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Part II

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10 CFR Parts 429 and 430
Energy Conservation Program: Energy Conservation Standards for Compressors; Proposed Rule

DEPARTMENT OF ENERGY

10 CFR Parts 429 and 430

[Docket Number EERE–2013–BT–STD–0040]

RIN 1904–AC83

Energy Conservation Program: Energy Conservation Standards for Compressors

AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy.

ACTION: Notice of proposed rulemaking (NOPR) and announcement of public meeting.

SUMMARY: The Energy Policy and Conservation Act of 1975 (EPCA), as amended, prescribes energy conservation standards for various consumer products and certain commercial and industrial equipment. EPCA also authorizes DOE to establish standards for certain other types of industrial equipment, including compressors. Such standards must be technologically feasible and economically justified, and must save a significant amount of energy. In this document, DOE proposes energy conservation standards for compressors and announces a public meeting to receive comment on the proposed standards and associated analyses and results.

DATES: *Meeting:* DOE will hold a public meeting on Monday, June 20, 2016 from 1:00 p.m. to 5:00 p.m. in Washington, DC. The test procedure portion will be held in the morning. The meeting will also be broadcast as a webinar. See section VIII, ''Public Participation,'' for webinar registration information, participant instructions, and information about the capabilities available to webinar participants.

Comments: DOE will accept comments, data, and information regarding this notice of proposed rulemaking (NOPR) before and after the public meeting, but no later than July 18, 2016. See section VIII, ''Public Participation,'' for details.

Comments regarding the likely competitive impact of the proposed standard should be sent to the Department of Justice contact listed in the **ADDRESSES** section before June 20, 2016.

ADDRESSES: The public meeting will be held at the U.S. Department of Energy, Forrestal Building, Room 8E–089, 1000 Independence Avenue SW., Washington, DC 20585.

Instructions: Any comments submitted must identify the NOPR on Energy Conservation Standards for compressors, and provide docket number EERE–2013–BT–STD–0040 and/or regulatory information number (RIN) 1904–AC83. Comments may be submitted using any of the following methods:

1. *Federal eRulemaking Portal: www.regulations.gov*. Follow the instructions for submitting comments.

2. *Email: AirCompressors2013STD0040@ee.doe.gov*. Include the docket number and/or RIN in the subject line of the message. Submit electronic comments in WordPerfect, Microsoft Word, PDF, or ASCII file format, and avoid the use of special characters or any form of encryption.

3. *Postal Mail:* Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Office, Mailstop EE–5B, 1000 Independence Avenue SW., Washington, DC, 20585–0121. If possible, please submit all items on a compact disc (CD), in which case it is not necessary to include printed copies.

4. *Hand Delivery/Courier:* Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Office, 950 L'Enfant Plaza, SW., Suite 600, Washington, DC 20024. Telephone: (202) 586–2945. If possible, please submit all items on a CD, in which case it is not necessary to include printed copies.

No telefacsimilies (faxes) will be accepted. For detailed instructions on submitting comments and additional information on the rulemaking process, see section VIII of this document (''Public Participation'').

Written comments regarding the burden-hour estimates or other aspects of the collection-of-information requirements contained in this proposed rule may be submitted to Office of Energy Efficiency and Renewable Energy through the methods listed above and by email to *Chad_S_Whiteman@omb.eop.gov*.

EPCA requires the Attorney General to provide DOE with a written determination of whether the proposed standard is likely to lessen competition. The U.S. Department of Justice Antitrust Division invites input from market participants and other interested persons with views on the likely competitive impact of the proposed standard. Interested persons may contact the Division at *energy.standards@usdoj.gov* before June 20, 2016. Please indicate in the ''Subject'' line of your email the title and Docket Number of this rulemaking notice.

Docket: The docket, which includes **Federal Register** notices, public meeting attendee lists and transcripts, comments, and other supporting documents/materials, is available for review at *www.regulations.gov*. All documents in the docket are listed in the *www.regulations.gov* index. However, some documents listed in the index may not be publicly available, such as those containing information that is exempt from public disclosure.

A link to the docket Web page can be found at: *https://www.regulations.gov/#!docketDetail;D=EERE-2013-BT-STD-0040*. This Web page contains a link to the docket for this document on the *www.regulations.gov* site. The *www.regulations.gov* Web page contains simple instructions on how to access all documents, including public comments, in the docket. See section VIII, ''Public Participation,'' for further information on how to submit comments through *www.regulations.gov*.

FOR FURTHER INFORMATION CONTACT: James Raba, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, EE–5B, 1000 Independence Avenue SW., Washington, DC 20585–0121. Telephone: (202) 586–8654. Email: *compressors@ee.doe.gov*.

Peter Cochran, U.S. Department of Energy, Office of the General Counsel, GC–71, 1000 Independence Avenue SW., Washington, DC, 20585–0121. Telephone: (202) 586–9496. Email: *Peter.Cochran@hq.doe.gov*.

For further information on how to submit a comment, review other public comments and the docket, or participate in the public meeting, contact Ms. Brenda Edwards at (202) 586–2945 or by email: *Brenda.Edwards@ee.doe.gov*.

SUPPLEMENTARY INFORMATION:

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I. Synopsis of the Proposed Rule

Title III of the Energy Policy and Conservation Act of 1975, as amended (''EPCA'' or, in context, ''the Act''), sets forth a variety of provisions designed to improve energy efficiency. (42 U.S.C. 6291, *et seq.*) Part C of Title III, which for editorial reasons was re-designated as Part A–1 upon incorporation into the U.S. Code (42 U.S.C. 6311–6317), establishes the ''Energy Conservation Program for Certain Industrial Equipment.'' EPCA provides that DOE may include a type of industrial equipment as covered equipment if it determines that to do so is necessary to carry out the purposes of Part A–1. (42 U.S.C. 6312(b)). DOE has proposed such a determination for compressors, the subject of this document (see section II.A for further discussion).

EPCA authorizes DOE to prescribe energy conservation standards for those types of industrial equipment which the Secretary classifies as covered equipment. (42 U.S.C. 6311(2) and 6312). Pursuant to EPCA, any new or amended energy conservation standard must be designed to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A) and 6316(a)). Furthermore, the new or amended standard must result in a significant conservation of energy. (42 U.S.C. 6295(o)(3)(B) and 6316(a)).

In accordance with the relevant EPCA provisions, DOE proposes new energy conservation standards for compressors. The proposed standards, which are expressed in terms of package isentropic efficiency (*i.e.,* a parameter used to measure the degree of degradation of energy in steady-flow devices), or the ratio of the theoretical isentropic power required for a compression process to the actual power required for the same process, are shown in Table I.1. Table I.2 through Table I.5 provide mathematical coefficients required to calculate package isentropic efficiency in Table I.1. For ''Fixed-speed compressor'' equipment classes, the relevant Package Isentropic Efficiency is Full-Load Package Isentropic Efficiency; for ''Variable-speed compressor'' equipment classes, the relevant Package Isentropic Efficiency is Part-Load Package Isentropic Efficiency. Both Full- and Part-Load Package Isentropic Efficiency are determined in accordance with the test methods proposed in the April 2016 Compressors Test Procedure Notice of Proposed Rulemaking (''test procedure NOPR'') 81 FR 27220.[1] These proposed standards, if adopted, would apply to all compressors listed in Table I.1 and manufactured in, or imported into, the United States starting five years after the publication of the final rule for this rulemaking.

V_1 denotes the full-load actual volume flow rate [2] of the compressor, in actual cubic feet per minute (''acfm'').[3] Standard levels are expressed as a function of full-load actual volume flow rate for each equipment class, and may be calculated by inserting values from rightmost two columns into the second leftmost column. Doing so will yield an efficiency-denominated function of actual volume flow rate in acfm.

TABLE I.1—PROPOSED ENERGY CONSERVATION STANDARDS FOR COMPRESSORS

Equipment class	Minimum package isentropic efficiency	η_{Regr} (package isentropic efficiency reference curve)	d (percentage loss reduction)
Rotary; Lubricated; Air-cooled; Fixed-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln(.472 * V_1)^2 + 0.139 * \ln(.472 * V_1) + 0.271$	−15
Rotary; Lubricated; Air-cooled; Variable-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.0155 * \ln(.472 * V_1)^2 + 0.216 * \ln(.472 * V_1) + 0.00905$	−10
Rotary; Lubricated; Water-cooled; Fixed-speed.	$.0235 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln(.472 * V_1)^2 + 0.139 * \ln(.472 * V_1) + 0.271$	−15
Rotary; Lubricated; Water-cooled; Variable-speed.	$.0235 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.0155 * \ln(.472 * V_1)^2 + 0.216 * \ln(.472 * V_1) + 0.00905$	−15
Rotary; Lubricant-free; Air-cooled; Fixed-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$A_1 * \ln(.472 * V_1)^2 + B_1 * \ln(.472 * V_1) + C_1$	−11
Rotary; Lubricant-free; Air-cooled; Variable-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$A_2 * \ln(.472 * V_1)^2 + B_2 * \ln(.472 * V_1) + C_2$	−13
Rotary; Lubricant-free; Water-cooled; Fixed-speed.	$A_3 * \ln(.472 * V_1)^2 + B_3 * \ln(.472 * V_1) + C_3 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$.	$A_1 * \ln(.472 * V_1)^2 + B_1 * \ln(.472 * V_1) + C_1$	−11
Rotary; Lubricant-free; Water-cooled; Variable-speed.	$A_4 * \ln(.472 * V_1)^2 + B_4 * \ln(.472 * V_1) + C_4 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$.	$A_2 * \ln(.472 * V_1)^2 + B_2 * \ln(.472 * V_1) + C_2$	−13

TABLE I.2—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, AIR- AND WATER-COOLED, FIXED-SPEED COMPRESSORS

Full-load actual volume flow rate range (actual cubic feet per minute (acfm))	A_1	B_1	C_1
$0 \le V_1 \le 161$	−0.00928	0.139	0.191
$161 \le V_1 \le 2125$	0.00281	0.0344	0.417
$2125 \le V_1$	−0.00928	0.139	0.271

[1] See *https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/78*.

[2] The test procedure NOPR defines a term ''actual volume flow rate'' to characterize compressor output flow as ''the volume flow rate of air, compressed and delivered at the standard discharge point, referred to conditions of total temperature, total pressure and composition prevailing at the standard inlet point.'' It also proposes a procedure for identifying a compressor's full-load actual volume flow rate.

[3] Actual cubic feet per minute (''acfm'') is an industry convention that describes the actual volume of air emerging from a compressor, but expressed as though the air were allowed to expand to ambient conditions at the compressor inlet.

TABLE I.3—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, AIR- AND WATER-COOLED, VARIABLE-SPEED COMPRESSORS

Full-Load Actual Volume Flow Rate Range (acfm)	A_2	B_2	C_2
$0 \le V_1 \le 102$	−0.0155	0.216	−0.0984
$102 \le V_1 \le 1426$	0.000	0.0958	0.134
$1426 \le V_1$	−0.0155	0.216	0.00905

TABLE I.4—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, WATER-COOLED, FIXED-SPEED COMPRESSORS

Full-Load Actual Volume Flow Rate Range (acfm)	A_3	B_3	C_3
$0 \le V_1 < 102$	0	0	0
$102 \le V_1$	−0.00924	0.117	−0.315

TABLE I.5—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, WATER-COOLED, VARIABLE-SPEED COMPRESSORS

Full-Load Actual Volume Flow Rate Range (acfm)	A_4	B_4	C_4
$0 \le V_1 < 74$	0	0	0
$74 \le V_1$	0.000173	0.00783	−0.0300

DOE has tentatively concluded that the proposed standards represent the maximum improvement in energy efficiency that is technologically feasible and economically justified, and would result in the significant conservation of energy. DOE further notes that air compressors achieving these standard levels are already commercially available for all proposed equipment classes. Based on the analyses described in this preamble, DOE has tentatively concluded that the benefits of the proposed standards to the nation (energy savings, positive NPV of consumer benefits, consumer LCC savings, and emission reductions) would outweigh the burdens (large loss of INPV for manufacturers and LCC increases for some consumers).

DOE is also seriously considering the adoption of a more-stringent energy efficiency standard in this rulemaking. Based on consideration of the public comments DOE receives in response to this notice and related information collected and analyzed during the course of this rulemaking effort, DOE may adopt energy efficiency levels presented in this notice that is higher than the proposed standards, or some combination of level(s) that incorporate the proposed standards in part. As discussed in more detail in section V.C.1, DOE is strongly considering a TSL 3 standard for a compressor standard as an option with greater than two times the annual net benefits of DOE's current proposed TSL 2.

The proposed standards correspond to trial standard level (TSL) 2. As discussed in section V.C, DOE has tentatively concluded that TSL 3, which is comprised of more stringent energy efficiency standards than TSL 2, is not economically justified. However, because TSL 3 has significant benefits, including much higher national energy savings, national NPV, and emissions reductions than those resulting from TSL 2 (see Table V.36), DOE is still considering the merits of standards at TSL 3. Accordingly, DOE invites comments on whether DOE should adopt standards for compressors at TSL 3 instead of at TSL 2. This is identified as Issue 1 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

A. Benefits and Costs to Consumers

Table I.6 presents DOE's evaluation of the economic impacts of the proposed standards on end users of compressors, as measured by the average life-cycle cost (LCC) savings and the simple payback period (PBP).[4] The average LCC savings are positive for all equipment classes for which a standard has been proposed, and the PBP is less than the average lifetime of compressors, which is estimated to be between 9 to 13 years (see section IV.F.6).

TABLE I.6—IMPACTS OF PROPOSED ENERGY CONSERVATION STANDARDS ON END USERS OF COMPRESSORS

Equipment Class	Average LCC Savings (*2015$*)	Simple Payback Period (*years*)
Rotary, Fixed Speed, Lubricated, Air Cooled (RP_FS_L_AC)	$8,902	1.7
Rotary, Fixed Speed, Lubricated, Water Cooled (RP_FS_L_WC)	15,011	2.4
Rotary, Fixed Speed, Lubricant-Free Air Cooled (RP_FS_LF_AC) *	n.a.	n.a.
Rotary, Fixed Speed, Lubricant-Free Water Cooled (RP_FS_LF_WC) *	n.a.	n.a.
Rotary, Variable Speed, Lubricated, Air Cooled (RP_VS_L_AC)	6,061	2.5

[4] The average LCC savings are measured relative to the no-new standards case efficiency distribution in the no-new-standards case, which depicts the market in the compliance year in the absence of standards (see section IV.F.9). The simple PBP, which is designed to compare specific efficiency levels, is measured relative to the baseline model (see section IV.C.1.a).

TABLE I.6—IMPACTS OF PROPOSED ENERGY CONSERVATION STANDARDS ON END USERS OF COMPRESSORS—Continued

Equipment Class	Average LCC Savings (*2015$*)	Simple Payback Period (*years*)
Rotary, Variable Speed, Lubricated, Water Cooled (RP_VS_L_WC)	13,865	3.4
Rotary, Variable Speed, Lubricant-Free Air Cooled (RP_VS_LF_AC) *	n.a.	n.a.
Rotary, Variable Speed, Lubricant-Free Water Cooled (RP_VS_LF_WC) *	n.a.	n.a.
Reciprocating, Single-Phase, Lubricated (R1_FS_L_XX) **	n.a.	n.a.
Reciprocating, Three-Phase, Lubricated (R3_FS_L_XX) **	n.a.	n.a.

* No increase in efficiency is proposed for this equipment class.
** No new standard is proposed for this equipment class.

DOE's analysis of the impacts of the proposed standards on end users is described in section V.B.1 of this document.

B. Impact on Manufacturers

The industry net present value (INPV) is the sum of the discounted cash flows to the industry from the base year through the end of the analysis period (2015 to 2051). Using a real discount rate of 8.7 percent, DOE estimates that the INPV for manufacturers of compressors in the case without standards is $497.1 million in 2014$. Under the proposed standards, DOE expects that manufacturers may lose up to 11.6 percent of this INPV, or approximately $57.8 million.

