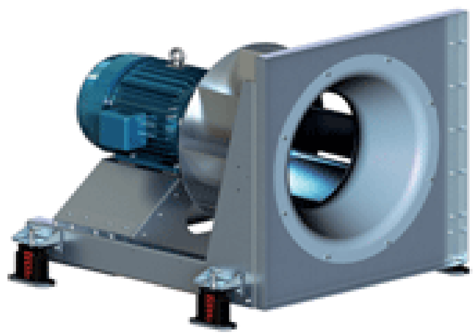
Cross-flow fans use impellers with blades similar to those of a forward-curved centrifugal blade, but the end shrouds have no inlet holes. Blade-length-to-tip-diameter ratios are limited only by structural considerations.

Fan Motor, Transmission, and Controls

Fan efficiency can depend on the fan itself, as described above, as well as on the related auxiliary components, including the motor, transmission, and motor controls. Fans use a variety of motors to operate, each with its own efficiency. The motors vary in horsepower and technology. In addition, the type of transmission used to move the fan also affects the efficiency of the motor and fan. Power is transmitted from the motor to the shaft of the fan by mounting the motor directly to the shaft or by using a belt mechanism.

With direct-shaft-driven fans, the motor is directly mounted onto the fan shaft, and the power is transmitted to the fan directly from the motor (**Figure 3-17**). The motor shaft and the fan shaft are connected by a belt on belt-driven fans (**Figure 3-18).** Controls improve the efficiency of the fan and enable the fan to operate at a specific number of revolutions per minute to provide the required volumetric flow. Some fans use a variable-speed electric motor and a control to change the speed or power at which the motor operates. In other cases, changing the belt tension or gear ratio can control or change the velocity of the fan.

Figure 3-17: Direct-Drive Fan



Source: Greenheck

Figure 3-18: Belt-Driven Fan

Source: Greenheck

CHAPTER 4: Regulatory Approaches

This chapter provides an overview of different regulatory and non-regulatory approaches to testing and improving the efficiency of commercial and industrial fans and blowers.

Metrics

Cubic Feet per Minute per Watt

A cubic-feet-per-minute-per-watt metric (CFM/watt) approach is the volumetric flow rate compared to the energy or watts needed by the motor to generate a flow rate. Although the approach is simple, it does not consider the efficiency of the electric motor, transmission, or controls, and does not consider static or total pressure. This metric is used by rebate programs for panel fans used in agricultural applications.

Fan Efficiency Grade

The fan efficiency grade (FEG) is a numerical rating that classifies fans by the associated aerodynamic ability to convert mechanical shaft power, or impeller power in the case of a direct-drive fan, to air power. Essentially, it reflects fan energy efficiency, allowing engineers to easily differentiate between fan models with FEG ratings. FEG applies to the efficiency of the fan only and not to the motor, drives, or both.

Fan Electrical Input Power

The fan electrical input power (FEP) is calculated for the motor (actual) and the fan (reference) at a specific pressure and volumetric flow. Both FEPs are calculated under the test procedure developed by the AMCA and incorporated by the American National Standards Institute (ANSI): ANSI/AMCA Standard 214-21 "Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers" (ANSI/AMCA 214-21) to calculate the duty points at which the fan will be most effective. Both FEP calculations take into consideration the efficiency of the motor, transmission, and controller.

Fan Energy Index

The fan energy index, or FEI, is a ratio of the electrical input power of a reference fan to the electrical input power of the actual fan calculated at the same duty point and calculated per ANSI/AMCA 214-21. The FEI can be calculated for each duty point (airflow and pressure) of a fan curve. The FEI metric considers the motor, transmission, and control efficiencies as part of the calculation. The FEI metric allows the consumer to pick the most efficient fan for the application based on an energy index, specific to a flow rate and pressure point. Because FEI is a ratio, it is based on an efficiency level. (See Chapter 6.)

Federal Regulations

There are no Federal standards or test procedures for commercial and industrial fans and blowers.

The U.S. Department of Energy (DOE) issued a notice of proposed determination June 28, 2011, proposing that commercial and industrial fans, blowers, and fume hoods meet the criteria for covered equipment under the Energy Policy and Conservation Act (EPCA).[15] On December 10, 2014, DOE issued a Notice of Data Availability (NODA),[16] followed by a second NODA[17] on May 1, 2015. Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) was formed to negotiate potential efficiency standards and test procedures for fans. The negotiations resulted in a term sheet that included scope, test procedures, and

[15] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Notice of proposed determination of coverage, https://www.regulations.gov/document?D=EERE-2011-BT-DET-0045-0001.

[16] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Energy Conservation Standards for Commercial and Industrial Fans and Blowers: Availability of Provisional Analysis Tools, Notice of Data Availability, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0037.

[17] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Notice of data availability, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0062.

standards for fans.[18] The DOE released a third NODA to support the recommendations in the term sheet on November 1, 2016.[19]

The ASRAC term sheet for fans recommended the following:

1. Define the scope of covered fans to include stand-alone and embedded fans and establish specific exclusions for stand-alone and embedded fans. The scope was agreed upon with a consensus of 24 votes in the affirmative, 0 votes in the negative, 0 abstention votes, and 1 absent vote.
2. Base the test procedure on "AMCA 210-16 Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating" under a specific installation type or testable configuration dependent on the fan category, and using FEP and FEI as the metric for efficiency. The test method, testable configuration, and metric were agreed upon with a consensus of 24 votes in the affirmative, 0 votes in the negative, 0 abstention votes, and 1 absent vote.
3. Test embedded fans outside the equipment in the same configuration as a stand-alone fan. This testing was agreed upon by consensus with 22 votes in the affirmative and 3 absent votes.
4. Use fan laws to determine the represented values of FEP and FEI for geometrically similar fans if a manufacturer offers geometrically similar fans. Consensus was reached with 24 votes in the affirmative and only 1 absent vote.

Other recommendations did not reach consensus, including how to calculate part-load motor losses and marking and labeling requirements.

DOE suspended its rulemaking for commercial and industrial fans and blowers in January 2017.

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[18] Appliance Standards and Rulemaking Federal Advisory Committee for Commercial and Industrial Fans and Blowers Working Group, Term Sheet, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0179.

[19] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Notice of data availability, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0194.

On August 19, 2021, DOE published a final determination of fans and blowers as covered equipment under EPCA.

California Regulations

California does not have appliance efficiency regulations under Title 20 of the California Code of Regulations for commercial and industrial fans and blowers.

The California Energy Code has requirements under Title 24, Part 6, Section 110.2 of the California Code of Regulations for some equipment that has an embedded commercial or industrial fan or blower or a combination. These requirements are for efficiency related to space conditioning, including requirements for minimum energy efficiency ratio, integrated energy efficiency ratio, coefficient of performance, integrated part-load value, or kilowatt-per-ton of refrigeration.

Moreover, there are direct fan requirements in the California Energy Code under Title 24, Part 6, Section 140.4(c) of the California Code of Regulations, but these requirements are applicable only to new buildings and on replacements for existing buildings. The Title 24 requirements apply to fan systems used for space conditioning and do not conflict with the requirements of the proposed regulation.

Regulations in Other States

There are no regulations in other states for commercial and industrial fans and blowers.

International Approaches

The European Union uses Regulation Number 327/2011, which sets eco-design requirements for fans driven by motors with an electric input power between 125 watts and 500 watts.[20] The regulation has two efficiency tiers, with the first tier effective January 1, 2013, and the second tier January 1, 2015. The regulation is applicable to axial fans, centrifugal forward-curved fans, centrifugal radial-bladed fans, centrifugal backward-curved fans without housing, centrifugal backward-curved fans with housing, mixed-flow fans, and cross-flow fans. The European

[20] Commission Regulation (EU) No. 237/2011 or March 2011, implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-design requirements for fans driven by motors with an electric input power between 125 W and 500kW Text with EEA relevance, https://publications.europa.eu/en/publication-detail/-/publication/c765ffb6-5f03-4a3f-ac61-08fc3f3874b7/language-en.

Union approach is based on a metric called *fan motor efficiency grade* (FMEG).[21] The regulation does not limit the fan selection point. Instead, an indirect mechanism discourages poor fan selection: the higher the electrical input power, the greater the required reference efficiency to stay within a given FMEG, and the greater the associated costs. The FMEG classification is based on full-speed operation at the optimum duty point and includes a small credit for the use of certain high-efficiency, variable-speed drives.

[21] Fan Motor Efficiency Grades in the European Market, Hauer, A. & Brook, J., https://www.amca.org/UserFiles/file/AMCA_014-021_Hauer.pdf.

CHAPTER 5: Alternative Considerations

CEC staff considered different potential regulatory pathways to achieve energy savings in fans, including consideration of the proposals submitted to the docket for this proceeding and a more stringent standard based on the efficiency levels presented in the DOE NODA released November 1, 2016. Staff considered alternative proposals provided to the CEC during the comment period to determine if the alternatives were more cost-effective and technically feasible than the proposed standard.

Baseline: No Standard

Under the baseline condition, the CEC would not have efficiency standards or test procedures for commercial and industrial fans and blowers. No costs would be imposed, and no energy savings would be achieved under this proposal. Staff believes that proposing no standard for commercial and industrial fans and blowers would represent a lost opportunity for energy savings in California and would not meet the state's greenhouse gas emission reduction and energy efficiency goals.

Alternative 1: CFM per Watt

The CEC reviewed the proposed alternative for the volumetric-flow-rate, CFM/watt option.[22] Staff found insufficient evidence of energy savings and technical feasibility since no data were provided to support this alternative. Although the CFM/watt metric could be used for fans that have no restrictions, this alternative is not applicable to other fans that have to work against static or total pressure. Therefore, staff does not propose the CFM per watt option as the preferred metric for this standard.

[22] Harry M. Graves Comments FAN EFFICIENCY INDEX A FALSE METRIC, https://efiling.energy.ca.gov/GetDocument.aspx?tn=221209&DocumentContentId=26703.

Alternative 2: FEI With an Efficiency Level 3

CEC staff proposed an FEI with a standard level equivalent to the DOE November 2016 NODA Efficiency Level 3 for stand-alone commercial and industrial fans and blowers.[23] The FEI metric using Efficiency Level 3, as explained in the metrics section under the Fan Energy Index of Chapter 4 above, provides significant energy savings for California. Staff finds there were sufficient data to conclude that the FEI standards at Efficiency Level 3 is technically feasible and cost-effective for stand-alone fans.

Alternative 3: FEI With an Efficiency Level of 4 or Higher

Staff reviewed the FEI standard with an Efficiency Level 4 or higher using information associated with the DOE November 2016 NODA. Although an FEI metric at Efficiency Level 4 would provide greater energy savings that are cost-effective and technically feasible, this level may not strike the right balance for a first-time regulation based on the comments received by manufacturers and stake holders because of the higher incremental cost it will take to achieve an efficiency level of 4. Furthermore, the efficiency level agreed during the negotiations of the ASRAC term sheet was that of an Efficiency Level 3.

Alternative 4: Stand-alone and Embedded Fans

Staff reviewed new data for shipments and recalculated the energy savings for embedded fans. The calculations show significant energy savings potential for embedded fans.[24.] However, the efficiency metric will not produce the same efficiency once the fan is embedded into a unit, nor can it be applicable to the entire unit as a whole. Data received by the CEC clarified that the energy used by embedded fans is at best 20 percent of the total energy used by the entire unit.[25] Staff does not recommend including embedded fans in the scope of this

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[23] AMCA, ASAP, NEEA, NRDC, ACEEE, PG&E, SDG&E, SCE, SoCalGas Comments AMCA and Efficiency Advocates Joint Proposal for Standalone Fans, https://efiling.energy.ca.gov/GetDocument.aspx?tn=221217&DocumentContentId=26705.

[24] ASAP, NEEA, NRDC, ACEEE, PG&E, SDG&E, SCE, SoCalGas Comments Efficiency Advocates Proposal for Embedded Fans, https://efiling.energy.ca.gov/GetDocument.aspx?tn=221220&DocumentContentId=26706.

[25] Ingersoll Rand Comment on CEC Draft Staff Report, Commercial and Industrial Fans and Blowers, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224815&DocumentContentId=55400.

proposal, as the test procedure does not accurately measure the efficiency of embedded fans.

CHAPTER 6: Staff Proposal

Scope

CEC staff proposes to cover stand-alone fans, which include axial-inline fans, axial-panel fans, centrifugal-housed fans, centrifugal-unhoused fans, centrifugal-inline fans, inline mixed-flow fans, and power roof/wall ventilators. The fans covered under this regulation must have a rated shaft input power, also known as *brake horsepower*, greater than or equal to 1 horsepower (HP). For fans without a rated shaft input power, an electrical input power must be greater than or equal to 1 kilowatt (kW). In addition, covered fans must have a fan airpower less than or equal to 150 HP. Fans smaller or larger than described are excluded from the scope of the staff proposal.