DOE's analysis of the impacts of the proposed standards on manufacturers is described in section IV.J of this document.

C. National Benefits and Costs [5]

DOE's analyses indicate that the proposed energy conservation standards for compressors would save a significant amount of energy. Relative to the case without new standards, the lifetime energy savings for compressors purchased in the 30-year period that begins in the anticipated first full year of compliance with the new standards (2022–2051) [6] amount to 0.18 quadrillion British thermal units (Btu), or quads.[7] This represents a savings of 0.4 percent relative to the energy use of these equipment in the case without new standards (referred to as the ''no-new-standards case'').

The cumulative net present value (NPV) of total consumer costs and savings of the proposed standards for compressors ranges from $0.21 billion (at a 7-percent discount rate) to $0.62 billion (at a 3-percent discount rate). This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased equipment costs for compressors purchased in 2022–2051.

In addition, the proposed standards for compressors would have significant environmental benefits. DOE estimates that the proposed standards would result in cumulative emission reductions (over the same period as for energy savings) of 10.6 million metric tons (Mt) [8] of carbon dioxide (CO_2), 5.8 thousand tons of sulfur dioxide (SO_2), 19.5 thousand tons of nitrogen oxides (NO_X), 46.7 thousand tons of methane (CH_4), 0.1 thousand tons of nitrous oxide (N_2O), and 0.02 tons of mercury (Hg).[9] The cumulative reduction in CO_2 emissions through 2030 amounts to 1.2 Mt, which is equivalent to the emissions resulting from the annual electricity use of 0.11 million homes.

The value of the CO_2 reductions is calculated using a range of values per metric ton of CO_2 (otherwise known as the Social Cost of Carbon, or SCC) developed by a recent Federal interagency process.[10] The derivation of the SCC values is discussed in section IV.L. Using discount rates appropriate for each set of SCC values (see Table I.X), DOE estimates the present monetary value of the CO_2 emissions reduction (not including CO_2 equivalent emissions of other gases with global warming potential) is between $0.06 billion and $0.99 billion, with a value of $0.32 billion using the central SCC case represented by $40.0/t in 2015. DOE also estimates the present monetary value of the NO_X emissions reduction to be $0.01 billion at a 7-percent discount rate and $0.03 billion at a 3-percent discount rate.[11] DOE is investigating appropriate valuation of the reduction in methane and other emissions, and did not include any values in this rulemaking.

Table I.7 summarizes the economic benefits and costs expected to result from the proposed standards for compressors.

[5] All monetary values in this document are expressed in 2015 dollars and, where appropriate, are discounted to 2015 unless explicitly stated otherwise. Energy savings in this section refer to the full-fuel-cycle savings (see section IV.H for discussion).

[6] The analysis uses January 1st, 2022 to represent the expected compliance date in late 2021. Therefore, the 30-year analysis period is referred to as 2022–2051.

[7] The quantity refers to full-fuel-cycle (FFC) energy savings. FFC energy savings includes the energy consumed in extracting, processing, and transporting primary fuels (*i.e.,* coal, natural gas, petroleum fuels), and, thus, presents a more complete picture of the impacts of energy efficiency standards. For more information on the FFC metric, see section IV.H.1.

[8] A metric ton is equivalent to 1.1 short tons. Results for emissions other than CO_2 are presented in short tons.

[9] DOE calculated emissions reductions relative to the no-new-standards case, which reflects key assumptions in the *Annual Energy Outlook 2015* (*AEO 2015*) Reference case. *AEO 2015* generally represents current legislation and environmental regulations for which implementing regulations were available as of October 31, 2014.

[10] United States Government—Interagency Working Group on Social Cost of Carbon. *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.* May 2013. Revised July 2015. *https://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf.*

[11] DOE estimated the monetized value of NO_X emissions reductions associated with electricity savings using benefit per ton estimates from the Regulatory Impact Analysis for the Clean Power Plan Final Rule, published in August 2015 by EPA's Office of Air Quality Planning and Standards. Available at *http://www.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.* See section IV.L.2 for further discussion. The U.S. Supreme Court has stayed the rule implementing the Clean Power Plan until the current litigation against it concludes. *Chamber of Commerce, et al.* v. *EPA, et al.,* Order in Pending Case, 136 S.Ct. 999 (Mem). However, the benefit-per-ton estimates established in the Regulatory Impact Analysis for the Clean Power Plan are based on scientific studies that remain valid irrespective of the legal status of the Clean Power Plan. Note that DOE is primarily using a national benefit-per-ton estimate for NO_X emitted from the Electricity Generating Unit sector based on an estimate of premature mortality derived from the ACS study (Krewski et al. 2009). If the benefit-per-ton estimates were based on the Six Cities study (Lepuele et al. 2011), the values would be nearly two-and-a-half times larger.

TABLE I.7.—SUMMARY OF ECONOMIC BENEFITS AND COSTS OF PROPOSED ENERGY CONSERVATION STANDARDS FOR COMPRESSORS

[TSL 2] *

Category	Present value *(billion 2015$)*	Discount rate (percent)
Benefits:		
Consumer Operating Cost Savings	0.3	7
	0.8	3
CO_2 Reduction (using mean SCC at 5% discount rate) **	0.1	5
CO_2 Reduction (using mean SCC at 3% discount rate) **	0.3	3
CO_2 Reduction (using mean SCC at 2.5% discount rate) **	0.5	2.5
CO_2 Reduction (using 95th percentile SCC at 3% discount rate) **	1.0	3
NO_X Reduction †	0.0	7
	0.0	3
Total Benefits ‡	0.7	7
	1.2	3
Costs:		
Consumer Incremental Installed Costs	0.1	7
	0.2	3
Total Net Benefits:		
Including CO_2 and NO_X Reduction Monetized Value ‡	0.6	7
	1.0	3

* This table presents the costs and benefits associated with compressors shipped in 2022 – 2051. These results include benefits to consumers which accrue after 2048 from the equipment purchased in 2022 – 2051. The costs account for the incremental variable and fixed costs incurred by manufacturers due to the standard, some of which may be incurred in preparation for the rule.

** The interagency group selected four sets of SCC values for use in regulatory analyses. Three sets of values are based on the average SCC from the integrated assessment models, at discount rates of 5%, 3%, and 2.5%. For example, for 2015 emissions, these values are $12.4/t, $40.6/t, and $63.2/t, in 2015$, respectively. The fourth set ($118/t in 2015$ for 2015 emissions), which represents the 95th percentile of the SCC distribution calculated using a 3% discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. The SCC values are emission year specific. See section IV.L.1 for more details.

† DOE estimated the monetized value of NO_X emissions reductions using benefit per ton estimates from the *Regulatory Impact Analysis for the Clean Power Plan Final Rule,* published in August 2015 by EPA's Office of Air Quality Planning and Standards. (Available at: *http://www.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.)* See section IV.L.2 for further discussion. Note that DOE is primarily using a national benefit-per-ton estimate for NO_X emitted from the Electricity Generating Unit sector based on an estimate of premature mortality derived from the ACS study (Krewski et al., 2009). If the benefit-per-ton estimates were based on the Six Cities study (Lepuele et al., 2011), the values would be nearly two-and-a-half times larger.

‡ Total Benefits for both the 3% and 7% cases are presented using only the average SCC with 3-percent discount rate.

The benefits and costs of the proposed standards, for compressors sold in 2022–2051, can also be expressed in terms of annualized values. The monetary values for the total annualized net benefits are the sum of: (1) The national economic value of the benefits in reduced consumer operating costs, minus (2) the increase in equipment purchase prices and installation costs, plus (3) the value of the benefits of CO_2 and NO_X emission reductions, all annualized.[12]

The national operating savings are domestic U.S. consumer monetary savings that occur as a result of purchasing the covered products. The national operating cost savings is measured for the lifetime of compressors shipped in 2022–2051. The CO_2 reduction is a benefit that accrues globally due to decreased domestic energy consumption that is expected to result from this rule. Because CO_2 emissions have a very long residence time in the atmosphere, the SCC values in future years reflect future CO_2-emissions impacts that continue beyond 2100 through 2300.

Estimates of annualized benefits and costs of the proposed standards are shown in Table I.8. The results under the primary estimate are as follows.

Using a 7-percent discount rate for benefits and costs other than CO_2 reduction (for which DOE used a 3-percent discount rate along with the average SCC series that has a value of $40.0/t in 2015), the estimated cost of the standards proposed in this rule is 10.4 million per year in increased equipment costs, while the estimated annual benefits are $36.0 million in reduced equipment operating costs, $19.2 million in CO_2 reductions, and $1.4 million in reduced NO_X emissions. In this case, the net benefit amounts to $46 million per year.

Using a 3-percent discount rate for all benefits and costs and the average SCC series that has a value of $40.0/t in 2015, the estimated cost of the proposed standards is $10.9 million per year in increased equipment costs, while the estimated annual benefits are $48.4 million in reduced operating costs, $19.2 million in CO_2 reductions, and $2.0 million in reduced NO_X emissions. In this case, the net benefit amounts to $59 million per year.

[12] To convert the time-series of costs and benefits into annualized values, DOE calculated a present value in 2016, the year used for discounting the NPV of total consumer costs and savings. For the benefits, DOE calculated a present value associated with each year's shipments in the year in which the shipments occur (*e.g.,* 2020 or 2030), and then discounted the present value from each year to 2016. The calculation uses discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions, for which DOE used case-specific discount rates, as shown in Table I.3. Using the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in the compliance year that yields the same present value.

TABLE I.8—ANNUALIZED BENEFITS AND COSTS OF PROPOSED ENERGY CONSERVATION STANDARDS FOR COMPRESSORS
[TSL 2]

	Discount rate	Million 2015$/year		
		Primary estimate *	Low net benefits estimate *	High net benefits estimate *
Benefits				
Consumer Operating Cost Savings	7%	36.0	29.3	43.7
	3%	48.4	38.9	60.4
CO_2 Reduction (using mean SCC at 5% discount rate) **.	5%	5.7	4.8	6.9
CO_2 Reduction (using mean SCC at 3% discount rate) **.	3%	19.2	16.0	23.2
CO_2 Reduction (using mean SCC at 2.5% discount rate) **.	2.5%	28.1	23.3	33.9
CO_2 Reduction (using 95th percentile SCC at 3% discount rate) **.	3%	58.5	48.6	70.6
NO_X Reduction †	7%	1.4	1.2	3.7
	3%	2.0	1.6	5.4
Total Benefit ††	7% plus CO_2 range	43 to 96	35 to 79	54 to 118
	7%	57	46	71
	3% plus CO_2 range	56 to 109	45 to 89	73 to 136
	3%	70	57	89
Costs				
Consumer Incremental Installed Equipment Costs.	7%	10.4	8.9	11.8
	3%	10.9	9.2	12.4
Net Benefits				
Total ††	7% plus CO_2 range	33 to 85	26 to 70	42 to 106
	7%	46	38	59
	3% plus CO_2 range	45 to 98	36 to 80	60 to 124
	3%	59	47	77

* This table presents the annualized costs and benefits associated with compressors shipped in 2022 – 2051. These results include benefits to consumers which accrue after 2051 from the equipment purchased in 2022–2051. The Primary, Low Benefits, and High Benefits Estimates utilize projections of energy prices from the *AEO 2015* Reference case, Low Economic Growth case, and High Economic Growth case, respectively. In addition, incremental product costs reflect a constant trend in the Primary Estimate, an increasing trend in the Low Benefits Estimate, and a decreasing trend in the High Benefits Estimate. The methods used to derive projected price trends are explained in section IV.H.1.]. Note that the Benefits and Costs may not sum to the Net Benefits due to rounding.

** The CO_2 reduction benefits are calculated using 4 different sets of SCC values. The first three use the average SCC calculated using 5%, 3%, and 2.5% discount rates, respectively. The fourth represents the 95th percentile of the SCC distribution calculated using a 3% discount rate. The SCC values are emission year specific. See section IV.L.1 for more details.

† DOE estimated the monetized value of NO_X emissions reductions using benefit per ton estimates from the *Regulatory Impact Analysis for the Clean Power Plan Final Rule,* published in August 2015 by EPA's Office of Air Quality Planning and Standards. (Available at: *http://www.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.)* See section IV.L.2 for further discussion. For DOE's Primary Estimate and Low Net Benefits Estimate, the agency is using a national benefit-per-ton estimate for NO_X emitted from the Electric Generating Unit sector based on an estimate of premature mortality derived from the ACS study (Krewski et al., 2009). For DOE's High Net Benefits Estimate, the benefit-per-ton estimates were based on the Six Cities study (Lepuele et al., 2011), which are nearly two-and-a-half times larger than those from the ACS study.

†† Total Benefits for both the 3% and 7% cases are derived using the series corresponding to the average SCC with a 3-percent discount rate ($40.0/t case). In the rows labeled "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

DOE's analysis of the national impacts of the proposed standards is described in sections IV.H, IV.K and IV.L of this document.

D. Conclusion

DOE has tentatively concluded that the proposed standards represent the maximum improvement in energy efficiency that is technologically feasible and economically justified, and would result in the significant conservation of energy. DOE further notes that air compressors achieving these standard levels are already commercially available for all proposed equipment classes. Based on the analyses described in this preamble, DOE has tentatively concluded that the benefits of the proposed standards to the nation (energy savings, positive NPV of consumer benefits, consumer LCC savings, and emission reductions) would outweigh the burdens (large loss of INPV for manufacturers and LCC increases for some consumers).

DOE is also seriously considering the adoption of a more -stringent energy efficiency standard in this rulemaking. Based on consideration of the public comments DOE receives in response to this notice and related information collected and analyzed during the course of this rulemaking effort, DOE may adopt energy efficiency levels presented in this notice that is higher than the proposed standards, or some combination of level(s) that incorporate the proposed standards in part. As discussed in more detail in section V.C.1, DOE is strongly considering a TSL 3 standard for a compressor standard as an option with greater than two times the annual net benefits of DOE's current proposed TSL 2.

II. Introduction

The following section briefly discusses the statutory authority underlying this proposed rule, as well as some of the relevant historical background related to the establishment of standards for compressors.

A. Authority

EPCA provides that DOE may include a type of industrial equipment, including compressors, as covered equipment if it determines that to do so is necessary to carry out the purposes of Part A–1. (42 U.S. 6311(2)(B)(i) and 6312(b)). The purpose of Part A–1 is to improve the efficiency of electric motors and pumps and certain other industrial equipment in order to conserve the energy resources of the Nation. (42 U.S.C. 6312(a)). DOE has proposed to determine that because (1) DOE may only prescribe energy conservation standards for covered equipment; and (2) energy conservation standards for compressors would improve the efficiency of such equipment more than would be likely to occur in the absence of standards, including compressors as covered equipment is necessary to carry out the purposes of Part A–1. 77 FR 76972 (Dec. 31, 2012).

Pursuant to EPCA, any new or amended energy conservation standard for compressors must be designed to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A) and 6316(a)). Furthermore, the new or amended standard must result in a significant conservation of energy. (42 U.S.C. 6295(o)(3)(B) and 6316(a)).