Embedded fans in regulated and nonregulated equipment will be excluded from the scope of the rulemaking. CEC staff proposes to exclude fans embedded in regulated and nonregulated equipment with a main function other than the movement of air, as long as the fan is not sold or offered for sale as a standalone product. Embedded fans in nonregulated equipment are excluded due to the complexity of testing embedded fans and the accuracy of the results. When an embedded fan is tested outside the appliance as a stand-alone fan, the FEI rating of that fan will not be the same once the fan is put back into the appliance, since the pressure and flow rate can differ due to cabinet losses not accounted for by the proposed test procedure. Although preliminary figures for embedded fans show an energy savings of about 115 GWh/year after full stock turnover (18 to 21 years), the proposed standard would only affect the fan component of the equipment to which the fan is embedded. This finding would prohibit future energy savings that could be captured by setting standards for each appliance as a whole. Therefore, embedded fans in nonregulated equipment with a main purpose other than the movement of air are excluded from the proposed regulation, as long as the fans are manufactured for the sole purpose of being embedded.

Other fans are excluded because they do not fit into the framework of a fan efficiency standard. Fans used in transport refrigeration and fans exclusively powered by internal combustion engines are not grid-connected and, therefore, do not present an opportunity for electricity or natural gas savings. Fans in vacuums are not designed to move air. Fans used in the specific types of heat-rejection equipment, such as those used in cooling towers, are exempt since regulating the fan efficiency of those fans could have unintended consequences in terms of overall energy consumption and heat rejection.

The proposed scope excludes embedded fans as defined in the proposed language in Chapter 10.

Staff also proposes to explicitly exclude the following types of fans:

a. Radial-housed unshrouded fans with diameter less than 30 inches or a blade width of less than 3 inches
b. Circulating fans
c. Induced-flow fans
d. Jet fans
e. Cross-flow fans
f. Fans manufactured for the sole purpose of embedding into an appliance with a primary function other than the movement of air

For definitions related to included and excluded products, see Chapter 10.

The intent of the recommended horsepower range is to cover fans that represent the majority of total fan energy consumption. AMCA found, through its survey of 2012 fan sales, that about 85 percent of the total connected stand-alone fan load is greater than or equal to 1 HP. According to a joint proposal presented by AMCA and efficiency advocates, there are a large number of small manufacturers who make fans under 1 HP.[26] Fans with air power greater than 150 HP make up a relatively small portion of the total connected load and are usually custom products used in industrial applications where customers are highly sensitive to the high operating costs at high power levels (efficiency of the fan). CEC staff is recommending a horsepower range that strikes an appropriate balance between capturing potential energy savings and testing the applicable stand-alone fans.

The lower bound of 1 HP is consistent with the lower bound of the DOE electric motor standards and commercial and industrial pump standards. The upper bound of 150 HP based on fan air power is roughly equivalent to the upper bound of 200 HP based on shaft power.[27] Fan air power measures the output power provided by the fan taking into consideration the efficiency of the impeller. Fan shaft power considers motor and transmission efficiency and measures the power at which the shaft rotates but ignores the efficiency of the

[26] AMCA and Efficiency Advocates Joint Proposal for Standalone Fans https://efiling.energy.ca.gov/GetDocument.aspx?tn=221217 p. 21.

[27] Industry term used for fans, brief explanation can be found in https://www.amca.org/UserFiles/file/Nospreads_FanEfficGrades.pdf.

impeller. CEC staff chose to use fan air power because that measurement captures the efficiency of the entire fan.

The lower bound of 1 kW fan electrical input power is roughly equivalent to a fan shaft power of 1 HP. To illustrate this, the default values for transmission and motor efficiencies would be applied to the ANSI/AMCA 214-21 standard for a fan with a shaft power of 1 HP. (See Calculation 1 in **Appendix A**).

Based on the default values for transmission efficiency and motor efficiency in ANSI/AMCA 214-21, a fan shaft power of 1 HP is almost equivalent to fan electrical input power of 1 kW. For all fans, fan air power shall be calculated based on either static pressure or total pressure depending on the type of fan, as described in ANSI/AMCA 214-21.

The fan categories covered by this proposal include a wide variety of common commercial and industrial applications. In contrast, the excluded fan categories are fan types that are primarily used in specialty applications including those embedded in equipment with a main function other than the movement of air. For Federally-regulated central air conditioners and heat pumps (single-phase, less than 65,000 British thermal units/hour [Btu/h]) and Federally-regulated commercial air conditioners and heat pumps that are three-phase and less than 65,000 Btu/h (air cooled), the Federal efficiency standards already regulate the equipment and, to some extent, the fan efficiency as a component of the cooling or heating efficiency of the unit. For regulated home furnaces, the furnace fan is already subject to a DOE efficiency standard.

Framework and Metric

The CEC staff proposal will apply to the entire certified operating range of each fan model. The rationale for this approach is that it will encourage better fan selection, which will significantly improve efficiency and decrease power consumption. Since the efficiency of a fan varies widely across the operating range, the peak efficiency of a fan has little relevance to actual efficiency and energy consumption in the field. Therefore, this approach is focused on driving better fan selection and can provide significantly greater savings than an approach based on the efficiency of a fan at just one or a few operating points. The importance of fan selection is discussed in Chapter 8.

To capture the entire certified operating range of a fan, staff proposes to use the FEI as the efficiency metric for fans covered under this proposal. CEC staff believes that the FEI metric will reflect the different duty points at which a fan will perform above the proposed minimum level by comparing a reference fan electrical input to that of the tested fan electrical input power. FEI considers the motor, transmission, and control efficiencies as part of the calculation. This consideration allows the consumer to pick the most efficient fan for the application, based on an energy index, rather than a specific flow rate or pressure point. A label with the FEI compliant information will be required by the proposed regulation. In addition to the label this regulation will also require that all marketing information, such as sale catalogs, reflect only the duty point(s) at which the fan is FEI compliant to further assist consumers on purchasing an FEI compliant fan. A higher FEI value indicates higher efficiency and lower power consumption. FEI provides an easy way to compare the power consumption of different fans at the same duty point. For example, a fan with an FEI of 1.2 at a given duty point would consume 17 percent less power than a fan with an FEI of 1.0 at the same duty point.

The FEI metric incorporates the efficiency of the bare-shaft fan and that of any transmission, motor, or motor controller sold with the fan or a combination. The advantage of the FEI metric is that it fully represents the actual power consumption of a fan since it considers the efficiencies of the impeller, transmission, motor, and controllers, encouraging more efficient fan selection and fan design.

FEI is calculated using total pressure for ducted fans or static pressure for unducted fans. The total pressure of a fan is composed of static pressure and velocity pressure components. Ducted fans can use static pressure and velocity pressure to overcome system pressure losses. In contrast, with unducted fans, any velocity pressure at the fan discharge immediately dissipates, making it unusable for further work.

ANSI/AMCA 214-21 defines FEI based on total pressure (FEI_t) and static pressure (FEI_s) as follows:

$$FEI_{t,i} \text{ or } FEI_{s,i} = \frac{\text{Reference Fan Electrical Input Power}}{\text{Actual Fan Electrical Input Power}} = \frac{FEP_{ref,i}}{FEP_{act,i}}$$

The reference fan electrical input power (FEP_{ref}) (in kW) is calculated as:

$$FEP_{ref,i} = H_{i,ref}\left(\frac{1}{\eta_{trans,ref}}\right)\left(\frac{1}{\eta_{mtr,ref}}\right) \times 0.7457$$

$$FEP_{act} = H_{i,act}\left(\frac{1}{\eta_{trans,act}}\right)\left(\frac{1}{\eta_{mtr,act}}\right) \times 0.7457$$

($\eta_{mtr,ref}$), and motor controller efficiency ($\eta_{ctrl,ref}$). The determination of these values for different fan configurations is detailed in the ANSI/AMCA 214-21 test procedure.

The reference fan shaft power ($H_{i,ref}$) is calculated as a function of the airflow and pressure at the specific duty point. For ducted fans, $H_{i,ref}$ (in HP) is calculated as:

$$H_{i,ref} = \frac{(Q_i + 250)\left(P_{t,i} + .40 * \frac{\rho}{\rho_{std}}\right)}{6343 * 0.66}$$

And for unducted fans, $H_{i,ref}$ (in HP) is calculated as:

$$H_{i,ref} = \frac{(Q_i + 250)\left(P_{s,i} + 0.40 * \frac{\rho}{\rho_{std}}\right)}{6343 * 0.60}$$

In the equations for calculating reference fan shaft power, Q_i is the fan airflow at duty point *i*; $P_{t,i}$ and $P_{s,i}$ are fan total pressure at duty point *i* and fan static pressure at duty point *i* for ducted and unducted fans, respectively; ρ is the fan air density, and ρ_{std} is standard air density.

The values of 0.66 for ducted fans and 0.60 for unducted fans in the equations for reference fan shaft power are reference fan efficiency values. However, the equations include an airflow constant (250) and a pressure constant (0.40), which have the effect of lowering the required fan efficiency for fans that deliver low airflows or pressures. The FEI metric accounts for the inherent efficiency differences of fans that deliver different combinations of airflows and pressures, making it applicable to the wide range of applications served by commercial and industrial fans and comparable across these diverse applications.

The actual fan shaft power ($H_{i,act}$) is measured as specified in the proposed test procedure AMCA 214-21.

Test Procedure

Staff proposes to use the ANSI/AMCA 214-21 test procedure to test and calculate the FEI for stand-alone commercial and industrial fans and blowers.

The proposed test procedure calculates FEI for any fan at any duty point and determines the actual electrical input power of a fan and the reference electrical input power at any duty point. As allowed by the test procedure, manufacturers can extrapolate for fans within the same fan series, as defined in Chapter 10, and calculate the efficiency of a larger or smaller fan using the fan laws available in the test procedure. In this case, manufacturers will choose the size of the fan or fans tested for each series, since all fans will either have a tested efficiency, or a calculated efficiency based on the allowable fan laws described in the test procedure AMCA 214-21. The test procedure and fan laws will reduce the test burden for manufacturers and allow manufacturers to test more than one fan to calculate the efficiency of others within the same series.

Standard Levels

CEC staff proposes that all covered fans meet a minimum FEI of 1.00. The proposed standard is based on Efficiency Level 3 analyzed in the DOE November 2016 NODA.[28] CEC staff also proposes that the efficiency standards for commercial and industrial fans and blowers apply to stand-alone fans manufactured on or after the effective date of the proposed regulation which will be a year after adoption by the CEC. . The FEI will provide a weighted value because it is a ratio of the electrical input power of a reference fan to the electrical input power of the actual fan calculated at the same duty point and characterized by airflow and pressure. If the FEI is equal to or greater than 1, it means that the fan tested complies with the proposed standard at the tested duty point. If the FEI is less than 1, the fan tested does not meet the proposed standard for the tested duty point. The proposed FEI level achieves significant energy savings, minimizes cost impacts to consumers (Chapter 7), and lowers the test burden on manufacturers.

Reporting Requirements

The reporting requirements would include information about each fan model. **Table 6-1** identifies which information manufacturers would need to report to the CEC's Modernized Appliance Efficiency Database System (MAEDbS) to certify compliance with the proposed regulations.

MAEDbS is the database used by manufacturers and maintained by the CEC that lists certified appliances authorized to be sold or offered for sale in California. In

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[28] Energy Conservation Standards for Commercial and Industrial Fans and Blowers: Availability of Provisional Analysis Tools, Notice of Data Availability, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0194.

addition to the information proposed in **Table 6-1**, for each fan model the required information includes manufacturer name, model, fan type, impeller diameter, transmission type, maximum compliant fan speed, maximum compliant pressure, maximum compliant air flow, series fan, associated series test fan (if not tested), and the method used to calculate FEP within the test procedure. Fans will include the motor model number as well as a controller model number, if applicable.

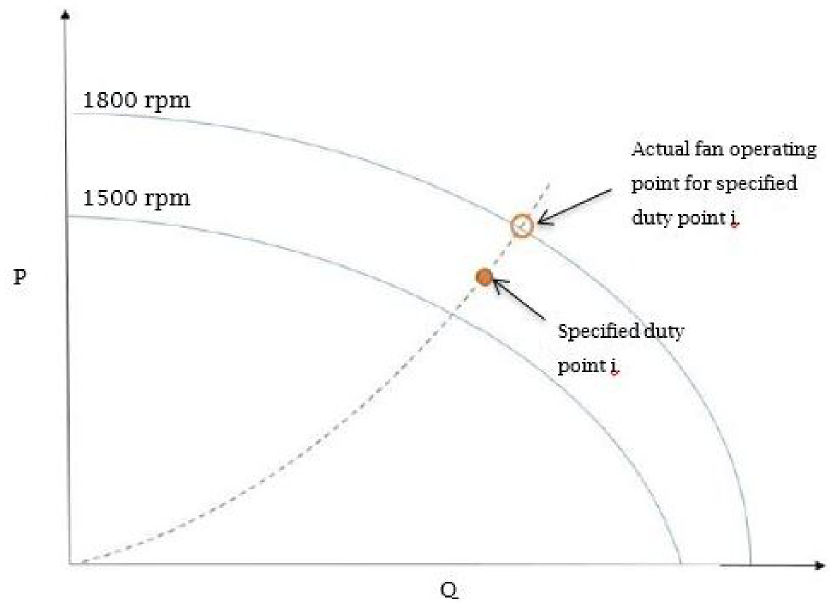
Table 6-1: Additional MAEDbS Reporting Fields

Manufacturer
Model
Fan Type
Fan impeller diameter (in)
Motor model number (if applicable)
Transmission type (if applicable)
Controller model number (if applicable)
Maximum compliant fan speed (RPM)
Maximum compliant pressure (in. w.g.)
Fan series (tested or calculated)
Associated series test fan (model number if calculated)
Method of test or calculation used in test procedure

Source: Air Movement and Control Association

Indicating the type of transmission (direct, v-belt, synchronous-belt, flexible coupling, or other) will help consumers compare the ability of different fans to serve a given operating point(s). Fans that have a controller will provide manufacturers with more FEI-compliant duty points. Direct-drive fans manufactured with single-speed motors will operate on a fixed performance curve, which may overshoot the specified operating point, resulting in increased power consumption. (See **Figure 6-1**) Units manufactured with variable-speed motors, adjustable transmission, VFDs, or a combination, will have a larger FEI-compliant performance capability.

Figure 6-1: Relationship of Actual to Specified Duty Point Direct-Drive Fans Without Controller

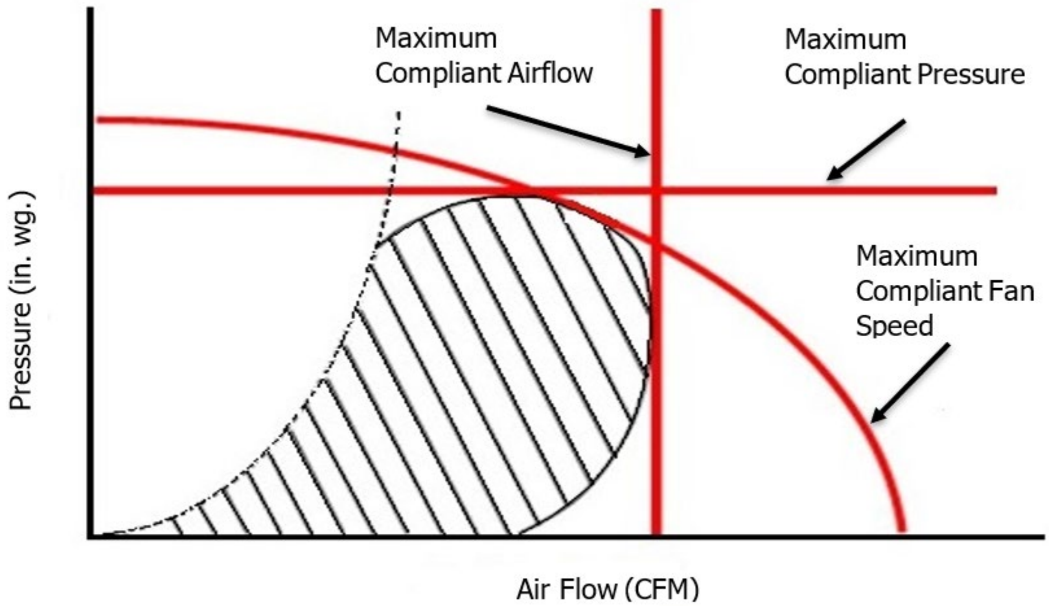


Source: Air Movement and Control Association

The data that a lab or manufacturer will provide to MAEDbS are depicted in **Figure 6-2** where the values within the boundaries are the area where the fan operates at an FEI of 1 or higher. CEC staff believes that the data depicted in Figure 6-2 will give consumers a general overview of the parameters where the commercial or industrial fan or blower is most efficient.

In addition to the fields explained in Table 6-1, the CEC would require reporting of test results for the tested fan including the maximum and minimum compliant points for each pressure curve tested for the airflow, air density, shaft power, actual FEP, reference FEP, and FEI for the compliant operating range. This information is required to verify compliance with the FEI standard. For a complete list of required information, please see **Chapter 10,** Section 1606. The information is also useful for consumers comparing two fan models with similar operating ranges, as the information would help determine which fan has a higher FEI across the specified operating range.

Figure 6-2 Fans and Blowers Reporting Boundaries



Source: California Energy Commission

Many fans that will be embedded in equipment are purchased by the OEM as stand-alone fans in a testable configuration. In the case where the OEM is the fan manufacturer, and where the fan is designed for the sole purpose of being embedded into an appliance with a main function other than the movement of air, the fan would be exempt under this proposal. However, if that same fan is also sold or offered for sale as a stand-alone fan the manufacturer would need to test and certified the fan into MAEDbS or be subject to an enforcement action.

Marking and Labeling

CEC staff proposes that fans shall be marked by the manufacturer where readily visible on the fan, fan motor or fan structure, and on the exterior packaging, when one is used, when sold. In addition, the unit shall include a separate label for the consumer records. The marking shall be on a fixed weather-resistant label. The label will require the manufacturer to include the information described in **Table 6-2**. For fans that are designed to a specific operation point, the label shall include the manufacturer name, model number, serial number and date of manufacture, design air flow, design pressure, and designed speed. For fans that are manufactured without a specific design operation point, the label shall include the manufacturer name, model number, serial number and date of manufacture, maximum compliant pressure, maximum compliant air flow, and maximum compliant speed. In addition to the label on the fan, staff also proposes that all marketing or catalog information shall include only the performance operating points where the fan is FEI-compliant. The inclusion of a label and updated marketing or catalog information will provide better guidance on the range where the fan is compliant with the proposed standards.

Table 6-2: Marking and Labeling Requirements

Specific Operating point	Unknown Operating Points
Manufacturer Name, Brand Name, or Brand Code	Manufacturer Name, Brand Name, or Brand Code
Model Number	Model Number
Serial Number and Date Manufactured	Serial Number and Date Manufactured
Design Flow (ft^3/min)*	Max. Compliant Pressure (in.wg.)
Design Pressure* (static or total, in.w.g.)	Max. Compliant Air Flow (CFM)
Designed Speed (RPM)	Max. Compliant Speed (RPM)

Source: California Energy Commission

CHAPTER 7: Savings and Cost Analysis

The proposed standards for commercial and industrial fans and blowers are cost-effective for consumers and will yield significant energy savings in California. The proposed standards ensure that the increased incremental cost to the consumer for a more efficient fan will be exceeded by the energy-saving benefits over the lifetime of the fan. While no fans will be removed from the market because of the proposed regulation, as explained in more detail in Chapter 8, manufacturers may want to improve the fan design to increase the compliant operating range. This chapter demonstrates how the proposed standards are cost-effective and details the statewide energy savings of the proposed standards.

Cost-Effectiveness

Incremental Costs

The incremental cost is the difference between the manufacturer's selling price of a fan that complies with the proposed standard and that of the same fan without the proposed standard (baseline). The manufacturer's selling price takes into consideration the manufacturing production cost (cost of a manufacturer to produce compliant fan) times the markup by the manufacturer, which is passed along to the consumer. The incremental costs to manufacture a complaint fan varies, but the most significant increase in cost is due to the improvement in aerodynamic efficiency. Staff used the same incremental costs used by the DOE, since in addition to the manufacturer's selling price, it includes the maintenance and installation cost that will be absorbed by the consumer and was calculated in DOE's November 2016 NODA. The most significant contributor to the increase in cost is the manufacturer's selling price, which includes the manufacturing production cost and a markup percentage that is passed on to the consumer. The incremental costs differ by type of fan and are listed in Column 3 of **Table 7-1**. Incremental cost increases may be attributed to improvements in blade design, material selection, guide vanes, and housing optimization. Staff used these incremental values because they provide a conservative incremental cost to consumers for our analysis.

Table 7-1: Annual Energy, Monetary Savings, and Net Benefit for Stand-Alone Fans

Stand-Alone Fan Type	Per-Unit Electricity Savings (kWh/yr)	Per-Unit Incremental Cost ($/Unit)	Per-Unit Average Annual Savings ($/yr)	Average Lifetime (years)	Per-Unit Life-Cycle Net Benefit ($/Unit)
Axial Cylindrical Housed	1,155	$399	$169	29	$2,842
Panel	501	$53	$94	28	$1,708
Centrifugal Housed	408	$33	$76	27	$1,368
Centrifugal Unhoused	130	$39	$24	27	$407
Inline and Mixed Flow	1,131	$689	$212	27	$3,196
Radial	2,211	$221	$323	30	$6,117
Power Roof Ventilator	927	$595	$174	30	$2,810

Monetary figures are in 2022 dollars rounded to nearest dollar.
Source: California Energy Commission and the U.S. Department of Energy

Per-Unit Savings

The DOE November 2016 NODA provides estimates of first-year operating costs and first-year operating savings at each efficiency level for each category of fan. Based on these first-year operating costs and average electricity prices, staff used the first year per-unit estimated baseline electricity consumption and the per-unit electricity consumption at each efficiency level for each category of stand-alone fan. Staff used December 2014 national commercial electricity rates to estimate energy used for stand-alone panel, centrifugal-housed, centrifugal-unhoused, power roof/wall ventilators, and inline and mixed-flow fans to match the operating costs provided by DOE in 2014 dollars. Staff used December 2014 industrial rates for stand-alone axial cylindrical-housed and radial fans from the

U.S. Energy Information Administration estimates for California.[29] The commercial/industrial distinction is based on information presented in the November 2016 NODA indicating where these fans are primarily used.

The DOE November 2016 NODA calculations were prepared in 2014. To calculate the energy used by the appliance, CEC staff obtained the national commercial and industrial rates for December 2014 to calculate the per-unit energy used for this analysis. (See **Appendix A** — Assumptions.) CEC staff calculated the national per-unit energy used for the baseline and the proposed standard in kWh per year per fan type as shown in **Appendix A** — Table A-1. By calculating the difference of the energy use for the baseline and the proposed standard, CEC staff obtained the energy savings per fan type in kWh per year.

The total national per-unit electricity savings for stand-alone fans is 6,462 kWh per year. (See **Appendix A** — Table A-1 Per-Unit Annual Electricity Savings Stand-Alone Fans). CEC staff then used the forecasted commercial and industrial rates for California reflected on the baseline forecast – state mid-demand case calculated by the CEC.[30]

CEC staff calculated the net present value for the average per-unit annual savings using a 3 percent discount rate (**Appendix A** — Table A-7 Net Present Value) necessary to calculate the life-cycle net benefit discussed per unit.

Staff determined the savings at Efficiency Level 3 in California by applying the average statewide electricity rate for 2022 to calculate the savings in kWh. (See assumptions in **Appendix A**.) Staff calculated the lifetime savings per fan as described in **Table 7-1** Annual Energy, Monetary Savings, and Net Benefit for Stand-Alone Fans.

Cost-Effectiveness Analysis

By comparing the incremental cost of improving a fan to meet the proposed minimum standard to the estimated utility bill savings over the lifetime of the fan from the higher efficiency, staff can assess the cost-effectiveness of the

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[29] U.S. Energy Information Administration. Electric Power Monthly With Data for October 2014. "Table ES1.B Total Electric Power Industry Summary Statistics, Year-to-Date 2014 and 2013", https://www.eia.gov/electricity/monthly/archive/december2014.pdf.

[30] CEDU 2020 Baseline Forecast - STATE Mid Demand Case-corrected; https://efiling.energy.ca.gov/getdocument.aspx?tn=236983.

proposed efficiency standard. As **Table 7-1** shows, the proposed efficiency standards for every category of fan are cost-effective for consumers.