Pursuant to EPCA, DOE's energy conservation program for covered products consists essentially of four parts: (1) Testing; (2) labeling; (3) the establishment of Federal energy conservation standards; and (4) certification and enforcement procedures. For commercial and industrial products, DOE is primarily responsible for labeling requirements. Subject to certain criteria and conditions, DOE is required to develop test procedures to measure the energy efficiency, energy use, or estimated annual operating cost of each covered product. (42 U.S.C. 6295(o)(3)(A) and 6314) Manufacturers of covered products must use the prescribed DOE test procedure as the basis for certifying to DOE that their products comply with the applicable energy conservation standards adopted under EPCA and when making representations to the public regarding the energy use or efficiency of those products. (42 U.S.C. 6293(c), 6295(s) and 6316(a)) Similarly, DOE must use these test procedures to determine whether the products comply with standards adopted pursuant to EPCA. (42 U.S.C. 6295(s) and 6316(a)) There are currently no DOE test procedures for compressors. DOE issued a test procedure NOPR for Compressors in April 2016. Upon finalization, any DOE test procedure for compressors will appear at title 10 of the Code of Federal Regulations (CFR) part 431, subpart T, appendix A.

DOE follows specific statutory criteria for prescribing new or amended standards for covered equipment, including compressors. Any new or amended standard for a covered product must be designed to achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. (42 U.S.C. 6316(a), and 6295(o)(2)(A) and (3)(B)) Furthermore, DOE may not adopt any standard that would not result in the significant conservation of energy. (42 U.S.C. 6295(o)(3) and 6316(a)) Moreover, DOE may not prescribe a standard: (1) For certain products, including compressors, if no test procedure has been established for the product, or (2) if DOE determines by rule that the standard is not technologically feasible or economically justified. (42 U.S.C. 6295(o)(3)(A)–(B) and 6316(a)) In deciding whether a proposed standard is economically justified, DOE must determine whether the benefits of the standard exceed its burdens. (42 U.S.C. 6295(o)(2)(B)(i) and 6316(a)) DOE must make this determination after receiving comments on the proposed standard, and by considering, to the greatest extent practicable, the following seven statutory factors:

(1) The economic impact of the standard on manufacturers and consumers of the products subject to the standard;

(2) The savings in operating costs throughout the estimated average life of the covered products in the type (or class) compared to any increase in the price, initial charges, or maintenance expenses for the covered products that are likely to result from the standard;

(3) The total projected amount of energy (or as applicable, water) savings likely to result directly from the standard;

(4) Any lessening of the utility or the performance of the covered products likely to result from the standard;

(5) The impact of any lessening of competition, as determined in writing by the Attorney General, that is likely to result from the standard;

(6) The need for national energy and water conservation; and

(7) Other factors the Secretary of Energy considers relevant. (42 U.S.C. 6295(o)(2)(B)(i)(I)–(VII) and 6316(a))

Further, EPCA, as codified, establishes a rebuttable presumption that a standard is economically justified if the Secretary finds that the additional cost to the consumer of purchasing a product complying with an energy conservation standard level will be less than three times the value of the energy savings during the first year that the consumer will receive as a result of the standard, as calculated under the applicable test procedure. (42 U.S.C. 6295(o)(2)(B)(iii) and 6316(a))

EPCA, as codified, also contains what is known as an ''anti-backsliding'' provision, which prevents the Secretary from prescribing any amended standard that either increases the maximum allowable energy use or decreases the minimum required energy efficiency of a covered product. (42 U.S.C. 6295(o)(1) and 6316(a)) Also, the Secretary may not prescribe an amended or new standard if interested persons have established by a preponderance of the evidence that the standard is likely to result in the unavailability in the United States in any covered product type (or class) of performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as those generally available in the United States. (42 U.S.C. 6295(o)(4) and 6316(a))

Additionally, 42 U.S.C. 6295(q)(1) and 6316(a) specifies requirements when promulgating an energy conservation standard for a covered product that has two or more subcategories. DOE must specify a different standard level for a type or class of product that has the same function or intended use, if DOE determines that products within such group: (A) Consume a different kind of energy from that consumed by other covered products within such type (or class); or (B) have a capacity or other performance-related feature which other products within such type (or class) do not have and such feature justifies a higher or lower standard. (42 U.S.C. 6295(q)(1) and 6316(a)) In determining whether a performance-related feature justifies a different standard for a group of products, DOE must consider such factors as the utility to the consumer of the feature and other factors DOE deems appropriate. *Id.* Any rule prescribing such a standard must include an explanation of the basis on which such higher or lower level was established. (42 U.S.C. 6295(q)(2) and 6316(a))

Federal energy conservation requirements generally supersede State laws or regulations concerning energy conservation testing, labeling, and standards. (42 U.S.C. 6297(a)–(c) and 6316(a)) DOE may, however, grant waivers of Federal preemption for particular State laws or regulations, in accordance with the procedures and other provisions set forth under 42 U.S.C. 6297(d) and 6316(a)).

B. Background

1. Current Standards

DOE does not currently have a test procedure or energy conservation standard for compressors. In considering whether to establish standards for compressors, DOE issued a Proposed Determination of Coverage on December 31, 2012. 77 FR 76972.

2. History of Standards Rulemaking for Compressors

DOE initiated its rulemaking efforts to examine the possibility of setting energy conservation standards for compressors by publishing a notice that announced the availability of a framework document and a public meeting to discuss that document and invite comment from interested parties.[13] 79 FR 06839. The Framework Document described the procedural and analytical approaches that DOE anticipated using to evaluate energy conservation standards for compressors, and also identified and solicited comment on various issues to be resolved in the rulemaking. DOE held that public meeting on March 3, 2014. Comments received both in response to the Framework Document and public meeting are discussed later in this document. In April 2016, DOE published a Notice of Proposed Rulemaking to address a potential test procedure for compressors.[14]

III. General Discussion

DOE developed this proposal after considering verbal and written comments, data, and information from interested parties representing a variety of interests. The following discussion addresses issues raised by these commenters. Commenters, are listed in Table III.1.

TABLE III.1—COMMENTERS AND AFFILIATION

Commenter	Affiliation
Air-Conditioning, Heating, and Refrigeration Institute	Trade Association.
American Council for an Energy Efficient Economy	Advocacy Organization.
Appliance Standards Awareness Project	Advocacy Organization.
Association of Equipment Manufacturers	Trade Association.
Atlas Copco	Manufacturer.
California Investor Owned Utilities (Pacific Gas and Electric Company, San Diego Gas, Southern California Edison)	Utility Association.
Compressed Air and Gas Institute	Trade Association.
Edison Electric Institute	Utility Association.
G.H.S. Corporation (parent to Saylor-Beall and Sullivan-Palatek)	Manufacturer.
Ingersoll-Rand	Manufacturer.
Jenny Products, Inc	Manufacturer.
Kaeser Compressors	Manufacturer.
Natural Resource Defense Council	Advocacy Organization.
Northwest Energy Efficiency Alliance	Utility Association.
Southern California Gas Company	Utility.
Sullair Distributor Council	Manufacturer.
Sullair, LLC	Manufacturer.
William Scales, P.E	Consultant.

A. Definition of Covered Equipment

Although compressors are listed as one type of industrial equipment under 42 U.S.C. 6311(2) that DOE may regulate provided certain conditions are met, the term ''compressor'' is not defined in EPCA. In the Framework Document, DOE introduced a possible a definition for ''compressor'' which centered on a mechanical device that uses a pressure ratio of 1.1.[15] This value had the possible advantage of consistency with International Organization for Standardization (ISO) Technical Report 12942:2012, ''Compressors—Classification—Complementary information to ISO 5390'' (ISO/TR 12942:2012).

In response to the Framework Document, the American Council for an Energy-Efficient Economy (ACEEE), the Appliance Standards Awareness Project (APSP), the Northwest Energy Efficiency Alliance (NEEA), and the Alliance to Save Energy (ASE) (hereafter referred to as the Joint Commenters), as well as the National Resources Defense Council (NRDC), and the California Investor Owned Utilities (CAIOU) recommended that, with respect to pressure-increase ratio, DOE take, as a lower limit for compressors, the upper limit (1.2) for Commercial and Industrial Fans and Blowers suggested in that equipment's 2013 Framework Document.[16] (Joint Comment, No. 0016 at p. 1; NRDC, No. 0019 at p. 1; CAIOU, No. 0018 at p. 2) The commenters noted that this would avoid creating a coverage gap, wherein certain air processing equipment would be uncovered if its pressure ratio fell between the respective scope limit of fans/blowers and compressors. (Docket No. EERE–2013–BT–STD–0006) DOE agreed that no gap in coverage should exist between this and the fans and blowers rulemaking and proposed a definition for ''compressor'' with a pressure ratio of 1.3 in the test procedure NOPR as follows:

''Compressor'' means a machine or apparatus that converts different types of energy into the potential energy of gas pressure for displacement and compression of gaseous media to any higher pressure values above

[13] Available at: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0002*.

[14] Available at: *https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/78*.

[15] DOE has previously used both the terms ''pressure ratio'' and ''pressure-increase ratio'' to refer to the ratio of absolute discharge pressure to absolute inlet pressure. DOE notes that, while it considers the terms to mean the same thing, only ''pressure ratio'' will be used in this document in order to preserve clarity.

[16] *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0006-0001*.

atmospheric pressure and has a pressure ratio[17] greater than 1.3.

In order to objectively and unambiguously determine which equipment meets the definition of ''compressor,'' DOE also proposed, in the test procedure NOPR, a definition of the term ''pressure ratio'' as ''the ratio of discharge pressure to inlet pressure, determined at full-load operating pressure . . .'' Such a definition allows DOE to quantitatively establish which equipment meet the pressure ratio requirement proposed in the definition of compressor.

This definition of ''pressure ratio'' relies on the terms discharge pressure and inlet pressure. Definitions for these, and several other technical terms specific to testing of compressors are established in of ISO 1217:2009 and DOE proposed in the test procedure NOPR to adopt those definitions as part of incorporating by reference certain portions of ISO 1217:2009.

B. Scope of the Energy Conservation Standards in This Rulemaking

DOE notes that while the definition of ''compressor,'' as proposed in the test procedure NOPR, is broad, the styles of compressors to which the proposed test procedure applies would be limited to a more narrow range of equipment. Specifically, after consideration of feedback from interested parties, as well as DOE research, DOE limited the scope of analysis of this document to compressors that meet the following criteria:

- Are air compressors, as described in section III.B.1,
- Are rotary or reciprocating compressors, as described in section III.B.3,
- Are driven by a brushless electric motor, as described in section III.B.4,
- Are distributed in commerce with a compressor motor nominal horsepower greater than or equal to 1 and less than or equal to 500 horsepower (hp), as described in section III.B.4, and
- Operate at a full-load operating pressure of greater than or equal to 31 and less than or equal to 225 pounds per square inch gauge (psig), as defined in section III.B.6.

DOE notes that ultimately, based on the results of the analyses performed for this NOPR, DOE does not propose to establish energy conservation standards for reciprocating compressors in this document. Section V provides further details on this decision. Consequently, the complete scope of the energy conservation standards proposed in this rulemaking is as follows:

- Are air compressors, as described in section III.B.1,
- Are rotary compressors, as described in section III.B.3,
- Are driven by a brushless electric motor, as described in section III.B.4,
- Are distributed in commerce with a compressor motor nominal horsepower greater than or equal to 1 and less than or equal to 500 horsepower (hp), as described in section III.B.4, and
- Operate at a full-load operating pressure of greater than or equal to 31 and less than or equal to 225 pounds per square inch gauge (psig), as defined in section III.B.6.

The following subsections discuss interested party comments related to the DOE's scope of analysis and ultimate scope of proposed energy conservation standards.

1. Equipment System Boundary

In the Framework Document, DOE discussed three separate boundary levels of compressor equipment—''bare'' compressor, compressor ''package,'' and compressed air system (CAS)—and requested comment regarding the feasibility of covering each boundary level of compressor equipment. Saylor-Beall commented that ''while it might be possible to rate the air compressor package, attention needs to be given to the entire compressed air system of the end user;'' whereas, Jenny Compressors (''Jenny'') stated that ''covering the entire 'CAS' may prove nearly impossible since many systems include components from many different manufacturers, and no two systems are the same.'' (Saylor-Beall, No. 0003 at p. 2; Jenny, No. 0005 at p. 2) Compressed Air and Gas Institute (CAGI) and the Joint Commenters agreed that DOE should cover the compressor package as part of this rulemaking. (CAGI, No. 0009 at p. 3; Joint Comment, No. 0016 at p. 2) the Joint Commenters also stated that, if DOE covers the package, DOE would need to ensure companies that assemble packages from purchased components are also covered under this rulemaking. (Joint Comment, No. 0016 at p. 2–3) In this NOPR, DOE proposes to align with the scope of applicability of the test procedure NOPR and cover the compressor ''package.'' DOE considers covering a ''bare'' compressor to represent significantly lower energy savings compared to the other two compressor equipment levels. DOE also understands that, while the CAS represents the largest available energy savings, covering the CAS has significant drawbacks that weigh against its adoption as the basis for an equipment classification for the following reasons:

- Each CAS is often unique to a specific installation;
- Each CAS may include equipment from several different manufacturers; and
- A single CAS can include several different compressors, of different types, which may all have different full-load operating pressures.

Implementing a broader, CAS-based approach to compressor efficiency would require DOE to (1) establish a methodology for measuring losses in a given air-distribution network; and (2) assess what certification, compliance, or enforcement practices would be required for a large variety of system designs, and potential waiver criteria. For these reasons, DOE does not believe the CAS to be a viable equipment classification for coverage and proposes to cover only compressor ''packages.''

In the test procedure NOPR, DOE proposed to use the following definition for ''air compressor,'' which is based on the concept of a compressor package and borrows language from the definitions used by the European Union's (EU) Lot 31 Ecodesign Study on Compressors (''Lot 31 Study,'' discussed further in section IV.A.2):

''Air compressor'' means a compressor designed to compress air that has an inlet open to the atmosphere or other source of air, and is made up of a compression element (bare compressor), driver(s), mechanical equipment to drive the compressor element, and any ancillary equipment.

Also in the test procedure NOPR, DOE proposed the following definitions which give meaning to terms used in the definition of ''air compressor'':

''Bare compressor'' means the compression element and auxiliary devices (*e.g.,* inlet and outlet valves, seals, lubrication system, and gas flow paths) required for performing the gas compression process, but does not include the driver; speed-adjusting gear(s); gas processing apparatuses and piping; or compressor equipment packaging and mounting facilities and enclosures.[18]

''Driver'' means the machine providing mechanical input to drive a

[17] DOE proposes to use terminology consistent with ISO 1217:2009 in describing the ratio of discharge to inlet pressures as ''pressure ratio,'' as opposed to ''pressure-increase ratio,'' which is the term used in some other industry documents. However, for the purpose of this document ''pressure-increase ratio'' and ''pressure ratio'' are synonymous.

[18] The compressor industry frequently uses the term ''air-end'' or ''air end'' to refer to the bare compressor. DOE uses ''bare compressor'' in the regulatory text of this proposed rule but clarifies that, for the purposes of this rulemaking, it considers the terms to be synonymous.

bare compressor directly or through the use of mechanical equipment.

''Mechanical equipment'' means any component of an air compressor that transfers energy from the driver to the bare compressor.

''Ancillary equipment'' means any equipment distributed in commerce with an air compressor that is not a bare compressor, driver, or mechanical equipment. Ancillary equipment is considered to be part of a given air compressor, regardless of whether the ancillary equipment is physically attached to the bare compressor, driver, or mechanical equipment at the time when the air compressor is distributed in commerce.