California Stock

Staff calculated the existing stock of fans in California by assuming a no-growth market and multiplied the shipments in 2021 (**Table 7-2**) by the lifetime of the fan. **Table 7-3** shows the estimated fan stock for California at full stock turnover. This number yields a total California stock of nearly 2.5 million fans.

Table 7-2: 2021 Shipments for Stand-Alone Fans in California

Type of Fan	California 2021 Stand-Alone Fan Shipments (Units)
Axial Cylindrical-Housed Fans	5,967
Panel Fans	27,474
Centrifugal Housed Fans	16,591
Centrifugal Unhoused Fans	12,410
Inline and Mixed-Flow Fans	4,424
Radial Fans	6,636
Power Roof Ventilators	13,273
Total	86,775

Source: California Energy Commission

Table 7-3 California Stock for Stand-Alone Fans

Fan Type	Estimated California Stock Stand-Alone Fans at Full Stock Turnover
Axial Cylindrical Housed	173,039
Panel	769,286
Centrifugal Housed	447,954
Centrifugal Unhoused	335,069
Inline and Mixed Flow	119,454
Radial	199,090
Power Roof Ventilator	398,181
Total	**2,442,073**

Source: California Energy Commission

First-Year and Stock Turnover Energy Savings

CEC staff calculated an estimated statewide first-year energy savings of nearly 61 GWh by multiplying the 2021 shipments by the energy savings at DOE's Efficiency Level 3. After full stock turnover, when all existing fans have been replaced with minimally compliant fans, the energy savings are estimated to be 1,755 GWh per year. Using projected electricity rates from the IEPR, the proposed regulation will have a monetary first year savings of approximately $11 million. After full stock turnover is achieved, approximately 30 years, it was calculated (**Table 7-4**) that the proposed regulation will create approximately $303 million dollars per year in electricity bill savings for Californians.

Table 7-4: Stand-Alone Fan Savings

Fan Type	Per-Unit Savings (kWh)	First-Year Savings (GWh)	Savings After Stock Turnover (GWh/yr)	First-Year Savings ($ in Millions)	Savings After Stock Turnover ($ in Millions per year)
Axial Cylindrical Housed	1,155	6.9	199.8	$1.01	$29.22
Panel	500	13.7	385.0	$2.58	$72.17
Centrifugal Housed	408	6.8	182.7	$1.27	$34.24
Centrifugal Unhoused	130	1.6	43.5	$0.30	$8.15
Inline and Mixed Flow	1,131	5.0	135.1	$0.94	$25.32
Radial	2,211	14.7	440.2	$2.15	$64.38
Power Roof Ventilator	927	12.3	369.0	$2.31	$69.18
Total		**61**	**1,755.33**	**$10.55**	**$302.67**

Monetary figures are in 2022 dollars rounded to nearest dollar.
Source: California Energy Commission

CEC staff calculated statewide energy savings by multiplying the lifetime net benefit per type of fan by the stock in California. The monetary net lifetime benefit for 2052, after stock turnover, is $5.3 billion. First-year gross monetary savings are about $11 million.

Peak Demand Reduction

For simplicity, staff assumed a flat load profile for stand-alone fans and calculated peak demand reduction by dividing energy savings after stock turnover by 8,760 hours (1 year). By using the number of hours of operation for stand-alone fans, assumed by staff to be 8,760 hours per year, the peak demand reduction after full stock turnover for stand-alone fans is 200 MW.[31]

[31] AMCA and Efficiency Advocates Joint Proposal for Standalone Fans, https://efiling.energy.ca.gov/GetDocument.aspx?tn=221217&DocumentContentId=26705.

CHAPTER 8: Technical Feasibility

The proposed efficiency standards for fans are technically feasible based on fans currently available in the market. As described below, the most significant opportunity for reducing the energy use of commercial and industrial fans is improved fan selection. Unlike other appliance efficiency standards, where inefficient products will need to be redesigned or cease to be sold once the standards takes effect, most fan models will not need to be redesigned to comply with the proposed standards. Instead, the manufacturer would certify the compliant operating range of current models, which in most cases will be smaller than the currently advertised operating range. Manufacturers and retailers would then be limiting the selling options based on operational efficiency to which the consumer will pick to purchase and purchase the correct fan for their need.

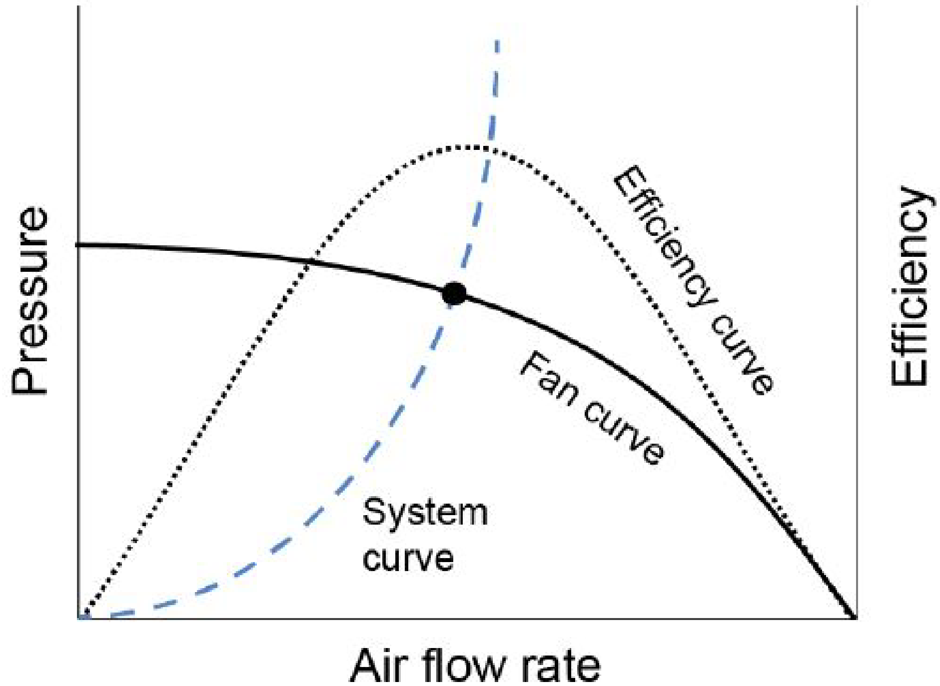
Manufacturers may choose to redesign fans to meet the proposed FEI level, where opportunities for efficiency improvements include improved fan design, improved materials, equipment that results in lower pressure drops, and more efficient transmission, motors, and motor controllers.

Fan Selection

Every fan has an efficiency curve, which describes the efficiency of the fan at each potential operating point along the fan curve. The peak efficiency of a fan occurs at a single point, and efficiency drops off significantly at operating points further away from the peak efficiency. In the example shown in **Figure 8-1**, the actual operating point of the fan (where the fan curve and system curve intersect) is close to the peak efficiency of the fan.[32] However, if a given system curve instead intersects the fan curve at a point far from the peak efficiency point, the fan will operate significantly less efficiently than peak efficiency.

[32] The fan efficiency curve is independent and represents the efficiency of the fan operating at given pressures and flow rates.

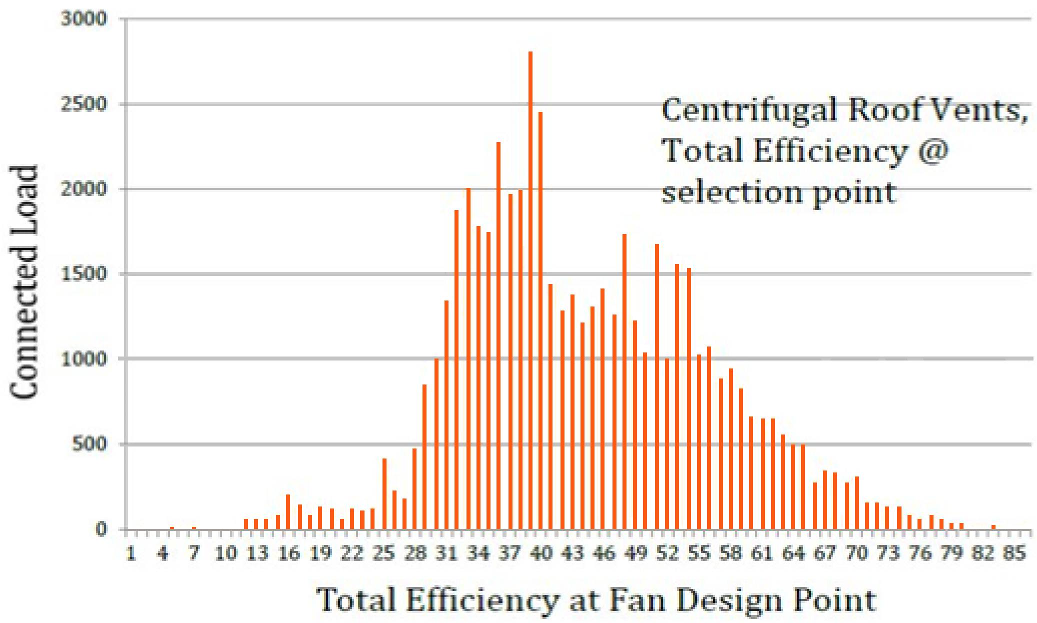
Figure 8-1: Fan Curve and Efficiency Curve Example Graph



Source: Air Movement and Control Association and Efficiency Advocates joint proposal to California Energy Commission

Actual fan selections vary widely in terms of efficiency at the specific design point. The following figures show how consumers are purchasing inefficient fans even though more efficient fans are available. **Figure 8-2** shows actual fan selection of centrifugal power roof ventilators. At the design point, total efficiency ranges from about 12 percent to 85 percent. The vertical lines indicating fan efficiency represent the number of fans selected for a specific design point in cubic feet per minute. Although fans that are more efficient are available, most of the fans selected are 40 percent efficient or less.

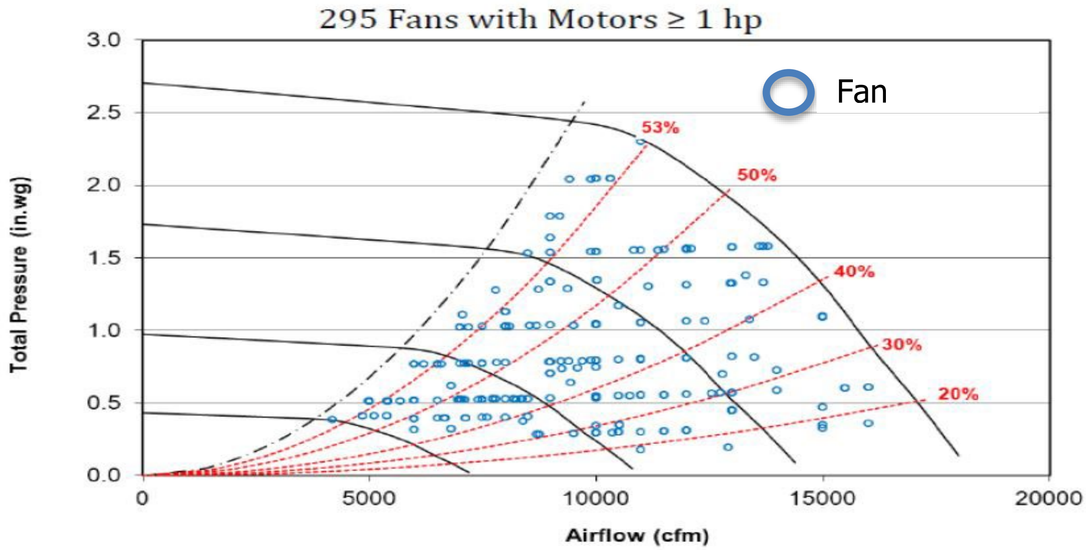
Figure 8-2: Centrifugal Power Roof Ventilator Fan Selection



Source: Air Movement and Control Association and Efficiency Advocates joint proposal to California Energy Commission

Similarly, **Figure 8-3** shows actual fan selections of 295 fans with motors greater or equal to 1 HP for one model of a centrifugal inline fan. While the peak efficiency of this fan is about 53 percent, a large number of fans were selected that operate under 40 percent efficiency.

Figure 8-3: Fan Selection of Centrifugal Inline Fan Model



Source: Air Movement and Control Association and Efficiency Advocates joint proposal to California Energy Commission

Fan Design

Improved fan design can increase efficiency across a range of duty points. The most significant opportunity for improving fan design is improving aerodynamic efficiency.

Opportunities exist for improving aerodynamic efficiency, including blade shape, material selection, guide vanes, and housing optimization. Blade shape can significantly affect fan efficiency. Most fans have single-thickness blades. Changing the curvature and the direction of curvature can provide efficiency improvements for fans with single-thickness blades. Further improvements can be made by switching to airfoil blades because of the Bernoulli's principle, where faster moving air across the top of a blade creates less pressure than the slower moving air on the bottom of the blade, creating airflow in an impeller.[33]

The choice of material can also affect fan efficiency. Impellers can be constructed using a variety of materials, including aluminum, steel, fiberglass,

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[33] Bernoulli's Principle, National Aeronautics and Space Administration, https://www.nasa.gov/sites/default/files/atoms/files/bernoulli_principle_k-4.pdf.

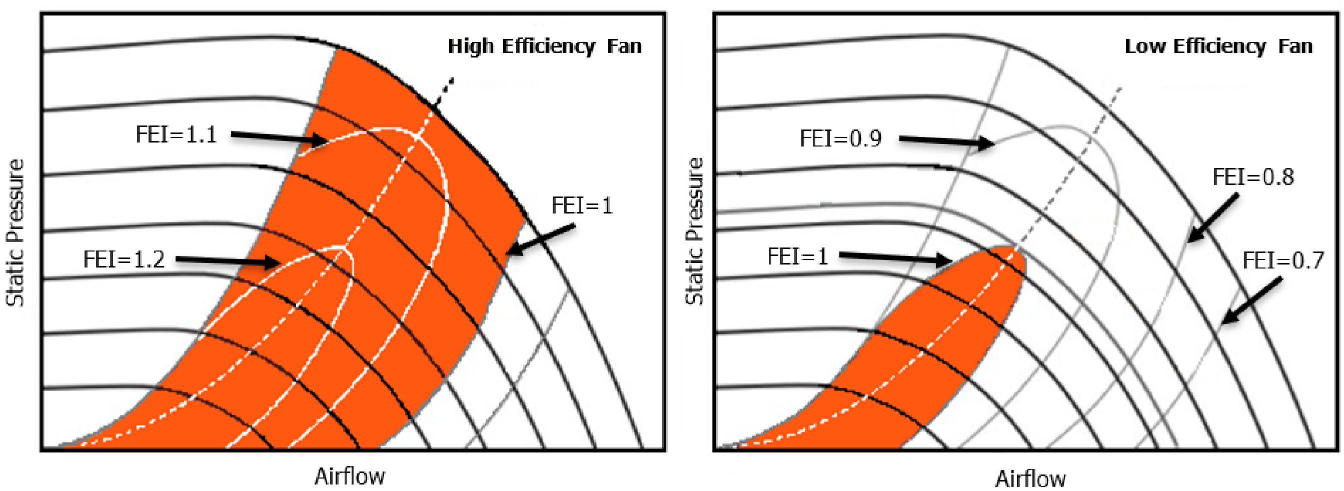
and plastic, which have different densities and other properties that can affect fan efficiency. Proper material selection can result in aerodynamic improvements and improved fan efficiency.

Guide vanes direct and straighten the airflow, which result in lower pressure drop through the impeller, increasing fan efficiency. However, in some instances, guide vanes cannot be installed due to space constraints or fan use or both.

Housing design can significantly affect efficiency as well. For example, housing that is too wide allows air recirculation, while housing that is too narrow may interfere with the inlet, reducing the cross-sectional area and restricting air movement. Improvements in the fan housing tolerances can improve efficiency, as it would decrease the pressure the fan experiences because of air recirculation that takes place at the fan blade edge and the fan housing.

The proposed approach for fan efficiency standards would encourage improved fan design. Designs that are more efficient would allow manufacturers to advertise a larger compliant operating range for their fans. For example, **Figure 8-4** shows fan curves for two fans along with the compliant (shaded area) operating ranges (in this case, for an FEI of 1.0). While both fans have a range of duty points that are compliant, the fan on the left has a more efficient design and has a larger compliant operating range, which means that it can meet the needs of numerous applications.

Figure 8-4: Compliant Operating Ranges of Two Fan Models



Source: California Energy Commission

Transmission

More efficient transmission can improve fan efficiency. As described earlier, fans can either be direct-drive or belt-driven. Direct-drive fans inherently have no transmission losses. Belt-driven transmissions do have some measure of transmission losses, depending on the belt design and other factors.

More efficient belts improve transmission efficiency. Most belt drives use V-belts. Standard V-belts have a trapezoidal cross section. Cogged V-belts have notches or grooves that run perpendicular to the length of the belt, which reduce the bending resistance of the belt and improves efficiency. Cogged V-belts can improve efficiency about 2 percent relative to standard V-belts. Synchronous belts may improve efficiency by up to 5 percent relative to standard V-belts.[34] Synchronous belts are toothed and reduce belt slippage and frictional losses. (See **Figure 8-5.**)

Figure 8-5: Examples of V-Belts

Source: National Renewable Energy Laboratory

Motors

The FEI of a fan can also be improved by using higher-efficiency motors such as induction motors, electronically commutated motors, and switched reluctance motors. Motors meeting the *super-premium* or International Efficiency 4 or IE4 motors designation reduce losses by about 15 percent relative to *NEMA premium* motors.

[34] Synchronous and Cogged Fan Belt Performance Assessment, National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy14osti/61448.pdf.

Motor Controllers

Motor controllers, such as variable-speed drives, are used to control the speed of a fan. While significant energy savings can be achieved by reducing the speed of a fan to match the required airflow rate, there are also losses associated with motor controllers. Motor controllers can improve fan efficiency by accurately adjusting the fan speed and decreasing the energy used by the motor driving the fan.

CHAPTER 9: Environmental Analysis

This chapter provides the basis for a staff determination that adoption of the proposed amendments are exempt from the requirements of the California Environmental Quality Act (CEQA)

Adverse Impacts

The proposed efficiency standards for commercial and industrial fans and blowers would apply only to fans newly manufactured on or after the effective date of the proposed standards. The standards would not cause additional waste, as they do not require replacement earlier than the normal product lifetime of the fan. The standards do not require the use of any specific materials to improve the efficiency and do not require any redesign of the fan at all, as the savings come from improving fan selection by consumers. Therefore, CEC staff could not identify any known or reasonably foreseeable adverse environmental impacts associated with the proposed efficiency standards.

Beneficial Impacts

The proposed standards will inform consumers and enable them to purchase compliant fans for intended use and will reduce overall energy consumption statewide, providing important air quality and climate benefits and reducing energy costs.

The proposed standards will lead to improved air quality in California. Reduced energy consumption translates to fewer power plants built and less pressure on the limited energy resources, land, and water use associated with energy production. In addition, lower electricity consumption results in reduced greenhouse gas and criteria pollutant emissions, primarily from reduced generation in fossil fuel power plants, such as natural gas power plants.

CEC Staff has determined that adoption of the proposed regulations is categorically exempt from CEQA under the "Class 7 and Class 8" exemptions (California Code of Regulations, Title 14, Sections 15307-15308).

Class 7 consists of actions taken by regulatory agencies as authorized by state law or local ordinance to assure the maintenance, restoration, or enhancement of a natural resource where the regulatory process involves procedures for protection of the environment.

Class 8 consists of actions taken by regulatory agencies, as authorized by state or local ordinance, to assure the maintenance, restoration, enhancement, or protection of the environment where the regulatory process involves procedures for protection of the environment.

In this case, adoption of the proposed regulations is an action taken by a regulatory agency for the protection of the state's natural resources and environment. As noted in the *Beneficial Impacts* section, the standards will reduce energy use and the related pollution and GHGs associated with energy generation. This will provide long-term benefits to the environment as contemplated in the Class 7 and Class 8 exemptions. As older less efficient industrial fans are replaced with new efficient fans, these long-lasting products will continue to save energy for years to come.

Based on CEC staff review, there is no reasonably foreseeable possibility that the proposed regulation may result in a significant adverse impact on the environment or that any of the exceptions to these exemptions apply (California Code of Regulations, Title 14, Sections 15300.2); therefore, adoption of the proposed regulations is exempt from CEQA.

CHAPTER 10: Proposed Regulatory Language

The proposed new language appears as underline (example) and proposed deletions appear as strikeout (~~example~~). Existing language appears as plain text. Three dots or "…" represents the substance of the regulations that exists between the proposed language and current language.

§ 1601. Scope.

This Article applies to the following types of new appliances, if they are sold or offered for sale in California, except those sold wholesale in California for final retail sale outside the state and those designed and sold exclusively for use in recreational vehicles, or other mobile equipment. Unless otherwise specified, each provision applies only to units manufactured on or after the effective date of the provision.

NOTE: For the applicability of these regulations to appliances installed in new building construction, see sections 110.0 and 110.1 of part 6 of Title 24 of the California Code of Regulations.

…[skipping (a) through (c)]

(d) Portable air conditioners, evaporative coolers, residential furnace fans, ceiling fans, ceiling fan light kits, whole house fans, residential exhaust fans, ~~and~~ dehumidifiers, and commercial and industrial fans and blowers.

…[skipping (e) through (x)]

The following documents ~~is~~ are incorporated by reference in section 1601.

Number	*Title*
AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC (AMCA)~~AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)~~	
ANSI/AMCA Standard 214-21	Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers

…[skipping "INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)" through end of section]

Note Authority cited: Sections 25213, 25218(e), 25401.9, 25402(a)-25402(c), and 25960, Public Resources Code; and Sections 16, 26, and 30, Governor's

Exec. Order No. B-29-15 (April 1, 2015). Reference: Sections 25216.5(d), 25401.9, 25402(a)-25402(c), 25402.5.4, and 25960, Public Resources Code; and Section 16, Governor's Exec. Order No. B-29-15 (April 1, 2015).

§ 1602. Definitions.

…[skipping (a) through (c)]

(d) Portable Air Conditioners, Evaporative Coolers, Ceiling Fans, Ceiling Fan Light Kits, Whole House Fans, Residential Exhaust Fans, Dehumidifiers, ~~and~~ Residential Furnace Fans, and Commercial and Industrial Fans and Blowers.

…[skipping "Adjusted cooling capacity at 83°F conditions" through "Adjusted cooling capacity at 95°F conditions"]

"Air curtain unit" means equipment providing a directionally controlled stream of air moving across the entire height and width of an opening that reduces the infiltration or transfer of air from one side of the opening to the other and/or inhibits the passage of insects, dust, or debris.

…[skipping "Airflow" through "Annual energy consumption in off-cycle mode"]

"Axial impeller" means an impeller (propeller) with a number of blades extending radially from a central hub in which airflow through the impeller is axial in direction; that is, airflow enters and exits the impeller parallel to the shaft axis with a fan flow angle less than or equal to 20 degrees. Blades can either be single thickness or airfoil shaped.

"Axial-inline fan" means a fan with an axial impeller and a cylindrical housing with or without turning vanes. Inlets and outlets can optionally be ducted.

"Axial-panel fan" means a fan with an axial impeller mounted in a short housing, non-cylindrical, that can be a panel, ring, or orifice plate. The housing is typically mounted to a wall separating two spaces, and the fans are used to increase the pressure across this wall. Inlets and outlets are not ducted.

"Axial power roof ventilator (PRV)" means a fan with an axial impeller and a cylindrical housing as well as a housing to prevent precipitation from entering the building with or without turning vanes used to supply or exhaust air from a building. Inlets and outlets can optionally be ducted.

"Bare shaft fan" means a fan without a driver.

…[skipping "Basic model" through "Belt-driven ceiling fan"]

"Belt driven fan" means a driven fan configuration which the fan impeller is connected to the driver through a set of belts and sheaves mounted on the driver shaft and fan shaft. This includes fans with V-belt or synchronous belt power transmission.

...[skipping "Blade span" through "Centrifugal ceiling fan"]

"Centrifugal housed fan" means a fan with a centrifugal or mixed flow impeller in which airflow exits into a housing that is generally scroll-shaped to direct the air through a single fan outlet. Inlets and outlets can optionally be ducted. It does not include a radial impeller.

"Centrifugal impeller" means an impeller with a number of blades extending between a back plate and shroud in which airflow enters axially through one or two inlets and exits radially at the impeller periphery. The airflow exits either into open space, or into a housing with a fan flow angle greater than or equal to 70 degrees. Impellers can be classified as single inline or double inlet. Blades can be tilted backward or forward with respect to the direction of impeller rotation. Impellers with backward-tilted blades can be airfoil-shaped (AF), backward-curved single-thickness (BC), backward-incline single-thickness flat (BI), or radial-tipped (RT). Impellers with forward titled blades are known as forward-curved impellers (FC).