DOE seeks comment on its proposal to limit the scope of energy conservation standard proposed in this document to only equipment that is made up of a compression element (bare compressor), driver(s), mechanical equipment to drive the compressor element, and any ancillary equipment (*i.e.,* a ''packaged compressor''), through the use of the defined term, ''air compressors.'' This is identified as Issue 2 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

2. Compressed Gas

Broadly, compressors are used to compress a wide variety of gases. In the Framework Document,[19] DOE requested comment on limiting the scope to only ''air compressors'' and stated that information gathered to that point indicated that non-air compressing equipment accounted for a relatively small fraction of the overall compressors market, in terms of both shipments and annual energy consumption. DOE received conflicting feedback on the topic from stakeholders. The Edison Electric Institute (EEI) recommended covering all compressor types regardless of gas type because natural gas compressor energy use is projected to increase, while CAGI agreed that DOE should cover only air compressors. (EEI, No. 0012 at p. 1–2; CAGI, No. 0009 at p. 1) The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) requested that compressors used in heating, ventilation, and air-conditioning (HVAC) equipment be specifically excluded. (AHRI No. 0015, at p. 1)

After the publication of the Framework Document, DOE announced several new initiatives to modernize the country's natural gas transmission and distribution infrastructure, including one to explore establishing efficiency standards for natural gas compressors.[20] As part of that effort, DOE's Appliance Standards Program published a Request for Information (RFI), on August 5, 2014, to help determine both the feasibility of energy conservation standards for natural gas compressors and whether they are similar enough to air compressors to be considered within the scope of this rulemaking. 79 FR 25377. Additionally, DOE announced the availability of some preliminary, high-level description of the market and technology for natural gas compressors. DOE also published a notice of public meeting [21] (NOPM), held on December 17, 2014, to present and seek comment on the content of that data. Based upon the feedback received from the RFI, NOPM, and public meeting, DOE opted to consider natural gas compressors separately from air compressors. (Docket No. EERE–2014–BT–STD–0051)

Regarding refrigerant compressors, DOE considers refrigerant compressors to have the same basic function as air compressors in that they both compress a working fluid to a higher pressure, but with the working fluid of refrigerant compressors being refrigerant instead of air. Refrigerant compressors are usually only included in equipment where cooling or heating is required, such as heating, ventilation, air-conditioning and refrigeration (HVACR) equipment. Similar to natural gas compressors, DOE has determined that refrigerant compressors serve a specific and unique application and also necessitate unique standards. As a result, DOE has opted not to consider refrigerant compressors in this rulemaking.

Furthermore, DOE's research found no large market segments or applications for compressor equipment used on gases other than air or natural gas. Information gathered during confidential manufacturer interviews indicated that non-air and non-natural gas compressing equipment represented relatively low sales volume and annual energy consumption.

Because air compressors comprise a significant portion of the compressor market and DOE intends to consider natural gas equipment as part of a separate rulemaking,[22] DOE proposes to consider standards for only air compressors in this rulemaking. DOE believes that compressors for other fluids serve different applications and are technically very different equipment than air compressors. As a result, compressors for gases other than air would likely require separate test procedures and energy conservation standards analyses. Consequently, DOE proposes to align with the scope of applicability of the test procedure NOPR, and limit the scope of energy conservation standards to only compressors that are designed to compress air and that have inlets open to the atmosphere or other source of air, through the use of the defined term, ''air compressors.'' As discussed in Section III.B.1, DOE proposed a definition for the term ''air compressor'' in the test procedure NOPR.

DOE seeks comment on its proposal to limit the scope of energy conservation standard proposed in this document to only compressors that are designed to compress air and that have inlets open to the atmosphere or other source of air, through the use of the defined term, ''air compressors.'' This is identified as Issue 3 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

3. Compression Principle

Compressor equipment can be classified by compression principle, and on that basis can include dynamic compressors, rotary compressors, and reciprocating compressors. In the Framework Document, DOE offered definitions for each:

''Dynamic compressor'' means ''a compressor in which the gas pressure increase is achieved in continuous flow essentially by increasing its kinetic energy in the flow path of the machine due to acceleration to the high velocities by mechanical action of blades placed on a rapid rotating wheel and further transformation of the kinetic energy into the potential energy of the elevated pressure by successive deceleration of the said flow.'' The definition for dynamic compressor is consistent with the definition included in ISO/TR 12942:2012 and aligns with industry standards.

''Rotary compressor'' means ''a positive displacement compressor in which gas admission and diminution of its successive volumes or its forced discharge are performed cyclically by rotation of one or several rotors in a compressor casing.'' The definition for rotary compressor is consistent with the definition included in ISO/TR 12942:2012 and aligns with industry standards.

''Reciprocating compressor'' means ''a positive displacement compressor in which gas admission and diminution of its successive volumes are performed

[19] Available at: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0001.*

[20] See: *http://energy.gov/articles/department-energy-announces-steps-help-modernize-natural-gas-infrastructure.*

[21] Available at: *http://www.regulations.gov/?s#!documentDetail;D=EERE-2014-BT-STD-0051-0005.*

[22] Docket viewable here: *http://www.regulations.gov/#!docketDetail;D=EERE-2014-BT-STD-0051.*

cyclically by straight-line alternating movements of a moving member(s) in a compression chamber(s).'' The definition for reciprocating compressor is consistent with the definition included in ISO/TR 12942:2012 and aligns with industry standards.

DOE's test procedure NOPR proposes those definitions for ''rotary compressor,'' and ''reciprocating compressor,'' and added a proposed definition for ''positive-displacement compressor.'' The test procedure NOPR did not propose a definition for ''dynamic compressor,'' as no test methods were proposed for equipment commonly referred to as ''dynamic compressors.'' In the test procedure NOPR, the term ''positive-displacement compressor'' is proposed to mean ''a compressor in which the admission and diminution of successive volumes of the gaseous medium are performed periodically by forced expansion and diminution of a closed space(s) in a working chamber(s) by means of displacement of a moving member(s) or by displacement and forced discharge of the gaseous medium into the high-pressure area.''

In response to the Framework Document, several stakeholders agreed that DOE should cover all three compressor types. (Joint Comment, No. 0016 at p. 2; CAGI, No. 0009 at p. 1) Scales commented that DOE should focus on centrifugal and rotary screw compressors above 350–hp. (W. Scales, No. 0020 at p. 1) DOE also received annual shipments data in industry stakeholder submittals. This shipments data are discussed in detail in section IV.G. DOE used these data to estimate the overall size of the air compressors market. The shipments data for 2013 provided to DOE suggest that rotary and reciprocating compressors account for the majority of the air compressors market by units shipped. By contrast, dynamic compressors account for fewer than 300 total units shipped, or roughly one percent of the total market.

DOE research indicated that dynamic compressors are typically larger in power than positive displacement compressors, and commonly engineered specifically for an order. Due to specialization and size, little cost and performance data are publicly available, as both will vary from unit to unit. Further, DOE found that the standard international test procedure for dynamic compressors, ISO 5389, was considered complicated and not widely used by industry. This fact may also contribute to the general lack of publicly available performance data.

Due to the lack of available data and relatively small market share of dynamic compressors, DOE did not include dynamic compressors within the scope of analysis of this energy conservation standards rulemaking; rather, DOE aligned with the scope of applicability of the test procedure NOPR, and analyzed and considered standards for rotary and reciprocating compressors. Although DOE considered reciprocating compressors within its scope of analysis, based on the results of DOE's analyses, DOE does not propose to establish standards for reciprocating compressors in this document. Consequently, in this NOPR, DOE proposes to establish energy conversation standards for only rotary compressors. Section V of this document provides further details on this decision. DOE notes that it may explore in the future whether standards for reciprocating or dynamic compressors are warranted.

4. Driver Type

Compressors can be powered using several types of drivers, commonly including electric motors and internal combustion engines. Electric motor-driven equipment may use either single-phase or three-phase electric motors. Combustion engine-driven air compressors can be powered by using different kinds of fuels, commonly including diesel, gasoline, and natural gas. In the Framework Document, DOE considered establishing standards for compressors regardless of driver type and requested stakeholder comments.

a. Combustion Engines

DOE received varying comments regarding the inclusion of combustion engine [23] driven compressors. Jenny, the Association of Equipment Manufacturers (AEM), and Sullair recommended excluding engine-driven compressors due to the burden imposed by current emissions regulations and overall low energy consumption by these products. (Jenny, No. 0005 at p. 2; AEM, No. 0011 at p. 1–2; Sullair, No. 0013 at p. 2) EEI and the CAIOU urged DOE to include engine-driven compressors to avoid creating a market trend towards engine-driven compressors. (EEI, No. 0012 at p. 2–3; CAIOU, No. 0018 at p. 2) The Joint Commenters recommended that DOE examine engine-driven compressors to evaluate possible energy savings but noted that generally they are used in low-duty cycle applications. (Joint Comment, No. 0016 at p. 2)

Engine-driven air compressors are generally portable and designed to be used in environments where access to electricity is limited or non-existent, particularly at the current or voltage levels required by comparable electric motor-driven compressors. Engine-driven compressors are also typically used as on-demand units, with a low duty cycle and annual energy consumption. Additionally, engine-driven compressors, by nature of their portability, are less able to be optimized for a specific set of operating conditions, which may harm efficiency relative to a stationary unit that is designed or selected with a specific load profile in mind. Consequently, engine-driven and electric motor-driven compressors do not serve the same applications and are not mutual substitutes.

DOE is aware that engine-driven compressors are currently covered by the Environmental Protection Agency's Tier 4 emissions regulations (40 CFR 1039).[24] DOE understands that these Tier 4 regulations have resulted in market-wide redesigns for the engines typically used in these compressors, which has required compressor manufacturers to redesign some of their own equipment. Based on the relatively lower annual energy consumption, non-overlapping applications of motor- and engine-driven equipment, and potentially competing priorities between current emissions regulations and potential energy conservation standards, DOE proposes to align with the scope of applicability of the test procedure NOPR and not include engine-driven equipment in the scope of this energy conservation standards this rulemaking. DOE may explore in the future whether standards for engine-driven units are warranted.

b. Motor Phase Count

In the Framework Document, DOE also considered excluding single-phase electric motor-driven equipment. Stakeholders generally agreed with excluding these products. (Saylor-Beall, No. 0003 at p. 2; CAGI, No. 0009 at p. 3; Joint Comment, No. 0016 at p. 2). Other stakeholders commented that compressors under 10-hp are generally packaged with single-phase electric motors. (CAGI, No. 0009 at p. 3; Jenny, No. 0005 at p. 2). Saylor-Beall commented that, particularly for compressors under 5-hp, three-phase shipment volumes are low. (Saylor-Beall, No. 0003 at p. 2) The Lot 31 Study estimated that single-phase compressors in the EU represent less than one

[23] For the purposes of this document, the term ''engine'' means ''combustion engine,'' equipment which can convert chemical energy into mechanical energy by combusting fuel in the presence of air.

[24] See also: *http://www.epa.gov/otaq/nonroad-diesel.htm.*

percent of total compressor annual energy consumption. DOE research suggests that the U.S. compressors market exhibits similar trends.

However, DOE is aware that some reciprocating compressors can be packaged with either single- or three-phase electric motors. Establishing energy conservation standards for only one variation of a shared platform (*e.g.,* three-phase motor-driven reciprocating compressors) could create a market shift towards less efficient single-phase motor-driven reciprocating compressors. Consequently, in this document, DOE analyzed energy conservations standards for both single-phase and three-phase reciprocating compressors. Ultimately, based on the results of its analyses, DOE does not propose to establish standards for either single- or three-phase motor-driven reciprocating compressors in this document.

For rotary compressors, DOE understands that a very small fraction of the market may be shipped as single-phase. DOE currently has no data on the performance of single-phase rotary equipment. If the applicable single-phase motors are less efficient than their three-phase counterparts, it is possible that single-phase compressor packages may be less efficient as well.

In the absence of more information on the relative cost and efficiency of single- and three-phase compressors, DOE wishes to avoid the risk of a substitution incentive. As a result, DOE proposes, in this document, to consider standards for single-phase and three-phase rotary compressors in this rulemaking.

DOE requests comment on its proposal to consider standards for both single- and three-phase compressor equipment. DOE also requests comment on any market trends that may affect the efficiency of such equipment in the future. DOE requests data that may aid in characterizing the relative cost and performance of equipment of different motor phase counts, so that DOE can better evaluate whether a substitution incentive is likely to be created. This is identified as Issue 4 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

c. Styles of Electric Motor

DOE is aware that some small compressors intended for very low duty-cycles may be manufactured with motors which use sliding electric contacts, or ''brushes.'' Although brushes are simple to control and inexpensive to construct, they are rarely used in applications with significant operating hours, for several reasons. First, brushes generally impose a reduction in efficiency, relative to brushless technology, and are thereby suitable only for applications with low duty cycles. Second, brushes wear and require replacement at regular intervals, which may pose risk of inducing costly downtime in an industrial process. Third, brushes may create electrical arcing, rendering them unsuitable for certain industrial environments where combustible or explosive gases or dust may exist. Finally, brushes may create greater acoustic noise than brushless technology, which can be viewed as a form of utility to the end user.

All of these factors limit the applications for which any compressors distributed in commerce with brushed motors are suitable. However, DOE recognizes the applications for which brushed motors are appropriate as a unique market segment serving specific applications where, in particular, operating life and durability are not important criteria.

DOE also notes that compressors sold with brushed motors play a niche role in the market and, as a result, DOE does is electing to focus on the dominant brushless motor technology in developing the energy conservation standards proposed herein. Consequently, DOE proposes to align with the scope of applicability of the test procedure NOPR, and limit the scope of energy conservation standards to only those compressors that are driven by brushless motors.[25] DOE may consider energy conservation standards for compressors sold with brushed electric motors as part of a separate, future, rulemaking, if it determines such actions are warranted.

5. Equipment Capacity

Compressors are sold in a very wide range of capacities. Compressor capacity refers to the overall rate at which a compressor can perform work. Although the ultimate end-user requirement is a specific output volume flow rate of air at a certain pressure, industry typically describes compressor capacity in terms of the ''nominal'' horsepower of the motor. As a result, in the test procedure NOPR, DOE proposed to consider equipment capacity in terms of the ''nominal'' horsepower of the motor with which the compressor is distributed in commerce.

[25] In the test procedure NOPR, DOE proposed to define ''brushless electric motor'' as a machine that coverts electrical power into rotational mechanical power without use of sliding electrical contacts.'' DOE considers ''brushless'' motors to include, but not be limited to, what are commonly known as ''induction,'' ''brushless DC,'' ''permanent magnet,'' ''electrically commutated,'' and ''reluctance'' motors. The term ''brushless'' motors would not include what are commonly known as ''brushed DC'' and ''universal'' motors.

However, DOE recognizes that although the term nominal motor horsepower is commonly used within the compressor industry, it is not explicitly defined in ISO 1217:2009. To alleviate any ambiguity associated with these terms, DOE proposed in the test procedure NOPR to define the term ''compressor motor nominal horsepower'' to mean the motor horsepower of the electric motor, as determined in accordance with the applicable procedures in subpart B and subpart X of 10 CFR 431, with which the rated compressor is distributed in commerce.

In the Framework Document, DOE discussed limiting the scope of applicability based on equipment capacity as measured in horsepower (hp) to units with capacities of between 1 to 500 hp in order to align the scope of compressor standards with the scope of DOE's electric motors standards. *See* 10 CFR 431.25. Commenters generally recommended expanding the scope to cover compressors larger than 500 hp, in order to capture the maximum possible energy savings. (EEI, No. 0012 at p. 3; Joint Comment, No. 0016 at p. 2; Natural Resource Defense Council (NRDC), No. 0019 at p. 1; CA IOUs, No. 0018 at p. 2) Jenny and the Joint Commenters also recommended that the lower hp limit should be increased due to the low annual energy usage of compressors under 10 hp. (Jenny, No. 0005 at p. 3; Joint Comment, No. 0016 at p. 2)

DOE considered the comments of interested parties regarding the range of equipment capacities. Shipment data, broken down by rated capacity and compression principle (*i.e.,* rotary, reciprocating, and dynamic) indicate that units above 400 hp represent less than 1 percent of the rotary market and virtually none of the reciprocating market. Although it is possible to build positive displacement compressors above 500 hp, shipments are very low and the equipment is typically custom-ordered. DOE notes that, above 500 hp, dynamic compressors are the dominant choice for industrial compressed air service. Furthermore, as discussed in section III.B.3, little performance data is available on units with capacities greater than 500 hp. Due to this lack of data and the small market share for positive displacement compressors with capacities greater than 500 hp, DOE proposes to align with the scope of applicability of the test procedure NOPR and limit the scope of this energy conservation rulemaking to compressors with a compressor motor nominal horsepower of greater than or equal to 1 and less than or equal to 500 hp. Based on available shipment data, DOE's proposal is expected to cover nearly the entirety of the rotary and reciprocating compressor market.