"Centrifugal inline fan" means a fan with a centrifugal or mixed-flow impeller in which airflow enters axially at the fan inlet and the housing redirects radial airflow from the impeller to exit the fan in an axial direction. Inlets and outlets can optionally be ducted.

"Centrifugal power roof ventilator exhaust (PRV-E) fan" means a PRV with a centrifugal or mix-flow impeller that exhausts air from a building. Inlets are typically ducted, but outlets are not ducted.

"Centrifugal power roof ventilator supply (PRV-S) fan" means a PRV with a centrifugal or mix-flow impeller that supplies air to a building. Inlets are not ducted, and outlets are typically ducted.

"Centrifugal unhoused fan" means a fan with a centrifugal or mix-flow impeller in which airflow enters through a panel and discharges into free space. Inlets and outlets are not ducted. This fan type also includes fan designed for use in fan arrays that have partition walls separating the fan from other fans in the array.

"Circulating fan" means a fan that is not a ceiling fan that is used to move air within a space, that has no provision for connection to ducting or separation of the fan inlet from its outlet. The fan is designed to be used for the general circulation of air.

…[skipping "Combined energy efficiency ratio (CEER)"]

"Commercial and industrial fan and blower" means a rotary-bladed machine used to convert mechanical power to air power, with a specific work limited to 25 kilojoule per kilogram (kJ/kg) or less and have a rated fan shaft power greater than or equal to 1 horsepower, or, for fans without a rated shaft input power, an electrical input power greater than or equal to 1 kW, and a fan output power less than or equal to 150 horsepower. They consist of an impeller, a shaft, bearings, and a structure or housing, including any transmissions, driver, and/or controls if integrated, assembled, or packaged by the manufacturer at the time of sale.

(1) Commercial and industrial fans and blowers do not include:

(A) safety fans as defined in Section 1602(d) of this Article;
(B) ceiling fans as defined in 10 CFR 430.2;
(C) circulating fans;
(D) induced-flow fans;
(E) jet fans;
(F) cross-flow fans;
(G) embedded fans as defined in ANSI/AMCA 214-21;
(H) fans mounted in or on motor vehicles or other mobile equipment;
(I) fans that create a vacuum of 30 in. water gauge or greater;
(J) air curtain unit as defined in Section 1602(d) of this Article.

…[skipping "Cooling efficiency ratio (CER)"]

"Cross-flow fan" means a fan with a housing that creates an airflow path through the impeller, in a direction at right angles to the axis of rotation and with airflow both entering and exiting the impeller at the periphery. Inlets and outlets can optionally be ducted.

…[skipping "Dehumidifier" through "Direct evaporative cooler"]

"Driver" means a machine, such as a motor, used to provide mechanical power to the impeller, either directly or through a transmission.

…[skipping "Dual-duct portable air conditioner"]

"Dual-use fan" means a fan having two operating modes to serve long-term ventilation purposes as well as short-time emergency duty at higher speeds for fire or smoke extraction.

…[skipping "Energy factor for dehumidifiers" through "Evaporative cooler"]

"Fan array" means multiple fans in parallel and in a single enclosure between two plenum sections in an air distribution system, where plenum means a compartment or chamber that forms a part of the air distribution system, and that is not used for occupancy or storage.

"Fan Energy Index or FEI" means the ratio of the electrical input power of a reference fan to the electrical input power of the actual fan as calculated under the test method in section 1604(d)(2) of this Article.

“Fan Electrical Power or FEP” means the electrical power required to operate a fan, including any motor controllers at a given duty point. It is calculated in the test method in section 1604(d)(2) of this Article.

“Fan flow angle” means the angle of the centerline of the air-conducting surface of a fan blade measured at the midpoint of its trailing edge with the centerline of the rotation axis, in a plane through the rotation axis and the midpoint of the trailing edge.

“Fan output power” means the power delivered to air by the fan; it is proportional to the product of the fan airflow rate, the fan total pressure and the compressibility coefficient as determined in accordance with the test procedure specified in section 1604(d)(2) of this Article.

“Fan series” means a group of fan models that are geometrically similar per the proportionality and dimensional requirements explained in Annex K of the test method in section 1604(d)(2) of this Article.

“Fan shaft power” means the mechanical input power to the shaft that is connected directly to the impeller.

…[skipping “Furnace fan” through “Highly decorative ceiling fan”]

“Housing” means any component or components of the fan that direct airflow into or away from the impeller and/or provide protection to the internal components. It may serve as the structure of the fan.

...[skipping “Hugger ceiling fan”]

“Impeller” means a rotary bladed aerodynamic component of a fan that transfers mechanical energy to the airstream.

…[skipping “Indirect evaporative cooler”]

“Induced-flow fan” means a type of laboratory exhaust fan with nozzle and windband; the fan’s outlet airflow is greater than the inlet airflow due to induced airflow. All airflow entering the inlet exits through the nozzle. Airflow exiting the windband includes the nozzle airflow as well as the induced airflow.

“Inline mixed-flow fan” means a fan with a mixed-flow impeller in which airflow enters axially at the fan inlet, and the housing redirects radial airflow from the impeller to exit the fan in an axial direction. Inlets and outlets can optionally be ducted.

…[skipping “Input power”]

“Jet fan” means a fan designed and marketed specifically to produce a high-velocity air jet in a space to increase its air momentum. Jet fans are rated using thrust. Inlets and outlets are not ducted but may include acoustic silencers.

…[skipping "Lamp ballast platform" through "Low-speed small-diameter (LSSD) ceiling fan"]

"Mixed-flow impeller" means an impeller with construction characteristics between those of an axial and centrifugal impeller with a fan flow angle greater than 20 degrees and less than 70 degrees. Airflow enters axially through a single inlet and exits with combined axial and radial directions at a mean diameter greater than the inlet.

"Mixed-flow fan" means a fan with fitted mixed-flow impeller that has a fan flow angle greater than 20 degrees and less than 70 degrees.

…[skipped "Multi-head ceiling fan" through "Portable or Spot Evaporative Cooler"]

"Power roof ventilator (PRV)" or "power wall ventilator (PWV)" means a fan with an internal driver and a housing to prevent precipitation from entering the building. It has a base designed to fit over a rood or wall opening, usually by means of a roof curb.

…[skipping "Product capacity for dehumidifiers"]

"Radial-housed fan" means a fan with a radial impeller in which airflow exits into a housing that is generally scroll-shaped to direct the air through a single fan outlet. Inlets and outlets can optionally be ducted.

"Radial impeller" means a form of centrifugal impeller with a number of blades extending radially from a central hub. The airflow enters axially through a single inlet and exits radially at the impeller periphery. The housing has impeller blades positioned such that the outward direction of the blade at the impeller periphery is perpendicular within 25 degrees to the axis of rotation. Impellers can optionally have a back plate and/or shroud.

…[skipping "Residential exhaust fan"]

"Safety fan" means:

(1) a fan that is designed and marketed to operate only at or above 482 degrees Fahrenheit (250 degrees Celsius);

(2) a reversible axial fan in cylindrical housing that is designed and marketed for use in ducted tunnel ventilation that will reverse operations under emergency ventilation conditions;

(3) a fan bearing an Underwriter Laboratories or Electric Testing Laboratories listing for "Power Ventilators for Smoke Control Systems";

(4) an open discharge exhaust fan with integral discharge nozzles which develop or maintain a minimum discharge velocity of 3000 FPM;

(5) a fan constructed in accordance with AMCA type A or B spark resistant construction as defined in ANSI/AMCA Standard 99-16 Standards Handbook;

(6) a fan designed and marketed for use in explosive atmospheres and tested and marked according to EN 13463-1:2001 Non-electrical Equipment for Potentially Explosive Atmospheres; or

(7) an electric-motor-driven- Positive Pressure Ventilator as defined in ANSI/AMCA Standard 240-15 Laboratory Methods of Testing Positive Pressure Ventilators for Aerodynamic Performance Rating.

_…[skipping "Seasonally adjusted cooling capacity (SACC)"]

"Series calculated fan " means the fan models for which the performance data was calculated based on a series-tested fan from the same fan series using the allowable fan laws listed in the test method in section 1604(d)(2) of this Article.

"Series tested fan " means the fan model tested in a laboratory to provide performance data for a fan series as explained in the test method in section 1604(d)(2) of this Article.

…[skipping "Single-duct portable air conditioner" through "Spot air conditioner"]

…[skipping the rest of (d) through (x)]

The following documents are incorporated by reference in section 1602.

Number	*Title*
…[skipping FEDERAL STATUTES AND REGULATIONS through ADOBE SYSTEMS INCORPORATED]	
~~AMERICAN NATIONAL STANDARDS INSTITUTE~~AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC (AMCA~~ANSI~~)	
~~ANSI/AMCA Standard 214-21~~ ANSI/AMCA Standard 99-16	~~Test Procedure for Calculating Fan Energy Index for Commercial and Industrial Fans and Blowers~~ Standards Handbook
ANSI/AMCA Standard 214-21	Test Procedure for Calculating Fan Energy Index for Commercial and Industrial Fans and Blowers
ANSI/AMCA Standard 240-15	Laboratory Methods of Testing Positive Pressure Ventilators for Aerodynamic Performance Rating

… [skipping AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) through SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS (SMPTE)

THE EUROPEAN COMMITTEE FOR STANDARIZATION

EN 13463-1:2001	Non-electrical Equipment for Potentially Explosive Atmospheres

… [skipping ANSI C78.3-1991 (R1996) through the end of section 1602]

Note: Authority cited: Sections 25213, 25128(e), 25401.9, 25402(a)-25402(c) and 25960, Public Resources Code; and Sections 16, 26 and 30, Governor's Exec. Order No. B-29-15 (April 1, 2015). Reference: Sections 25216.5(d), 25401.9, 25402(a)-25402(c), 25402.5.4 and 25960, Public Resources Code; and Section 16, Governor's Exec. Order No. B-29-15 (April 1, 2015).

§ 1604. Test Methods for Specific Appliances.

…[skipping (a) through (c)]

(d) Portable Air Conditioners, Evaporative Coolers, Ceiling Fans, Ceiling Fan Light Kits, Whole House Fans, Residential Exhaust Fans, Dehumidifiers, ~~and~~ Residential Furnace Fans, and Commercial and Industrial Fans and Blowers.

(1) The test methods for portable air conditioners, evaporative coolers, ceiling fans, ceiling fan light kits, whole house fans, residential exhaust fans, dehumidifiers, and residential furnace fans are shown in Table D-3.

Table D-3
~~Portable Air Conditioner, Ceiling Fan, Ceiling Fan Light Kit, Evaporative Cooler, Whole House Fan, Residential Exhaust Fan, Dehumidifier, and Residential Furnace Fan Test Methods~~ Testing Requirements for the following Appliances

Appliance	Test Method
Spot Air Conditioners	ANSI/ASHRAE 128-2001
Single-Duct and Dual-Duct Portable Air Conditioners	10 C.F.R. section 430.23(dd) (Appendix CC to subpart B of part 430)
Ceiling Fans	10 C.F.R. section 430.23(w) (Appendix U to subpart B of part 430)
Ceiling Fan Light Kits	10 C.F.R section 430.23(x) (Appendix V to subpart B of part 430)
Evaporative Coolers	ANSI/ASHRAE 133-2008 for packaged direct evaporative coolers and packaged indirect/direct evaporative coolers; ANSI/ASHRAE 143-2007 for packaged indirect evaporative coolers
Whole House Fans	HVI-Publication 916 29 September 2015 HVI Airflow Test Procedure, as specified in section 5.2. Use setups for whole house comfort ventilators.
Dehumidifiers	10 C.F.R. section 430.23(z) (Appendix X to subpart B of part 430, active mode portion only)

Appliance	Test Method
Portable Dehumidifiers and Whole-Home Dehumidifiers Manufactured On or After June 13, 2019	10 C.F.R. section 430.23(z) (Appendix X1 to subpart B of part 430)
Residential Exhaust Fans	HVI-Publication 916 29 September 2015 HVI Airflow Test Procedure, as specified in section 5.2.
Residential Furnace Fans	10 C.F.R. section 430.23(cc) (Appendix AA to subpart B of part 430)

(2) Commercial and Industrial Fans and Blowers. The test method for Commercial and Industrial Fans and Blowers is ANSI/AMCA Standard 214-21 Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers with the following additions:

(A) lab reports and calculated results used for certification and marking shall be maintained by the manufacturer per the requirements of Annex J of ANSI/AMCA 214-21. Records shall be retained per the requirements of section 1608(c)(1) of this Article.~~;~~

…[skipping (e) through (x)]

The following documents are incorporated by reference in section 1604.

Number	*Title*

…[skipping “CALIFORNIA ENERGY COMMISSION TEST METHODS” through “~~AMERICAN NATIONAL STANDARDS INSITUTE~~ (ANSI)AIR-CONDITIONING, HEATING AND REFRIGERATION (AHRI)”]

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL, INC (AMCA)

ANSI/AMCA Standard 214-21	Test Procedure for Calculating Fan Energy Index (FEI) for Commercial and Industrial Fans and Blowers

…[skipping “~~ANSI C78.43-2004~~AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)” through the end of section 1604]

Note: Authority cited: Section cited: Sections 25213, 25218(e), 25401.9, 25402(a)-25402(c) and 25960, Public Resources Code; and Sections 16, 26 and 30, Governor’s Exec. Order No. B-29-15 (April 1, 2015). Reference: Sections

25216.5(d), 25401.9, 25402(a)-25402(c) and 25960, Public Resources Code; and Section 16, Governor's Exec. Order No. B-29-15 (April 1, 2015).

§ 1606. Filing by Manufacturers; Listing of Appliances in MAEDbS.

…[Skipping (a) through "Residential Furnace Fans" section D of Table X]

	Appliance	Required Information	Permissible Answers
	Commercial and Industrial Fans and Blowers	Fan type	Centrifugal housed, centrifugal inline, centrifugal unhoused, centrifugal PRV supply, centrifugal PRV exhaust, axial inline, axial PRV, inline mixed-flow, power roof/wall ventilators, axial panel, radial housed
	Commercial and Industrial Fans and Blowers	Fan impeller diameter (in.)	
	Commercial and Industrial Fans and Blowers	Motor model number (if fan is certified with a motor)	
	Commercial and Industrial Fans and Blowers	Transmission	Direct, V-belt, synchronous-belt, flexible coupling, none
	Commercial and Industrial Fans and Blowers	Controller model number (if fan is certified with a controller)	
	Commercial and Industrial Fans and Blowers	Maximum fan speed (RPM) at FEI=1.0	
	Commercial and Industrial Fans and Blowers	Maximum pressure (inches water gauge) at FEI=1.0	
	Commercial and Industrial Fans and Blowers	Maximum compliant air flow (SCFM) at FEI=1.0	
	Commercial and Industrial Fans and Blowers	FEP_{act}	Tested, calculated

	Commercial and Industrial Fans and Blowers	Associated Series Tested Fan Model Number (if calculated)	Fan product line and model, (N/A if tested)
	Commercial and Industrial Fans and Blowers	Method of FEP_{act} determination	Section 6.1, 6.2, 6.3, 6.4, or 6.5 of the test method
	Commercial and Industrial Fans and Blowers	FEP_{ref} at FEI=1.0	Reference fan electrical power (kW)
	Commercial and Industrial Fans and Blowers	FEP_{act} at FEI=1.0	Actual fan electrical power (kW)

…[skipping through the end of section 1606]

Note: Authority cited: Sections 25213, 25218(e), 25401.9, 25402(a)-25402(c) and 25960, Public Resources Code; and Sections 16, 26 and 30, Governor's Exec. Order No. B-29-15 (April 1, 2015). Reference: Sections 25216.5(d), 25401.9, 25402(a)-25402(c), 25402.5.4 and 25960, Public Resources Code; and Section 16, Governor's Exec. Order No. B-29-15 (April 1, 2015).

§ 1607. Marking of Appliances.

…[skipping (a) through (d)(15))]

(16) Commercial and Industrial Fans and Blowers. Each commercial and industrial fan and blower shall be marked with a legible and permanently fixed label, which may be in tabular form (as shown below):

(A) The label shall include the following information:

1. manufacturer name;
2. brand name or brand code;
3. model number;
4. serial number;
5. date of manufacture;
6. FEP_{ref} at FEI=1.0;
7. maximum air flow (SCFM) at FEI=1.0;
8. maximum speed (RPM) at FEI=1.0; and

9. maximum pressure (inches water gauge) at FEI=1.0.

(B) No marketing or catalog information shall provide performance data for any duty point where the FEI is less than 1.0. Performance data provided to consumers shall be provided only for the operation of the fan where the FEI is equal or greater than 1.0.

…[skipping through the end of section 1607]

Note: Authority cited: Sections 25213, 25218(e), 25402(a)-25402(c) and 25960, Public Resources Code. Reference: Sections 25216.5(d), 25401.9, 25402(a)-25402(c) and 25960, Public Resources Code

Acronyms & Definitions

Acronym/Term	Description/Definition
AHRI	Air-Conditioning, Heating, & Refrigeration Institute
Airflow	The volume of air that a fan can move per unit of time.
AMCA	Air Movement and Control Association International, Inc.
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASRAC	Appliance Standards and Rulemaking Federal Advisory Committee
Btu/h	Unit of power measuring energy per unit time, equal to 1 Btu per hour. Commonly used to describe the power output of different appliances
CARB	California Air Resources Board
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CFM/Watt	Cubic Feet per minute per watt. It is the volumetric flow rate compared to the energy needed by the motor to generate a flow rate.
CPUC	California Public Utilities Commission
Decarbonization	The conversion to an economic system that sustainably reduces and compensates the emissions of carbon dioxide (CO_2); the long term goal is to create a CO_2 free economy.
DOE	U.S. Department of Energy

Embedded Fan	A fan that operates within a piece of equipment with a main function other than the movement of air, specifically to units that condition air.
EPCA	Energy Policy and Conservation Act
FEG	A numerical rating that classifies fans by the associated aerodynamic ability to convert mechanical shaft power to air power.
FEI	Fan energy index is a ratio of the electrical input power of a reference fan to the electrical input power of the actual fan calculated at the same duty point using the test procedure ANSI/AMCA 214-21. $FEI = \frac{FEP_{ref,i}}{FEP_{act,i}}$
FEP	Fan electric input power is calculated for the motor (actual) and the fan (reference) at a specific pressure and volumetric flow using the test procedure ANSI/AMCA 214-21.
FMEG	Fan/Motor Efficiency Grades
GHG	Greenhouse gases are any gas that has the property of absorbing infrared radiation emitted from Earth’s surface and reradiating it back to the Earth’s surface, thus contributing to the greenhouse effect. Carbon dioxide, methane, and water vapor are some examples of greenhouse gases.
GWh	Gigawatt-hour, a unit of energy representing 1 billion watts hours and is equivalent to 1 million kilowatt hours.
H_i	Fan shaft power at duty point

HP	Horsepower; Unit used to measure the power of engines and motors. One unit of horsepower is equal to the power needed to lift 550 pounds one foot in one second. 1 HP = 745.7 watts
IEPR	Integrated Energy Policy Report
IOU	Investor-Owned Utility
in.	Inches
in. w.g.	Pressure units in inches in water column gauge
ISO	International Organization for Standardization
Joule	Unit of energy in the International System of Units equivalent to the energy transferred to an object when a force of one newton acts on the object in the direction of the force's motion through a distance of one meter.
Kilogram	Base unit of mass in the International System of Units.
kW	Unit of measure for 1,000 watts of electrical power.
kWh	Kilowatt-hour: A unit of energy equal to 3600 kilojoules usually used as a billing unit of energy.
MAEDbS	Modernized Appliance Efficiency Database System
MW	Megawatt, a unit power equal to one million watts; equal to one thousand kilowatts.
Newton	Unit of force in the International System of Units. The unit is the force necessary to accelerate one kilogram of mass one meter per second.

η_{ctrl}	Motor controller efficiency
η_{mtr}	Motor efficiency
NODA	Notice of Data Availability issued by the Department of Energy
η_{trans}	Transmission efficiency
OEM	Original equipment manufacturer
P	Fan pressure can either be static or total pressure.
PRV	Power roof ventilator. It can exhaust or supply air to a building.
Q	Fan airflow
RPM	Revolutions per minute
Stand-alone Fan	A fan that moves air through a system and is installed as an independent piece of equipment. Will do work, or move air, through a system of vents. It does not include fans that are embedded in appliances that have an additional function other than just moving air.
Static Pressure	The ability of a fan to push air against resistance.
Watt	Unit of power equal to the work done at the rate of one joule per second or to the power produced by a current of one ampere across a potential difference of one volt. 745.7 watts = 1 HP

Source: California Energy Commission

APPENDIX A:
Staff Assumptions, Calculations, Tables, and Equations

Appendix A discusses the information and calculations used to characterize commercial and industrial fans and blowers in California, the current energy use, costs, and potential savings. Staff considered information from a variety of sources, including information contained in the joint AMCA and energy efficiency advocates proposal and the Air-Conditioning, Heating, & Refrigeration Institute (AHRI) proposal submitted to the CEC. [35, 36] Staff presents the research and methods used to illustrate staff approach to energy consumption, costs, and savings. Staff has rounded the results of the calculations as presented in this appendix.

Assumptions

- ☐ National electricity prices for the commercial and industrial sectors of 10.79 cents per kilowatt-hour ($0.1079/kWh) and 7.1 cents per kilowatt-hour ($0.071/kWh) in 2014, respectively.[37]

[35] AMCA-Advocates Comments on Draft Staff Report, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224829&DocumentContentId=55411.

[36] AHRI Comments – Title 20 Pre-Rulemaking – June 2018 Draft Staff Report – Commercial and Industrial Fans and Blowers, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224812&DocumentContentId=55394.

[37] U.S. Energy Information Administration, *Electric Power Monthly With Data for October 2014* "Table ES1.B
Total Electric Power Industry Summary Statistics, Year-to-Date 2014 and 2013 , https://www.eia.gov/electricity/monthly/archive/december2014.pdf.

- ☐ 2022 California electricity forecast prices for the commercial and industrial sectors of 18.75 cents per kilowatt-hour ($0.1875/kWh) and 14.62 cents per kilowatt-hour ($0.1462/kWh) for 2022.[38]
- ☐ The CEC used data from the U.S. Department of Energy November 2016 NODA, National Impact Analysis (NIA), and Life-Cycle Cost (LCC) for this analysis, including the assumptions made in those analyses.
- ☐ Fourteen percent of the total U.S. shipments was used to calculate the shipments in California.[39]
- ☐ Average lifetimes for stand-alone fans was calculated per the LCC analysis.[40]
- ☐ LCC assumptions for calculating operating hours per fan were used.[41]
- ☐ Efficiency Level 3 energy consumption per fan was calculated from the NIA.[42]

Calculation:

1. One HP is equivalent to 0.7457 kW
2. Per ANSI/AMCA 214-21 equation in section 5.2 (SI), the default transmission efficiency for a shaft power of 0.7457 kW is:

$$\eta = .96\left(\frac{H_{i,ref}}{H_{i,ref}+1.64}\right)^{0.05} = 0.96\left(\frac{0.7457}{.0.7457+1.64}\right)^{0.05} = \mathbf{90.6\%}$$

[38] 2020 IEPR Update Workshops, Notices and Documents, California Energy Commission, https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2020-integrated-energy-policy-report-update-0, https://www.eia.gov/electricity/monthly/current_month/july2020.pdf.

[39] The percent California contributed to the National Gross Domestic Product for 2021.

[40] 2016 Noda Life-Cycle Cost (LCC) and Payback Period (PBP) Analyses Spreadsheet, Summary by EC tab, U.S. Department of Energy, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0190.

[41] 2016 Noda Life-Cycle Cost (LCC) and Payback Period (PBP) Analyses Spreadsheet, Lifetime tab, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0190.

[42] 2016 Noda National Impact Analysis (NIA) Spreadsheet, LCC Inputs tab, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0192.