DOE requests comment on the proposal to include only compressors with a compressor motor nominal horsepower of greater than or equal to 1 and less than or equal to 500 within the scope of this energy conservation standard. This is identified as Issue 5 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

6. Full-Load Operating Pressure

Because different compressed air applications require air to be delivered at specific pressure ranges, output pressure is a critical characteristic in equipment selection and compressed air system design. DOE notes that there may be several ways to characterize output pressure. In the test procedure NOPR, DOE proposed to use ''full-load operating pressure'' as the most relevant metric, where ''full-load operating pressure'' is a declared pressure, which must be greater than or equal to 90 percent and less than or equal to 100 percent of the maximum full-flow operating pressure.

The test procedure NOPR also proposed a definition and test method for finding ''maximum full-flow operating pressure,'' which is a term needed to characterize ''full-load operating pressure.'' DOE proposed that ''maximum full-flow operating pressure'' means the maximum discharge pressure at which the compressor is capable of operating.

Industry convention holds that when output pressure is cited absolutely or in ''gauge'' (*i.e.,* not as a ratio), the input pressure is assumed to be that at which a compressor would ingest ambient air at sea level.[26] ''Gauge'' pressure, whether given in U.S. or metric units, normally means ''the amount above intake pressure.'' A compressor described as delivering 100 psig,[27] then, can be assumed to produce 114.7 psi in absolute terms when operated in a standard atmosphere. Gauge pressure is commonly used because for most purposes, the pressure differential is more critical to the application than the absolute measurement. Another commonly-used pressure descriptor is ''pressure ratio.'' Simply, it is the ratio of the absolute output (discharge) and absolute input (suction) pressures. For compressors operating in the same conditions, this value expresses identical information.

In response to discussions of operating pressure in the Framework Document, CAGI provided the following detailed breakdown of output pressures in the rotary compressors market. (CAGI, No. 0030 at p. 4):

• Approximately 4.4 to 30 pounds per square inch gauge (psig) (pressure ratio greater than 1.3 and less than or equal to 3.0): The compressors industry generally refers to these products as blowers—a term DOE is considering defining as part of its fans and blowers rulemaking (Docket No. EERE–2013–BT–STD–0006). The majority of these units are typically distributed in commerce as bare compressors and do not include a driver, mechanical equipment, or controls.

• 31 to 79 psig (pressure ratio greater than 3.1 and less than or equal to 6.4): There are relatively few compressed air applications in this pressure range, contributing to both low product shipment volume and low annual energy consumption.

• 80 to 139 psig (pressure ratio greater than 6.4 and less than or equal to 10.5): This range represents the majority of general compressed air applications, shipments, and annual energy use.

• 140 to 215 psig (pressure ratio greater than 10.5 and less than or equal to 15.6): This range represents certain specialized applications, relatively lower sales volumes and annual energy consumption when compared to the 80 to 139 psig rotary compressor segment.

• Greater than 215 psig (pressure ratio greater than 15.6): This range represents even more specialized applications, which require highly engineered rotary compressors that vary based on each application.

DOE did not receive any additional information that separated the market of reciprocating compressors by pressure. According to the Lot 31 preparatory study final report,[28] single- and two-stage reciprocating compressors typically operate from 0.8 to 12 bar (12 to 174 psig; pressure ratio 1.8 to 13), and multi-stage reciprocating compressors typically operate from 12 to 700 bar (174 to 10,152 psig; pressure ratio 13 to 701). However, based on market research and discussions with various compressor manufacturers, DOE believes that pressure ranges for reciprocating compressors are similar to rotary compressors.

In the test procedure NOPR, DOE proposed defining a ''compressor'' as equipment with a pressure ratio exceeding 1.3. Furthermore, in the test procedure NOPR, DOE proposed that the test procedure only be applicable to compressors with full-load operating pressures greater than or equal to 31 psig and less than or equal to 225 psig. In this document, DOE proposes to align with the scope of applicability of the test procedure NOPR, and limit the scope of energy conversation standards to compressors with full-load operating pressures of between 31 and 225 psig (pressure ratios greater than ~3.1 and less than or equal to 16.3). DOE notes that while some commenters suggested an upper limit of 215 psig, full-load operating pressure values may be generated differently by each manufacturer and it is not clear that they are completely comparable between manufacturers.[29] For example, a product listed at 215 psig from one manufacturer may compete with a product listed at 217 psig from another, which may compete with one listed at 212 psig from a third. Although DOE's proposed test procedure seeks to eliminate this issue, DOE must still account for the current lack of consistent pressure rating methodology in the compressor industry. As a result, DOE proposes to adopt an upper limit of 225 psig to include the majority of non-special purpose equipment DOE could identify on the market. Compressor equipment with full-load operating pressures below 31 psig and above 225 psig generally represent a different equipment type and serve applications that do not often overlap with the 31–225 psig compressor market, and do not represent a significant volume of sales.

C. Test Procedure

DOE is currently conducting a rulemaking to establish a uniform test procedure for determining the energy efficiency of compressors. DOE proposed a test method for calculating the package isentropic efficiency of compressors, by measuring the delivered power (in the form of compressed air) and the electric input power to the motor or controls. DOE proposed that the methods be based on International Organization for Standardization (ISO) Standard 1217:2009, ''Displacement

[26] Commonly approximated in pounds per square inch (psi) as 14.7.

[27] *i.e.,* psi in gauge terms.

[28] The European Union regulatory body is also exploring standards for compressors, which is part of a product group which it refers to as ''Lot 31.'' For copies of the EU Lot 31 Final Report of a study on Compressors please go to: *www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.* For copies of the EU Lot 31 draft regulation: *www.regulations.gov/contentStreamer?documentId=EERE-2013-BT-STD-0040-0031&disposition=attachment&contentType=pdf.*

[29] DOE notes that there is no universally accepted procedure for establishing full-load operating pressure and, thus, no assurances that values are comparable.

compressors—Acceptance tests,'' (hereinafter referred to as ''ISO 1217:2009'') with modifications. In response to the Framework, Jenny recommended that compressors not be separated based on rated horsepower, as they do not always run at full horsepower. (Jenny, No. 0005 at p. 2) The Joint Commenters recommended that a metric using both package specific power [30] and package isentropic efficiency be used to provide useful information for consumers. (Joint Comment, No. 0016 at p. 3)

In the test procedure NOPR, DOE proposed that the energy conservation standards for compressors be expressed in terms of fixed-speed package isentropic efficiency ($\eta_{isen,FS}$) for fixed-speed compressors and variable-speed package isentropic efficiency ($\eta_{isen,VS}$) for variable-speed compressors. The terms $\eta_{isen,FS}$ and $\eta_{isen,VS}$ describe the power required for an ideal isentropic compression process, divided by the actual input power of the packaged compressor. The $\eta_{isen,FS}$ considers this ratio at full-load operating pressure and $\eta_{isen,VS}$ considers this ratio at a weighted-average of full-load and part-load operating pressures. The metrics are defined in Equations 1 and 2 as follows:

$$\eta_{isen,FS} = \frac{P_{isen,FL}}{P_{real,FL}} \quad \textbf{Equation 1}$$

Where:

- $\eta_{isen,FS}$ is the package isentropic efficiency at full-load operating pressure;
- $P_{isen,FL}$ is the isentropic power required for compression at full-load operating pressure, as determined in accordance with the DOE test procedure. This metric applies only to fixed-speed compressors, and;
- $P_{real,FL}$ is the packaged compressor power input at full-load operating pressure, as tested in accordance with the DOE test procedure. This metric applies only to fixed-speed compressors.

$$\eta_{isen,VS} = \sum_{i=40\%,70\%,100\%} \omega_i \frac{P_{isen,i}}{P_{real,i}} \quad \textbf{Equation 2}$$

Where:

- $\eta_{isen,VS}$ is the package isentropic efficiency as applied to variable-speed compressors;
- $P_{isen,i}$ is the isentropic power required for compression at rating point i, as determined in accordance with the DOE test procedure. This metric applies only to variable-speed compressors;
- $P_{real,i}$ is the packaged compressor power input at rating point i, as tested in accordance with the DOE test procedure. This metric applies only to variable-speed compressors;
- ω_i is the weighting at each rating point, as described in the DOE test procedure; and
- *i* are the load points corresponding to 40-, 470-, and 100-percent of the full-load actual volume flow rate.

The measured value of package isentropic efficiency would then be compared to DOE's proposed energy conservation standard. A value greater than the proposed standard indicates that the compressor exceeds the minimum efficiency standard, while a value lower than the proposed standard indicates that the compressor fails to meet the proposed standard.

D. Technological Feasibility

1. General

In each energy conservation standards rulemaking, DOE conducts a screening analysis based on information gathered on all current technology options and prototype designs that could improve the efficiency of the products or equipment that are the subject of the rulemaking. As the first step in such an analysis, DOE develops a list of technology options for consideration in consultation with manufacturers, design engineers, and other interested parties. DOE then determines which of those means for improving efficiency are technologically feasible. DOE considers technologies incorporated in commercially-available products or in working prototypes to be technologically feasible. See, *e.g.,* 10 CFR part 430, subpart C, appendix A, section 4(a)(4)(i).

After DOE has determined that particular technology options are technologically feasible, it further evaluates each technology option in light of the following additional screening criteria: (1) Practicability to manufacture, install, and service; (2) adverse impacts on product utility or availability; and (3) adverse impacts on health or safety. See, *e.g.,* 10 CFR part 430, subpart C, appendix A, section 4(a)(4)(ii)–(iv). Additionally, DOE generally does not include in its analysis any proprietary technology that is a unique pathway to achieving a certain efficiency level. Section IV.B of this document discusses the results of the screening analysis for compressors, particularly with respect to the designs DOE considered, those it screened out, and those serving as the basis for the proposed standards being considered. For further details on the screening analysis for this rulemaking, see chapter 4 of the NOPR technical support document (TSD).

2. Maximum Technologically Feasible Levels

When DOE proposes to adopt a new standard for a type or class of covered product, it must determine the maximum improvement in energy efficiency or maximum reduction in energy use that is technologically feasible for such product. (42 U.S.C. 6295(p)(1) and 6316(a)) Accordingly, in the engineering analysis, DOE determined the maximum technologically feasible (''max-tech'') improvements in energy efficiency for compressors, using the design parameters for the most efficient products available on the market or in working prototypes. The max-tech levels that DOE determined for this rulemaking are described in section IV.C of this proposed rule and in chapter 5 of the NOPR TSD.

E. Compliance Date

DOE estimates that any final rule would publish in late 2016. Therefore, DOE has used an estimated compliance date for this rulemaking in late 2021.[31]

[30] In the test procedure NOPR, DOE proposes to define the term ''package specific power'' as ''the compressor power input at a given load point, divided by the actual volume flow rate at the same load point, as determined in accordance with the test procedures prescribed in § 431.344.''

[31] DOE's analysis begins in the first full year of compliance with new standards, 2022.

F. Energy Savings

1. Determination of Savings

For each trial standard level (TSL), DOE projected energy savings from applying the TSL to compressors purchased in the 30-year period that begins in the first full-year of compliance with the proposed standards (2022–2051).[32] The savings are measured over the entire lifetime of compressors purchased during this 30-year period. DOE quantified the energy savings attributable to each TSL as the difference in energy consumption between each standards case and the no-new-standards case. The no-new-standards case represents a projection of energy consumption that reflects how the market for a product would likely evolve in the absence of new energy conservation standards.

DOE used its national impact analysis (NIA) spreadsheet model to estimate national energy savings (NES) from potential for compressors. The NIA spreadsheet model (described in section IV.H of this document) calculates energy savings in terms of site energy, which is the energy directly consumed by products at the locations where they are used. Based on the site energy, DOE calculates NES)in terms of primary energy savings at the site or at power plants, and also in terms of full-fuel-cycle (FFC) energy savings. The FFC metric includes the energy consumed in extracting, processing, and transporting primary fuels (*i.e.,* coal, natural gas, petroleum fuels), and thus presents a more complete picture of the impacts of energy conservation standards.[33] DOE's approach is based on the calculation of an FFC multiplier for each of the energy types used by covered products or equipment. For more information on FFC energy savings, see section IV.H.1 of this document.

2. Significance of Savings

To adopt any new or amended standards for a covered product, DOE must determine that such action would result in ''significant'' energy savings. (42 U.S.C. 6295(o)(3)(B) and 6316(a)) Although the term ''significant'' is not defined in the Act, the U.S. Court of Appeals for the District of Columbia Circuit, in *Natural Resources Defense Council* v. *Herrington,* 768 F.2d 1355, 1373 (D.C. Cir. 1985), opined that Congress intended ''significant'' energy savings in the context of EPCA to be savings that were not ''genuinely trivial.'' The energy savings for all of the TSLs considered in this rulemaking, including the proposed standards (presented in section V), are nontrivial, and, therefore, DOE considers them ''significant'' within the meaning of section 325 of EPCA.

[32] Each TSL is comprised of specific efficiency levels for each product class. The TSLs considered for this NOPR are described in section V.A. DOE conducted a sensitivity analysis that considers impacts for products shipped in a 9-year period.

[33] The FFC metric is discussed in DOE's statement of policy and notice of policy amendment. 76 FR 51282 (Aug. 18, 2011), as amended at 77 FR 49701 (Aug. 17, 2012).

G. Economic Justification

1. Specific Criteria

As noted in this preamble, EPCA provides seven factors to be evaluated in determining whether a potential energy conservation standard is economically justified. (42 U.S.C. 6295(o)(2)(B)(i)(I)–(VII) and 6316(a)) The following sections discuss how DOE has addressed each of those seven factors in this rulemaking.

a. Economic Impact on Manufacturers and Consumers

DOE considers the economic impacts of its potential standards on both manufacturers and consumers. See 42 U.S.C. 6295(o)(2)(B)(i)(I) and 6316(a). In determining the impacts of a potential amended standard on manufacturers, DOE conducts a manufacturer impact analysis (MIA), as discussed in section IV.J. DOE first uses an annual cash-flow approach to determine the quantitative impacts. This step includes both a short-term assessment—based on the cost and capital requirements during the period between when a regulation is issued and when entities must comply with the regulation—and a long-term assessment over a 30-year period. The industry-wide impacts analyzed include: (1) Industry net present value (INPV), which values the industry on the basis of expected future cash flows; (2) cash flows by year; (3) changes in revenue and income; and (4) other measures of impact, as appropriate. Second, DOE analyzes and reports the impacts on different types of manufacturers, including impacts on small manufacturers. Third, DOE considers the impact of standards on domestic manufacturer employment and manufacturing capacity, as well as the potential for standards to result in plant closures and loss of capital investment. Finally, DOE takes into account cumulative impacts of various DOE regulations and other regulatory requirements on manufacturers.

For individual consumers, measures of economic impact include the changes in LCC and payback period (PBP) associated with new or amended standards. These measures are discussed further in the following section. For consumers in the aggregate, DOE also calculates the national net present value of the consumer costs and benefits expected to result from particular standards. DOE also evaluates the impacts of potential standards on identifiable subgroups of consumers that may be affected disproportionately by a standard.

b. Savings in Operating Costs Compared to Increase in Price (LCC and PBP)

DOE considers the savings in operating costs throughout the estimated average life of the covered equipment in the type (or class) compared to any increase in the price, initial charges, or maintenance expenses of that equipment that are likely to result from a standard. (42 U.S.C. 6295(o)(2)(B)(i)(II) and 6316(a)) DOE conducts this comparison in its LCC and PBP analysis.