3. Per equation in section 5.3 in ANSI/AMCA 214-21, the reference fan motor output is:

$$H_{t,ref} = \frac{H_{i,ref}}{\eta_{trans,ref}} = \frac{.7457}{.906} = \mathbf{0.823kW}$$

$$\eta_{mtr,ref} = A * \left[\log_{10}\left(H_{t,ref}\right)\right]^4 + B * \left[\log_{10}\left(H_{t,ref}\right)\right]^3 + C * \left[\log_{10}\left(H_{t,ref}\right)\right]^2 + D * \left[\log_{10}\left(H_{t,ref}\right)\right]^1 + E$$

$$\eta_{mtr,ref} = -0.0038 * [\log_{10}(0.823)]^4 + 0.0258 * [\log_{10}(0.823)]^3 - 0.0726 * [\log_{10}(0.823)]^2 + 0.1256 * [\log_{10}(0.823)]^1 + 0.8503 = 83.9\%$$

$$FEP = fan\ shaft\ power * \frac{1}{transmission\ efficiency} * \frac{1}{motor\ efficiency}$$

$$FEP = 0.7457 * \frac{1}{.906} * \frac{1}{.839} = \mathbf{0.98\ kW}$$

Tables

Table A-1: Per Unit Annual National Stand-Alone Fan Electricity Savings

Fan Type	Average National Electricity Rates in 2014 ($/kWh)	First-year U.S. Operating Cost at Baseline Level ($)	First-Year U.S. Operating Cost at Proposed Standard Level ($)	Per-Unit Annual Electricity Use at Baseline Level (kWh)	Per-Unit Annual Electricity Use at Proposed Standard Level (kWh)	Per-Unit Annual Electricity Savings (kWh)
Axial cylindrical-housed	$0.071	$4,027	$3,945	56,718	55,563	1,155
Panel	$0.108	$1,325	$1,271	12,280	11,779	500
Centrifugal-housed	$0.108	$6,559	$6,515	60,788	60,380	408
Centrifugal-unhoused	$0.108	$5,133	$5,119	47,572	47,442	130
Inline and mixed-flow	$0.108	$2,209	$2,087	20,479	19,342	1,131
Radial	$0.071	$5,660	$5,503	79,718	77,507	2,211
Power roof ventilator	$0.108	$1,066	$966	9,880	8,953	927
Total						**6,462**

Monetary figures are in 2014 dollars
Source: California Energy Commission

Equation used for Table A-1:

$$Per\ Unit\ Annual\ Electricity\ Savings = \left(\frac{Operating\ cost\ Baseline}{National\ average\ Electricity\ rate}\right) - \left(\frac{Operating\ cost\ at\ standard}{National\ average\ Electricity\ rate}\right)$$

Table A-2: Stand-Alone Fan Shipments

Fan Type	Total 2021 US Shipments*	Percent of Stand-Alone Fans 2019	Stand-Alone 2021 US Shipments*	2021 California Shipments
Axial cylindrical housed	44,887	90%	40,399	5,967
panel	344,473	54%	186,015	27,474
Centrifugal housed	449,313	25%	112,328	16,591
Centrifugal unhoused	494,244	17%	84,021	12,410
Inline and mixed flow	29,954	100%	29,954	4,424
Radial	44,931	100%	44,931	6,636
Power roof ventilator	89,863	100%	89,863	13,273
Total	**1,497,665**		**587,882**	**86,775**

* Numbers from U.S. Department of Energy National Impact Analysis for the November 2016 NODA

Source: California Energy Commission and U.S. Department of Energy

Equations used for Table A-2 Stand-Alone Fan Shipments

$$\begin{aligned} &\mathit{Standalone}\ 2019\ \mathit{US\ Shipments} \\ &\qquad = \mathit{Total}\ 2019\ \mathit{US\ shipments} \\ &\qquad * \mathit{Percent\ of\ Stand\text{-}alone\ Fans}\ 2019 \end{aligned}$$

$$2019\ \mathit{California\ Shipments} = \mathit{Stand\text{-}alone}\ 2019\ \mathit{US\ Shipments} * 0.12$$

Table A-3: California Stock for Stand-Alone Fans

Fan Type	2021 California Stand-Alone Fan Shipments	Average Lifetime (Years)	Estimated California Stock
Axial cylindrical-housed	5,967	29	173,039
Panel	27,474	28	769,286
Centrifugal-housed	16,591	27	447,954
Centrifugal-unhoused	12,410	27	335,069
Inline and mixed-flow	4,424	27	119,454
Radial	6,636	30	199,090
Power roof ventilator	13,273	30	398,181
Total	**86,775**		**2,442,073**

Source: California Energy Commission

Equations used for Table A-3:

$$\mathit{Estimated\ California\ Stock\ stand\text{-}alone\ fan} = (2019\ \mathit{California\ stand\text{-}alone\ fan\ shipment}) * (\mathit{Average\ lifetime})$$

Table A-4: California Energy Savings for Stand-Alone Fans

Fan Type	Per-Unit Savings (kWh)	2021 Fan Sales	California Stock	First-Year Savings (GWh/yr)	Savings After Stock Turnover (GWh/yr)
Axial Cylindrical housed	1,155	5,967	173,039	7	200
Panel	500	27,474	769,286	14	385
Centrifugal-housed	408	16,591	447,954	7	183
Centrifugal-unhoused	130	12,410	335,069	2	43
Inline and mixed flow	1,131	4,424	119,454	5	135
Radial	2,211	6,636	199,090	15	440
Power Roof Ventilator	927	13,273	398,181	12	369
Total	**6,462**	**86,775**	**2,442,073**	**61**	**1,755**

Source: California Energy Commission

Equations used for Table A-4

$$First\ year\ Savings = (per\ unit\ savings) * (2019\ Fan\ Sales) * \left(\frac{1 * 10^3}{1 * 10^9}\right)$$

$$Savings\ after\ stock\ turnover = (per\ unit\ savings) * (California\ Stock) * \left(\frac{1 * 10^3}{1 * 10^9}\right)$$

Table A-5: Peak Demand Reduction Stand-Alone Fans

Stand-Alone Fan Type	Peak Demand Reduction After Stock Turnover (Megawatt)
Axial Cylindrical housed	22.8
Panel	43.9
Centrifugal-housed	20.9
Centrifugal-unhoused	5.0
Inline and mixed flow	15.4
Radial	50.3
Power roof ventilator	42.1
Total	**200.4**

Source: California Energy Commission

Equation used for Table A-5:

$$\text{Peak demand reduction after stock turnover} = \left(\frac{\text{Savings after stock turnover}^{*}}{\text{8,760 hours per year}}\right) * \left(\frac{1 * 10^{9}}{1 * 10^{6}}\right)$$

* Savings after stock turnover from Table A-4

Table A-6: California Net Benefit for Stand-Alone Fans

Fan Type	Per-Unit Electricity Savings (kWh)	Per-Unit Incremental Cost [43] ($/unit)	Average Lifetime (years)	Per-Unit Average Annual Savings ($/yr)[44]	Per-Unit Lifetime Net Benefits ($)
Axial cylindrical housed	1,155.93	$399	29	$169	$ 2,842
Panel	500.46	$53	28	$94	$1,708
Centrifugal housed	407.78	$33	27	$76	$1,368
Centrifugal unhoused	129.75	$39	27	$24	$407
Inline and mixed flow	1,130.67	$689	27	$212	$3,196
Radial	2,211.26	$221	30	$323	$6,117
Power roof ventilator	926.78	$595	30	$174	$2,810
Total		**$2,028**			$**18,448**

Monetary figures are in 2022 dollars rounded to nearest dollar.
Source: California Energy Commission

[43] U.S. Department of Energy, Energy Conservation Standards for Commercial and Industrial Fans and Blowers: Availability of Provisional Analysis Tools, Notice of Data Availability, https://www.regulations.gov/document?D=EERE-2013-BT-STD-0006-0194.

[44] California commercial and industrial May 2020 rates referenced in the assumptions were used.

Table A-7: California total Net Monetary Benefit for Stand-Alone Fans

Fan Type	Per-Unit Lifetime Net Benefits ($)	California Stock	Total Lifetime Net Benefit at Full Stock Turnover ($ in Billions)
Axial cylindrical housed	$ 2,842	173,039	0.49
Panel	$1,708	769,286	1.31
Centrifugal housed	$1,368	447,954	0.61
Centrifugal unhoused	$407	335,069	0.14
Inline and mixed flow	$3,196	119,454	0.38
Radial	$6,117	199,090	1.22
Power roof ventilator	$2,810	398,181	1.12
Total	$**18,448**	**1,985,337**	**5.27**

Monetary figures are in 2022 dollars rounded to nearest dollar.
Source: California Energy Commission

Table A-8: California Monetary Savings

Fan Type	Per Unit Annual Savings ($/yr)	2021 Fan Sales	California Stock	First Year Saving ($ in Millions)	Savings after Full Stock Turnover ($ in Millions)
Axial cylindrical housed	$169	5,967	173,039	$1.01	$29.22
Panel	$94	27,474	769,286	$2.58	$72.17
Centrifugal housed	$76	16,591	447,954	$1.27	$34.24
Centrifugal unhoused	$24	12,410	335,069	$0.30	$8.15
Inline and mixed flow	$212	4,424	119,454	$0.94	$25.32
Radial	$323	6,636	199,090	$2.15	$64.38
Power roof ventilators	$174	13,273	398,181	$2.31	$69.18
Total		**86,775**	**2,442,073**	**$10.55**	**$302.67**

Monetary figures are in 2022 dollars rounded to nearest dollar
Source: California Energy Commission

Table A-9: Net Present Value Calculation (3% Discount Rate)

Year	Axial Cylin-drical housed	Panel	Centri-fugal housed	Centri-fugal Un-housed	Inlined Mixed Flow	Radial	Power Roof Ventila-tor
1	$163.97	$91.09	$74.22	$23.61	$205.79	$313.94	$168.68
2	$159.19	$88.43	$72.06	$22.93	$199.79	$304.79	$163.76
3	$154.56	$85.86	$69.96	$22.93	$193.97	$295.92	$158.99
4	$150.05	$83.36	$67.92	$21.61	$188.32	$287.30	$154.36
5	$145.68	$80.93	$65.94	$20.98	$182.84	$278.93	$149.87
6	$141.44	$78.57	$64.02	$20.37	$177.51	$270.81	$145.50
7	$137.32	$76.28	$62.16	$19.78	$172.34	$262.92	$141.26
8	$133.32	$74.06	$60.35	$19.20	$167.32	$255.26	$137.15
9	$129.44	$71.90	$58.59	$18.64	$162.45	$247.83	$133.15
10	$125.67	$69.81	$56.88	$18.10	$157.72	$240.61	$129.28
11	$121.01	$67.78	$55.22	$17.57	$153.12	$233.60	$125.51
12	$118.45	$65.80	$53.62	$17.06	$148.66	$226.80	$121.86
13	$115.00	$63.89	$52.05	$16.56	$144.33	$220.19	$118.31
14	$111.65	$62.02	$50.54	$16.08	$140.13	$213.78	$114.86
15	$108.40	$60.22	$49.07	$15.61	$136.05	$207.55	$111.51
16	$105.24	$58.46	$47.64	$15.16	$132.09	$201.51	$108.27
17	$102.18	$56.76	$46.25	$14.72	$128.24	$195.64	$105.11
18	$99.20	$55.11	$44.90	$14.29	$124.50	$189.94	$102.05
19	$96.31	$53.50	$43.59	$13.87	$120.88	$184.41	$99.08
20	$93.51	$51.94	$42.33	$13.47	$117.36	$179.03	$96.19
21	$90.79	$50.43	$41.09	$13.07	$113.94	$173.82	$93.39
22	$88.14	$48.96	$39.90	$12.69	$110.62	$168.76	$90.67
23	$85.57	$47.54	$38.73	$12.32	$107.40	$163.84	$88.03
24	$83.08	$46.15	$37.61	$11.97	$104.27	$159.07	$85.47
25	$80.66	$44.81	$36.51	$11.62	$101.23	$154.44	$82.98
26	$78.31	$43.50	$35.45	$11.28	$98.28	$149.94	$80.56
27	$76.03	$42.24	$34.41	$10.95	$95.42	$145.57	$78.21
28	$73.82	$41.01				$141.33	$75.94
29	$71.67					$137.22	$73.72
30						$133.22	$71.58
Total	**$3,240.68**	**$1,760.41**	**$1,400.99**	**$455.77**	**$3,884.57**	**$6,337.94**	**$3,405.31**

Source: California Energy Commission

Equation used for Tables A-6, A-7,A-8 and A-9:

$$First\ Year\ Savings = Per\ Unit\ Annual\ Savings\ \times 2021\ Fan\ Sales$$

$$Savings\ after\ Full\ Stock\ Turnover$$
$$= Per\ Unit\ Annual\ Savings \times California\ Stock$$

$$Net\ Present\ Value(NPV) = \sum \left(\frac{Annual\ savnigs}{(1 + discount\ rate)^{year}}\right)$$

$$Per\text{-}unit\ Lifetime\ Net\ benefit = (Net\ present\ value - Incremental\ Cost)$$

$$Average\ Annual\ Savings = \big(Electricity\ Savings(kWh)\big) * \left(\frac{\$0.1365}{1\ kWh}\right)$$

$$Average\ Annual\ Savings = \big(Electricity\ Savings(kWh)\big) * \left(\frac{\$0.1669}{1\ kWh}\right)$$

$$Total\ Lifetime\ Net\ Benefit\ at\ full\text{-}stock\ turnover$$
$$= (Per\text{-}unit\ lifetime\ Net\ Benefit \times California\ Stock)$$