The LCC is the sum of the purchase price of a product (including its installation) and the operating expense (including energy, maintenance, and repair expenditures) discounted over the lifetime of the product. The LCC analysis requires a variety of inputs, such as product prices, product energy consumption, energy prices, maintenance and repair costs, product lifetime, and discount rates appropriate for consumers. To account for uncertainty and variability in specific inputs, such as product lifetime and discount rate, DOE uses a distribution of values, with probabilities attached to each value.

The PBP is the estimated amount of time (in years) it takes consumers to recover the increased purchase cost (including installation) of a more-efficient product through lower operating costs. DOE calculates the PBP by dividing the change in purchase cost due to a more stringent standard by the change in annual operating cost for the year that standards are assumed to take effect.

For its LCC and PBP analysis, DOE assumes that consumers will purchase the covered products in the first year of compliance with amended standards. The LCC savings for the considered efficiency levels are calculated relative to the case that reflects projected market trends in the absence of amended standards. DOE's LCC and PBP analysis is discussed in further detail in section IV.F.

c. Energy Savings

Although significant conservation of energy is a separate statutory requirement for adopting an energy conservation standard, EPCA requires

DOE, in determining the economic justification of a standard, to consider the total projected energy savings that are expected to result directly from the standard. (42 U.S.C. 6295(o)(2)(B)(i)(III) and 6316(a)) As discussed in section III.D, DOE uses the NIA spreadsheet models to project national energy savings.

d. Lessening of Utility or Performance of Equipment

In establishing equipment classes and in evaluating design options and the impact of potential standard levels, DOE evaluates potential standards that would not lessen equipment utility or performance. (42 U.S.C. 6295(o)(2)(B)(i)(IV) and 42 U.S.C. 6316) Based on data available to DOE, the standards proposed in this document would not reduce the utility or performance of the products under consideration in this rulemaking.

e. Impact of Any Lessening of Competition

EPCA directs DOE to consider the impact of any lessening of competition, as determined in writing by the Attorney General, which is likely to result from a proposed standard. (42 U.S.C. 6295(o)(2)(B)(i)(V) and 6316(a)) It also directs the Attorney General to determine the impact, if any, of any lessening of competition likely to result from a proposed standard and to transmit such determination to the Secretary within 60 days of the publication of a proposed rule, together with an analysis of the nature and extent of the impact. (42 U.S.C. 6295(o)(2)(B)(ii) and 6316(a)) DOE will transmit a copy of this proposed rule to the Attorney General with a request that the Department of Justice (DOJ) provide its determination on this issue. DOE will include the Attorney General's response in the docket for this rulemaking and will respond to the Attorney General's determination in the final rule.

f. Need for National Energy Conservation

DOE also considers the need for national energy conservation in determining whether a new or amended standard is economically justified. (42 U.S.C. 6295(o)(2)(B)(i)(VI) and 6316(a)) The energy savings from the proposed standards are likely to provide improvements to the security and reliability of the nation's energy system. Reductions in the demand for electricity also may result in reduced costs for maintaining the reliability of the nation's electricity system. DOE conducts a utility impact analysis to estimate how standards may affect the nation's needed power generation capacity, as discussed in section IV.M.

The proposed standards also are likely to result in environmental benefits in the form of reduced emissions of air pollutants and greenhouse gases associated with energy production and use. DOE conducts an emissions analysis to estimate how potential standards may affect these emissions, as discussed in section IV.K; the emissions impacts are reported in section V.L of this document. DOE also estimates the economic value of emissions reductions resulting from the considered TSLs, as discussed in section IV.L.

g. Other Factors

In determining whether an energy conservation standard is economically justified, DOE may consider any other factors that the Secretary deems to be relevant. (42 U.S.C. 6295(o)(2)(B)(i)(VII) and 6316(a)) To the extent there are other factors relevant to evaluating whether the proposed standards are economically justified, DOE may consider other factors that fall outside of the categories discussed above.

2. Rebuttable Presumption

As set forth in 42 U.S.C. 6295(o)(2)(B)(iii) and 6316(a), EPCA creates a rebuttable presumption that an energy conservation standard is economically justified if the additional cost to the consumer of a product that meets the standard is less than three times the value of the first year's energy savings resulting from the standard, as calculated under the applicable DOE test procedure. DOE's LCC and PBP analyses generate values used to calculate the effects that proposed energy conservation standards would have on the payback period for consumers. These analyses include, but are not limited to, the 3-year payback period contemplated under the rebuttable-presumption test. In addition, DOE routinely conducts an economic analysis that considers the full range of impacts to consumers, manufacturers, the nation, and the environment. See 42 U.S.C. 6295(o)(2)(B)(i) and 6316(a). The results of this analysis serve as the basis for DOE's evaluation of the economic justification for a potential standard level (thereby supporting or rebutting the results of any preliminary determination of economic justification). The rebuttable presumption payback calculation is discussed in section V.B.1.c of this proposed rule.

H. Compressor Industry Recommendation

DOE received a comment on proposed standards and test methods from CAGI, the primary compressor trade association. That recommendation is summarized below.[34] DOE responds to the points made within the comment in the appropriate sections of this document.

1. Summary

CAGI recommended making mandatory the use of standardized test methods and reporting formats that are presently voluntary. With respect to scope, CAGI suggested that DOE address lubricated, rotary compressors operating from 80–139 psig and with ''flows'' from 35 to 2000 cfm. (CAGI, No. 0030 at p. 1) The benefits, according to CAGI, include energy savings, regulatory simplicity, and granting industry the ability to continue energy efficiency efforts undisrupted. *Id.*

2. Specific Provisions

CAGI makes the following comments and recommendations in its submission:

- With respect to European efforts, that the Lot 31 Study made use of CAGI-published data, and that those efforts can inform the work being done by DOE. (CAGI, No. 0030 at p. 3)
- The biggest part of the compressed air industry serves ''general industrial air'' customers which primarily use rotary equipment, rated from 80–139 psig and 35–2000 cfm, and driven by electric motors rated from 10 to 500-hp. (CAGI, No. 0030 at p. 3)
- There is little risk of substitution for compressors if DOE opts to leave certain market segments unregulated. Customer needs generally define which equipment is purchased. (CAGI, No. 0030 at p. 4)
- Lubricant-free[35] equipment is used in more specialized applications and carries significantly smaller market size. As a result, regulation carries smaller potential to save energy and greater risk of negative impact to manufacturers and consumers. (CAGI, No. 0030 at p. 5) DOE, like EU Lot 31, should not include lubricant-free equipment.
- Reciprocating compressors should not be included in the rulemaking. Low duty cycle and small average capacity means that energy savings potential is

[34] Available at: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0030.*

[35] Although industry frequently uses the term ''oil-free'' to describe equipment with substances injected during the compression process, not all of the substances used are oils, in the chemical sense, and so DOE will use the term ''lubricant-free'' to refer to such equipment.

significantly lower than for other compressor types. The market is highly fragmented, with many assemblers purchasing parts from a variety of suppliers. Finally, low production volumes could generate large negative impacts to manufacturers forced to redesign in order to comply with a standard. (CAGI, No. 0030 at p. 6)

• CAGI supplies proposed definitions for ''basic package compressor,'' ''standard air compressor,'' and ''rotary standard air compressor.'' (CAGI, No. 0030 at p. 8)

• With respect to measurement, CAGI proposes use of ISO 1217:2009 for both fixed- (Annex C) and variable-speed (Annex E) equipment. For variable-speed equipment, CAGI proposes a weighted average performance across certain load points, also proposed for use by EU Lot 31. (CAGI, No. 0030 at p. 8–9)

• In CAGI's view, standardizing measurement and data publication will be sufficient to drive continued energy conservation in compressors. CAGI asserts that the market already self-establishes a de facto minimum performance standard, and attempts by DOE to introduce one may be counterproductive to both energy savings and manufacturer welfare. (CAGI, No. 0030 at p. 9)

IV. Methodology and Discussion of Related Comments

This section addresses the analyses DOE has performed in this rulemaking for compressors. Separate subsections address each component of DOE's analyses.

DOE used several analytical tools to estimate the impact of the standards proposed in this document. The first tool is a spreadsheet that calculates the LCC savings and PBP of potential amended or new energy conservation standards. The national impacts analysis uses a second spreadsheet set that provides shipments forecasts and calculates national energy savings and net present value of total end user costs and savings expected to result from potential energy conservation standards. DOE uses the third spreadsheet tool, the Government Regulatory Impact Model (GRIM), to assess manufacturer impacts of potential standards. These spreadsheet tools are available at *http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/78*. Additionally, DOE used output from the latest version of EIA's *Annual Energy Outlook* (*AEO),* a widely known energy forecast for the United States, for the emissions and utility impact analyses.

A. Market and Technology Assessment

DOE develops information in the market and technology assessment that provides an overall picture of the market for the equipment concerned, including the purpose of the equipment, the industry structure, manufacturers, market characteristics, and technologies used in the equipment. This activity includes both quantitative and qualitative assessments, based primarily on publicly-available information (*e.g.,* manufacturer specification sheets, and industry publications) and data submitted by manufacturers, trade associations, and other stakeholders. The subjects addressed in the market and technology assessment for this rulemaking include: (1) A determination of the scope of the rulemaking and equipment classes; (2) manufacturers and industry structure; (3) existing efficiency programs; (4) shipments information; (5) market and industry trends; and (6) technologies or design options that could improve the energy efficiency of compressors. The key findings of DOE's market assessment are summarized below. See chapter 3 of the NOPR TSD for further discussion of the market and technology assessment.

1. Equipment Classes

When evaluating and establishing energy conservation standards, DOE divides covered products into equipment classes by the type of energy used or by capacity or other performance-related features that justify differing standards. In making a determination whether a performance-related feature justifies a different standard, DOE must consider such factors as the utility of the feature to the consumer and other factors DOE determines are appropriate. (42 U.S.C. 6295(q) and 6316(a)) DOE proposes dividing compressors based on the following factors, which are discussed in sections IV.A.1.a through IV.A.1.e:

• Compression principle,
• Lubricant presence,
• Cooling method,
• Motor speed type, and
• Motor phase count.

In the Framework Document, DOE requested stakeholder comment regarding whether and how compressors should be divided into separate classes. Stakeholder comments regarding equipment classes, the specific separation of equipment classes based on the listed factors, and the final list of proposed equipment classes are discussed further in the following sections. Generally, the notion of establishing separate equipment classes was supported by commenters.

a. Compression Principle

In response to the Framework Document, Saylor-Beall and Jenny compressors commented that rotary compressors are generally high-duty cycle equipment, while reciprocating compressors are generally low-duty cycle equipment. (Saylor-Beall, No. 0003 at p. 3; Jenny, No. 0005 at p. 4) As noted in section III.A, DOE considered standards for both reciprocating and rotary compressors as part of this rulemaking. DOE also proposes to divide these two compressor types into separate equipment classes. Rotary and reciprocating compressors have significantly different operating characteristics; as a result these equipment types are used in different applications and have different levels of attainable efficiency. Both rotary and reciprocating are considered to be positive displacement compressors, which act by compressing successive trapped volumes of air.

Reciprocating compressors compress air using the repeated linear motion of a moving member (*e.g.,* a piston) within a sealed compression chamber. Reciprocating compressors do not require a warm up period and can be operated using an on/off control scheme, making them best suited for intermittent and low duty cycle applications. This is because low cycles require frequent starting and stopping. Equipment which required warming up to operate properly would operate inefficiently, wear prematurely, or both. Reciprocating compressors use actuated valves to seal the compression chamber, which holds air leakage (a form of energy loss) to modest levels even when operating cold. Rotary compressors, by contrast, do not use valves but rely on carefully designed and manufactured rotor clearances, which are efficient after the rotor has heated and expanded to design specifications, in order to limit air leakage. Customers with low duty cycles may find additional utility, therefore, in reciprocating compressors. By contrast, reciprocating compressors, by nature of their reciprocating motion, produce more vibration and, therefore, may wear more quickly and, therefore, may offer reduced utility to customers with higher duty cycles and high cost of downtime.

Rotary compressors compress air progressively as it moves from the inlet point to the discharge point using the cyclical motion of one or several rotors. Rotary compressors may require a warm-up period to operate properly, and are therefore better suited for high duty cycle applications, in which equipment is less frequently cycled on and off and, therefore, in which design operating temperatures may be maintained. Rotary compressors typically cannot be operated using an on/off control scheme; rather, they may be controlled by other methods such as load/unload, inlet flow modulation, and variable displacement drives. As mentioned in the previous paragraph, rotary compressors rely on reaching a certain operating temperature, or ''warming up,'' to allow mechanical parts to expand to reach the proper design clearances. Operating a rotary compressor in a low-duty, on/off manner, may cause the compressor to operate inefficiently, wear prematurely, or both. These control methods are discussed further in chapter 3 of the NOPR TSD.

Although reciprocating compressors typically have lower isentropic efficiencies than rotary compressors, reciprocating compressors excel in low duty cycle or intermittent applications and may consume less overall energy than a rotary compressor when deployed in such settings. Alternatively, to provide air for intermittent loads, a rotary compressor would be required to remain running in a modulated or unloaded condition, even at times of low or zero load. This is inherent in the scheme; a technology which cannot start and stop (either literally or because doing so would cause adverse consequences such as premature wear) must employ other capacity-reducing measures such as modulation or unloading to match supply to demand. Consequently, DOE concludes that dividing rotary and reciprocating compressors into separate equipment classes on the basis of suitability for different duty cycles is appropriate.

DOE requests comment on its proposal to establish separate equipment classes for rotary and reciprocating equipment, and on whether and why utility or performance differences exist between the two types of equipment. This is identified as Issue 6 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

b. Lubricant Presence

In response to the Framework Document, Atlas Copco commented that compressors can be divided into two separate groups, lubricated and lubricant-free.[36] (Atlas-Copco, No. 0008 at p. 3) DOE proposes to divide lubricated and lubricant-free into separate equipment classes. Compressors are manufactured in both lubricated and lubricant-free configurations. For the purposes of this rulemaking, DOE is proposing to define these lubrication types as follows:

''Lubricated compressor'' means a compressor that introduces an auxiliary substance into the compression chamber during compression.

''Lubricant-free compressor'' means a compressor that does not introduce any auxiliary substance into the compression chamber at any time during operation.

For the purposes of this rulemaking, DOE proposes to define ''auxiliary substance'' as follows:

''Auxiliary substance'' means any substance deliberately introduced into a compression process to aid in compression of a gas by any of the following: Lubricating, sealing mechanical clearances, or absorbing heat.

DOE notes that lubricant-free compressors may still use lubricant within other portions of the compressor, as long as the lubricant does not enter the compression chamber at any point during operation. DOE also notes that, under the proposed definitions, compressors would be considered ''lubricated'' if an auxiliary substance of any sort were introduced into the compression chamber. This would include oil, and water, which is not typically described as a lubricant within the compressor industry.

DOE's analysis and research found that lubricated compressors are generally more efficient than lubricant-free compressors. In lubricated compressors, the lubricant is injected into the compression chamber to serve two primary purposes:

1. Sealing the compression chamber mechanical clearances and reduce air leakage by using the surface tension of the liquid to form a barrier to air escape, and

2. Cooling the compressed air during compression, increasing efficiency by bringing the compression process closer to a thermodynamic ideal.

Due to their inherently lower efficiencies and comparatively higher costs, lubricant-free compressors do not compete directly with lubricated compressors for general-purpose compressed air applications. However, certain applications with specific air purity requirements cannot use lubricated compressors due to the presence of residual lubricant that cannot be effectively removed from the output air using filtration. Examples of these applications include food processing equipment, clean-room manufacturing, and air for medical uses. Lubricant-free compressors are necessary to meet the air purity requirements of these applications. By contrast, a lubricant-free compressor could likely be used with no loss of utility in applications traditionally served by lubricated compressors. Because of their higher cost, however, they are typically deployed only when called for by customer utility requirements.

Lacking lubricant to aid in sealing clearances, lubricant-free compressors are usually manufactured with smaller clearances. Although this practice adds cost, it reduces some of the air leakage that result from a lack of lubrication. However, reducing clearances too far may result in increased friction and maintenance requirements. This limits how tight the clearances of lubricant-free compressors can be. As such, lubricant-free compressors still allow more leakage relative to lubricated compressors. This leakage reduces efficiency, because as the air is lost, so is the energy that was used to treat it. Further, lubricant-free compressors may require larger after-coolers than lubricated compressors. An after-cooler is used to cool the compressed air after compression and prior to discharge. The after-cooler causes package pressure losses and decreases in efficiency.

DOE notes that an ISO standard, 8573–1:2010,[37] exists and is used by industry to measure and describe the purity of air. Air is described as being ''class zero'' if it is determined to meet the most stringent air purity levels recognized by this standard. DOE is aware that some compressors that meet the proposed definition of lubricated in this document may also be able to meet the class zero standard of ISO 8573–1:2010. For example, the compressor may include an advanced lubricant filtration system to bring lubricant concentration below a certain threshold. Alternatively, the compressor may inject only water into the chamber, which may be removed with ordinary cooling and drying equipment.

DOE requests comment on separating equipment classes by lubricant presence, and specifically on whether ISO 8573–1:2010 is suitable for characterizing compressors on that basis. DOE also requests comments on the proposed definitions for lubricated compressor, lubricant-free compressors, and auxiliary substance. This is identified as Issue 7 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

[36] Although industry frequently uses the term ''oil-free'' to describe equipment with substances injected during the compression process, not all of the substances used are oils, in the chemical sense, and so DOE will use the term ''lubricant-free'' to refer to such equipment.

[37] See: *http://www.iso.org/iso/catalogue_detail.htm?csnumber=46418*

c. Cooling Method

DOE proposes to divide air-cooled and water-cooled rotary compressors into separate equipment classes. Due to considerable heat created during compression, compressors are normally packaged with cooling systems for both the air itself, and, if applicable, the lubricant. The cooling system may utilize either air or water to remove heat from the system. For the purposes of this rulemaking, DOE proposes to define the two cooling methods as follows:

''Air-cooled compressor'' means a compressor that utilizes air to cool both the compressed air and, if present, any auxiliary substance used to facilitate compression.

''Water-cooled compressor'' means a compressor that utilizes chilled water provided by an external system to cool both the compressed air and, if present, any auxiliary substance used to facilitate compression.

DOE's research and analysis of industry data indicates that water-cooled compressors are typically more efficient than air-cooled compressors, as measured by ISO 1217:2009.

Air-cooled compressors circulate ambient air through the heat exchangers to cool both the compressed air and lubricant. Air-cooled compressors usually require fans to circulate air through the heat exchangers; these fans increase the total package energy consumption, thus decreasing the total package efficiency.

Water-cooled compressors circulate chilled water from an external water supply through heat exchangers to cool both the compressed air and lubricant. The chilled water heat exchanger does not cause any additional energy consumption within the compressor package, as the cooling water is chilled and pumped from a remote location. However, water-cooled compressors can only be used in locations where chilled water is available, thus limiting the utility and applicability of water-cooled compressors. Conversely, air-cooled compressors require only air for cooling and can be used in locations where chilled water may not be available. Therefore, air-cooled compressors present a utility advantage to customers without access to a cooling water supply.

DOE notes that efficiency, as measured by the proposed test procedure NOPR, would reflect slightly different concepts for air- and water-cooled compressors. In both cases, a cooling medium is being actively circulated to remove heat from the unit and energy is being consumed to circulate the medium. But only in the case of air-cooled units is that energy consumption reflected in the efficiency metric. The consumption occurs remotely for water-cooled units. Without further analysis, it is difficult to assess which consumption may be greater overall. But this difference is what is measured by efficiency, in addition to the difference in end user utility already discussed, and offers a second justification for establishment of separate equipment classes.

DOE is not aware of any water-cooled reciprocating compressors currently available in the U.S. market. However, if such equipment does exist, or enters the market in the future, the data presented earlier in this section suggest that water-cooled compressors may be more efficient than similar air-cooled units. As a result, DOE proposes to consider both air- and water-cooled reciprocating compressors in a single equipment class and to base any energy conservation standards for both only on available air-cooled data. Based on comparison of air- and water-cooled rotary compressors, DOE concludes that it is technologically feasible for any water-cooled reciprocating compressor introduced to the market to meet an energy conservation standard set based on the current air-cooled reciprocating compressors market.

DOE requests comment on its proposal to establish separate equipment classes for air- and water-cooled equipment. DOE also requests comments on the proposed definitions for air- and water-cooled compressor. This is identified as Issue 8 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

d. Motor Speed

DOE's research indicates that electric motor-driven compressors can be further separated by the style of electric driver used in the package. Specifically, DOE found that compressors are sold with either a variable-speed driver, which can operate across a continuous range of driver speeds, or a fixed-speed driver, which can operate at only a single fixed-speed. In the test procedure NOPR, DOE proposed definitions for ''fixed-speed compressor'' and ''variable-speed compressor.''

The term ''fixed-speed compressor'' means an air compressor that is not capable of adjusting the speed of the driver continuously over the driver operating speed range in response to incremental changes in the required compressor flow rate.

The term ''variable-speed compressor'' means an air compressor that is capable of adjusting the speed of the driver continuously over the driver operating speed range in response to incremental changes in the required compressor actual volume flow rate.

DOE found that variable-speed compressors are typically less efficient at full load than comparable fixed-speed compressors, partially due to efficiency losses within the variable-speed drive. Variable-speed compressors are typically intended for use in systems where air demand is expected to vary over the course of operation; this takes advantage of the unit's ability to operate more efficiently at part load. For this reason, variable-speed compressors are sometimes optimized for efficiency at part-load; this will typically result in full-load efficiencies lower than those of comparable fixed-speed units. Additionally, they may function as ''trim'' compressors in multi-unit installations. Trim compressors are normally the first ones to adjust their capacity output when overall system air demand changes. If the overall system air demand changes outside what the trim compressor is able to accommodate, additional compressors may be turned on and off according to which configuration would produce most efficient operation. By contrast, a ''base load'' compressor is expected to be operated either on or off a large fraction; this compressors is a poor candidate for variable-speed functionality, because of both the financial and full-load performance cost of adding that capability. Due to the difference in utility and attainable efficiency between fixed and variable-speed compressors, DOE proposes to separate these two compressor styles into separate equipment classes.

e. Motor Phase Count

DOE also proposes to divide single- and three-phase reciprocating compressors into separate equipment classes. Lower power reciprocating compressors, typically less than 10 hp, can be packaged with either single-phase or three-phase electric motors. Reciprocating compressors packaged with single-phase electric motors are typically less efficient than those packaged with three-phase electric motors due to the inherent lower efficiency of single-phase motors. Single-phase reciprocating compressors are generally used in applications with lower duty cycles and no access to three-phase power, such as tire inflation at a local service station, or oral surgery at a dental office. Three-phase reciprocating compressors typically see higher duty cycles and can only be used for applications in which three-phase power is available. An automotive body shop or very light industrial production may have such compressors, but they would likely not be found as the primary air source for a high-volume industrial production application. Few residential applications have access to three-phase power. As a result, DOE concludes that single- and three-phase compressors offer different end user utility. Consequently, DOE proposes to divide reciprocating compressors packaged with single-phase and three-phase electric motors into separate equipment classes.

By contrast, DOE was able to find little data on single-phase rotary compressors, which appear to form a very small fraction of the market. As a result, DOE was not able to determine whether such equipment was able to meet the same performance levels as three-phase equipment. To avoid the risk of in advertently incentivizing the market to shift to single-phase rotary equipment (if separated or not included), DOE proposes in this NOPR not to separate rotary equipment classes by motor phase count. As such, each rotary equipment class encompasses both single- and three-phase equipment.

Based on interviews with manufacturers, DOE is aware that single-phase rotary equipment may be gaining popularity in European markets. If such equipment is being chosen to conserve energy, and if the adoption of increased standards may hinder the adoption or development of single-phase rotary equipment to save energy, DOE may consider establishing a separate standard for single-phase rotary equipment in the final rule.

DOE requests comment on the establishment of separate equipment classes, by motor phase count, for reciprocating equipment. This is identified as Issue 9 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

DOE also requests comment on the proposal to combine single- and three-phase rotary equipment in each rotary equipment class. This is identified as Issue 10 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

f. List of Proposed Equipment Classes

DOE's list of proposed equipment classes is provided in Table IV.1:

TABLE IV.1—LIST OF DOE PROPOSED COMPRESSOR EQUIPMENT CLASSES

Compressor type	Lubrication type	Cooling method	Driver type	Motor phase	Equipment class designation
Rotary	Lubricated	Air-Cooled	Fixed-Speed	Any	RP_FS_L_AC
			Variable-speed		RP_VS_L_AC
		Water-Cooled	Fixed-Speed		RP_FS_L_WC
			Variable-speed		RP_VS_L_WC
	Lubricant-Free	Air-Cooled	Fixed-Speed		RP_FS_LF_AC
			Variable-speed		RP_VS_LF_AC
		Water-Cooled	Fixed-Speed		RP_FS_LF_WC
			Variable-speed		RP_VS_LF_WC
Reciprocating	Lubricated	Air-Cooled or Water-Cooled	Fixed-Speed	Three-Phase	R3_FS_L_XX
				Single-Phase	R1_FS_L_XX
	Lubricant-Free			Three-Phase	R3_FS_LF_XX
				Single-Phase	R1_FS_LF_XX

2. European Union Regulatory Action

The EU Ecodesign directive established a framework under which manufacturers of energy-using products are obliged to reduce the energy consumption and other negative environmental impacts occurring throughout the product life cycle.[38] Products are broken out in to different ''Lots,'' with compressors studied in Lot 31. In June 2014, the EU completed and published its final technical and economic study of Lot 31 compressors.[39]

As part of its study, the EU examined the entire compressors market to determine an appropriate scope of coverage for its energy conservation standards. The results of this study led the Commission of the European Communities to establish a working document proposing possible energy efficiency requirements for compressors. The EU draft regulation[40] proposed to cover the following compressor types:

- Oil-lubricated Rotary Air Compressor Packages with:
  - Rated output flow rate of between 5 to 1,280 liters per second,[41]
  - Three-phase electric motors,
  - Fixed or variable-speed drives, and
  - Full-load operating pressure of between 7 to 14 bar gauge.
- Oil-lubricated Reciprocating Air Compressor Packages with:
  - Rated output flow rate of between 2 to 64 liters per second,
  - Three-phase electric motors,
  - Fixed-speed drives, and
  - Full-load operating pressure of between 7 to 14 bar gauge.

The Lot 31 study used data collected from CAGI Performance Verification Program data sheets to determine the market distribution of compressor efficiency for rotary compressors and data collected from a confidential survey conducted of European manufacturers for reciprocating compressors.

The EU draft regulation proposed to separate the covered products into the following three equipment classes and to set a different standard level, based on package isentropic efficiency, for each class:

- Fixed-speed Rotary Standard Air Compressors—Standard level set as package isentropic efficiency at full-load operating conditions;
- Variable-speed Rotary Standard Air Compressors—Standard level set as a weighted average of package isentropic efficiency at 100-percent, 70-percent, and 40-percent of full-load operating conditions; and
- Piston Standard Air Compressors—Standard level set as package isentropic efficiency at full-load operating conditions.

a. Specific Suggested Requirements

The EU draft proposal suggests compliance beginning in 2018, and are increased in 2020 for certain compressor

[38] Source: *www.eceee.org/ecodesign/products/Compressors.*

[39] For copies of the EU Lot 31 Final Report on Compressors, please go to: *www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

[40] For copies of the EU draft regulation: *www.regulations.gov/contentStreamer?documentId=EERE-2013-BT-STD-0040-0031&disposition=attachment&contentType=pdf.*

[41] When express in terms of inlet conditions, as is industry convention.

types, as explain in Table IV.2 and Table IV.3:

TABLE IV.2—DRAFT FIRST TIER MINIMUM ENERGY EFFICIENCY REQUIREMENTS FOR STANDARD AIR COMPRESSORS FROM JANUARY 1, 2018

Standard air compressor type	Formula to calculate the *minimum* package isentropic efficiency, depending on the flow rate (V_1) an proportional loss factor (d)	Proportional loss factor (d) to be used in the formula
Fixed-speed Rotary Standard Air Compressor.	$(-.0928 \ln^2(V_1) + 13.911 \ln(V_1) + 27.110) + (100-(-.0928 \ln^2(V_1) + 13.911 \ln(V_1) + 27.110) * d/100$.	−5
Variable-speed Rotary Standard Air Compressor.	$(-1.549 \ln^2(V_1) + 21.573 \ln(V_1) + 0.905) + (100-(-1.549 \ln^2(V_1) + 21.573 \ln(V_1) + 0.905) * d/100$.	−5
Piston Standard Air Compressor.	$(8.931 \ln(V_1) + 31.477) + (100-(8.931 \ln(V_1) + 31.477) * d/100$	−5

TABLE IV.3—DRAFT SECOND TIER MINIMUM ENERGY EFFICIENCY REQUIREMENTS FOR STANDARD AIR COMPRESSORS FROM JANUARY 1, 2020

Standard air compressor type	Formula to calculate the *minimum* package isentropic efficiency, depending on the flow rate (V_1) an proportional loss factor (d)	Proportional loss factor (d) to be used in the formula
Fixed-speed Rotary Standard Air Compressor.	$(-0.928 \ln^2(V_1) + 13.911 \ln(V_1) + 27.110) + (100-(-0.928 \ln^2(V_1) + 13.911 \ln(V_1) + 27.110) * d/100$.	0
Variable-speed Rotary Standard Air Compressor.	$(-1.549 \ln^2(V_1) + 21.573 \ln(V_1) + 0.905) + (100-(-1.549 \ln^2(V_1) + 21.573 \ln(V_1) + 0.905) * d/100$.	0
Piston Standard Air Compressor.	$(8.931 \ln(V_1) + 31.477) + (100-(8.931 \ln(V_1) + 31.477) * d/100$	0

b. Next Steps

The outcome of this draft regulation is undetermined, based on publicly available information. Based on the process outlined on the Ecodesign Web site, the document may need to be reviewed internally by the European Commission, sent to the World Trade Organization, submitted to the Regulatory Committee (composed of one representative from each EU Member State), and the finally sent to the European Parliament and Council for scrutiny.[42]

In parallel, the EU has announced [43] a second compressors study focusing on low-pressure and oil-free equipment. From the Web site,[44] the study was kicked off on 17 June, 2015, draft publications for ''Task 1–4'' were posted on 31 March, 2016, and additional draft publications and stakeholder meetings are planned for the future (with dates yet to be determined). Publication of the final report is scheduled for April 2017.

[42] As detailed here: *www.eceee.org/ecodesign/products/Ecodesign135lg.png.*

[43] As viewed here: *http://www.eco-compressors.eu/documents.htm.*

[44] As viewed here: *http://www.eco-compressors.eu/documents.htm.*

3. Technology Options

In the Framework Document, DOE identified several design options that could be used to improve compressor package efficiency including:

- Improved controls;
- Improved bare compressor [45] efficiency;
- Improved cooling fan efficiency;
- Improved part-load efficiency;
- Improved electric motors; and
- The use of multistage compressors.

In response to the Framework Document, the Joint Commenters recommended that DOE consider equipment that affect compressor efficiency, such as zero-loss condensate traps and waste heat recovery technologies. (Joint Comment, No. 0016 at p. 3–4) Further, DOE research indicated that even though all of the options listed in the Framework Document were valid paths to higher efficiency, in practice, they were not considered independently by manufacturers but, rather, deployed as needed depending on the specifics of the compressor design and ultimate desired efficiency level. As for this document, DOE is altering its proposed categorization of options to improve efficiency. This is because the options listed above are in some cases able to be deployed independently (*e.g.,* cooling fan efficiency) and in other cases require coordination (*e.g.,* using a more efficient motor). Instead of a bottom-up approach, wherein DOE could attempt to assign a characteristic improvement, DOE's proposed approach ''top-down,'' where the primary consideration is the overall package efficiency and exploration is of the overall cost required to achieve certain efficiencies. Instead of independent options, DOE will generally consider all efficiency improvement to come from a ''package redesign'' which could include any, or all of the listed options from the Framework Document. This package redesign can be thought of as including three broad categories of improvements:

- Multi-staging;
- Air-end Improvement; and
- Auxiliary Component Improvement.

These package redesign options are addressed separately in the sections that follow.

[45] Frequently described in the compressor industry as an ''air-end'' or ''airend.'' For the purposes of this rulemaking, DOE considers the terms to be synonymous.

a. Multi-Staging

Compressors ingest air at ambient conditions and compress it to a higher pressure required by the specific application. Compressors can perform this compression in one or multiple stages, where a stage corresponds to a single air-end and offers the opportunity for heat removal before the next stage. Units that compress the air from ambient to the specified design pressure of the compressor in one step are referred to as single-stage compressors, while units that use multiple steps are referred to as multistage compressors.

The act of compression generates inherent heat in a gas. If the process occurs quickly enough to limit the transfer of that heat to the environment, the compression is known as ''adiabatic.'' By contrast, compression may be performed slowly such that heat flows from the gas at the same rate it is generated, and such that the temperature of the gas never exceeds that of the environment. This process is called ''isothermal.'' DOE notes that a hotter gas is conceptually ''harder'' to compress; the compressor must overcome the heat energy present in the gas in order to continue the compression process. As a result, compression to a given volume requires less work if performed isothermally. ''Real'' (*i.e.,* not idealized in any respect) compressors are neither adiabatic nor isothermal, and dissipate some portion of compressive heat during the process. If a compressor is able to dissipate more heat, the resulting act of compression becomes easier and the compressor requires less input energy.

Multi-stage compressors are specifically designed to take advantage of this principle and split the compression process into two or more stages (each performed in a single air-end) to allow heat removal between the stages using a heat-exchange device sometimes called an ''intercooler.'' The more stages used, the closer the compressor behavior comes to the isothermal ideal. Eventually, however, the benefits to adding further stages diminish; gains from each marginal stage is countered by the inherent inefficiencies of using smaller compressor units. Depending on the specific pressure involved, the optimal number of stages may vary widely. Most standard industrial air applications, however, do not use more than two stages.

Lubricant-free compressors typically realize greater efficiency gains than lubricated compressors, as the lubricant used, usually oil, acts as a coolant during the compression process, thus reducing the benefit of intercooling between stages.

b. Air-End Improvement

The efficiency of any given air-end depends upon a number of factors, including:

- Rated compressor output capacity;
- Compression chamber geometry;
- Operating speed;
- Surface finish;
- Manufacturing precision; and
- Designed equipment tolerances.

Each individual air-end has a best efficiency operating point based upon the characteristics listed. However, because air-ends can operate at multiple flow rates, manufacturers commonly utilize a given air-end in multiple compressor packages to reduce overall costs. This results in air-ends operating outside of the best efficiency point. Using one air-end in multiple compressor packages reduces the total number of air-ends a manufacturer needs to provide across the entire market, reducing costs at the price of reduced efficiency for those packages operating outside of the best efficiency point for the air-end. However, a manufacturer could redesign and optimize air-ends for any given flow rate and discharge pressure, increasing the overall efficiency of the compressor package.

Manufacturers can use two viable design pathways to increase compressor efficiency via air-end improvement. The first is to enhance a given air-end design's properties that affect efficiency, which could include manufacturing precision, surface finish, mechanical design clearances, and overall aerodynamic efficiency. The second is to more appropriately match air-ends and applications by building an overall larger number of air-end designs. As a result, a given air-end will be used less frequently in applications requiring it to operate further from its optimal operating point. These two practices may be employed independently or jointly; the option that is prioritized will depend on the specifics of a manufacturer's equipment line and the ultimate efficiency level desired.

c. Auxiliary Component Improvement

As discussed in the previous section, compressor manufacturers normally use one air-end in multiple compressor packages that are designed to operate at different discharge pressures and flow rates. Each compressor package consists of multiple design features that affect package efficiency, including valves, piping system, motor, capacity controls, fans, fan motors, filtration, drains, and driers. This equipment, for example, may control the flow of air, moisture, or oil, or the temperature and humidity of output air, or regulate temperature and operation, Compressor manufacturers do not normally provide the option to replace any individual part of a compressor package to increase efficiency, as each feature also has a direct effect on compressor performance. However, improving the operating characteristics of any of these ''auxiliary'' parts may offer a chance to improve the overall efficiency of the compressor package.

For example, package isentropic efficiency can be increased by reducing the internal pressure drop of the package using improved valves and pipe systems, or by improving the efficiency of (1) both the drive and fan motors (if present), (2) the fan, itself, (3) condensate drains, (4) both air and lubricant filters (if present), (4) air driers, and (5) controls. The improvement must be considered relative to a starting point, however. Even if the modifications could be deployed independently of each other, and not all can, the spread of efficiencies available in the market likely already reflects the more cost effective choice for improving efficiency at any given point. Perhaps one manufacturer, by virtue of features of its product lines, finds that reaching a given efficiency level in a particular equipment class, is most cost effectively done by improving Technology X. Another may find that it is more cost effective to improve Technology Y. And both could be correct, because each may have had a different starting point. Adding to this difficulty in ascertaining exactly when a given technology should be deployed (as with a bottom-up technology option approach) is a manufacturing reality—it is not cost effective to offer an infinite number of combinations and equipment sizes. Perhaps a compressor of output level between two others would most optimally use a fan sized specifically for that compressor. Because it is not cost effective for that compressor's manufacturer to stock another fan size, however, the compressor ends up sub-optimally using a fan either slightly too large or slightly too small, at some small cost to efficiency. So, less may be learned by scrutinizing the design choices of a specific model that is learned by considering the overall spread of costs and efficiencies available in the market at-large.

DOE notes that, because the compressor packages function as an ensemble of complementary parts, changing one part often calls for changing others. A special case may come with more efficient electric motors. Compressors normally use induction motors, which generally vary operating speed as efficiency is improved. Using a more efficient (but otherwise identical) induction motor without considering the rest of the compressor design could be counterproductive if the gains in motor efficiency were more than offset by subsequent loss in performance of the air-end and other parts. DOE's proposal assumes that the best-performing compressors on the market are built using the most-efficient available electric motors that are suited to the task. However, it could not confirm instances of a manufacturer using ''super premium'' or ''IE4'' induction motors, which appear to only recently have been made available commercially.[46] These terms (''super premium'' and ''IE4'') have been used (in the U.S. and Europe, respectively) to describe the motor industry's ''next tier'' of efficiency. Possible reasons for this include the motors not being suitable for use in compressors, manufacturers are still exploring the relatively new motors and have not yet introduced equipment redesigned to make use of them, or that manufacturers are already, in fact, using them in the most efficient compressor offerings.

As an example of the influence of auxiliary componentry, the European Union Draft Standard offers a list of equipment with which the unit must be tested in order to certify compliance with standards.[47] It does not provide definitions for the terms, but as an example, for fixed-speed rotary compressors, required equipment includes:

1. Electric motor
2. Cooling fan
3. Compression element
4. Transmission (Belt, Gear, Coupling . . .), (if applicable)
5. Inlet filter
6. Inlet valve
7. Minimum pressure check valve/ backflow check valve
8. Oil separator
9. Air piping
10. Oil piping
11. Oil pump (if applicable)
12. Oil filter
13. Oil cooler
14. Thermostatic valve
15. Electrical switchgear
16. Compressor after-cooler
17. Compressor control device (pressure switch, pressure transducer, etc.)

The list implies that each component affects efficiency, but does not say whether improvement of any particular component is possible. Nonetheless, it is illustrative of the set of componentry that needs to function harmoniously in order for the package to perform well.

DOE also requests comment specifically on IE4 or ''super premium'' electric motors, their suitability for compressors, and on any efforts to incorporate them into newly developed equipment. This is identified as Issue 11 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

B. Screening Analysis

DOE generally uses the following four screening criteria to determine which technology options are suitable for further consideration in an energy conservation standards rulemaking:

1. Technological feasibility. Technologies that are not incorporated in commercial products or in working prototypes will not be considered further.

2. Practicability to manufacture, install, and service. If it is determined that mass production and reliable installation and servicing of a technology in commercial products could not be achieved on the scale necessary to serve the relevant market at the time of the projected compliance date of the standard, then that technology will not be considered further.

3. Impacts on product utility or product availability. If it is determined that a technology would have significant adverse impact on the utility of the product to significant subgroups of consumers or would result in the unavailability of any covered product type with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not be considered further.

4. Adverse impacts on health or safety. If it is determined that a technology would have significant adverse impacts on health or safety, it will not be considered further.

See 10 CFR part 430, subpart C, appendix A, 4(a)(4) and 5(b).

Technologies that pass through the screening analysis are referred to as ''design options'' in the engineering analysis. The screening analysis and engineering analysis are discussed in detail, respectively, in Chapters 4 and 5 of the TSD.

The subsequent sections include comments from interested parties pertinent to the screening criteria, DOE's evaluation of each technology option against the screening analysis criteria, and whether DOE screened out a particular technology option based on the above criteria.

1. Screened-Out Technologies

Of the identified technology options, DOE was not able to identify any that would fail the screening criteria. The cost of additional engineering resources is considered in the Manufacturer Impact Analysis of section IV.J. DOE seeks comment on whether sufficient resources would be available such that criterion 2 of the screening analysis is satisfied. This is identified as Issue 12 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

2. Remaining Technologies

After reviewing each technology, DOE tentatively concludes that all of the identified technologies listed in section IV.A.3 met all four screening criteria to be examined further as design options in DOE's NOPR analysis. In summary, DOE did not screen out the following technology options:

- Multi-staging
- Air-end Improvement
- Auxiliary Component Improvement

DOE determined that these technology options are technologically feasible because they are being used or have previously been used in commercially-available products or working prototypes. DOE also finds that all of the remaining technology options meet the other screening criteria (*i.e.,* practicable to manufacture, install, and service and do not result in adverse impacts on consumer utility, equipment availability, health, or safety). For additional details, see chapter 4 of the NOPR TSD.

C. Engineering Analysis

In the engineering analysis, DOE describes the relationship between manufacturer selling price (MSP) to improved compressor package isentropic efficiency. This relationship serves as the basis for cost-benefit calculations for individual end users, manufacturers, and the Nation. DOE typically structures the engineering analysis using one of three approaches: (1) Design-option; (2) efficiency level; or (3) reverse-engineering (or cost assessment). The design-option approach involves adding the estimated cost and associated efficiency of various efficiency-improving design changes to the baseline equipment to model different levels of efficiency. The

[46] One manufacturer, for example, describes its IE4 offerings here: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0033.*

[47] See page 12 of *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0032.*

efficiency level approach uses estimates of costs and efficiencies of equipment available on the market at distinct efficiency levels to develop the cost-efficiency relationship. The reverse-engineering approach involves testing equipment for efficiency and determining cost from a detailed bill of materials (BOM) derived from reverse-engineering representative equipment. The efficiency ranges from that of the least-efficient compressor sold today (*i.e.,* the baseline) to the maximum technologically feasible efficiency level. At each efficiency level examined, DOE determines the MSP; this relationship is referred to as a cost-efficiency curve.

DOE conducted the engineering analysis for this rulemaking using an efficiency level approach. The decision to use this approach was made due to several factors, including the wide variety of equipment sizes analyzed, the availability of reliable performance data, the availability of a comparable European Union study, and the nature of the design options available for the equipment.

1. Summary of Significant Data Sources

For the engineering analysis, DOE utilized four principal data sources: (1) A database of compressor performance data from CAGI data sheets; (2) results from the EU Lot 31—Ecodesign Preparatory Study on Compressors; (3) a dataset of confidential manufacturer price data; and (4) a dataset of online retailer prices. The following subsections provide a brief description of each significant data source. Complete details are found in Chapter 5 of the NOPR TSD.

a. CAGI Data Sheets

CAGI's Performance Verification program provides manufacturers a standardized test method and performance data reporting format for rotary compressors.[48] DOE compiled into one database the information contained in every CAGI Performance Verification data sheet found on the Web sites of individual manufacturers. The resulting database contains performance data on each verified individual compressor and is referred to as the ''CAGI database'' throughout this NOPR.

b. Lot 31—European Union Ecodesign Preparatory Study on Compressors

The Lot 31 study, described in section IV.A.2, investigated three types of compressors: Fixed-speed rotary standard air compressors, variable-speed rotary standard air compressors, and piston standard air compressors. For each compressor type, the Lot 31 study established two types of relationships between package isentropic efficiency and flow rate. The first relationship represents the market average package isentropic efficiency, as a function of flow, for each compressor type; this relationship is referred to as the ''Lot 31 regression curve.'' Generally the Lot 31 regression curves show an increase in package isentropic efficiency with an increase in flow rate.[49] The second relationship is derived from each Lot 31 regression curve and is known as the ''Lot 31 regulation curve.'' Lot 31 regulation curves are scaled from the Lot 31 regression curves using ''d-values'', which are explained further in section IV.C.5. The regression curves allowed the Lot 31 study to evaluate various standard levels, similar to how DOE would typically investigate various efficiency and trial standard levels. Chapter 5 and chapter 3 of the NOPR TSD provide further detail on the Lot 31 regression and regulation curves.

To evaluate the energy savings potential of these efficiency levels, the Lot 31 study established relationships between compressor package isentropic efficiency, flow rate, and list price for each compressor type. List price represents the price paid by the final customer. To determine the manufacturer selling price (MSP), or the price paid by the manufacturer's first customer, the Lot 31 study scaled the list price by a constant markup factor. Throughout this NOPR these relationships will be referred to as the ''Lot 31 MSP-Flow-Efficiency Relationships.'' Chapters 5 and chapter 3 of the NOPR TSD provide further detail on the Lot 31 MSP-Flow-Efficiency Relationships.

c. Confidential Manufacturer Equipment Data

DOE's contractor collected MSP and performance data for a range of compressor sizes and equipment classes from manufacturers.[50] These data are confidential and covered under non-disclosure agreement between the DOE contractor and the manufacturers. Data collected included pressure, flow rate, motor horsepower, full-load power (kW), motor efficiency, package specific power, and MSP for individual compressor models. Throughout this NOPR these will be referred to as the ''confidential, U.S. MSP data.''

d. Online Retailer Price Data

DOE collected price data for compressors sold by the online retailers Grainger,[51] Air Compressors Direct,[52] and Compressor World.[53] DOE also collected price and performance data for electric motors from Grainger to develop the scaling relationship for the R1_FS_L_XX equipment class described in section IV.C.5.c. These data are publicly available on each retailer's Web site and were compiled into a database that will be referred to as the ''online retailer price database'' throughout this NOPR.

2. Harmonization With Lot 31

The Lot 31 study resulted in a working document which proposed energy conservation standards for compressors. The current working document has not been formally adopted as a final regulation.

Many manufacturers participate in both the EU and U.S. markets, and during confidential interviews multiple manufacturers indicated that they have begun preparation to meet the requirements of the draft proposal, despite its not having been formally adopted as a regulation. Additionally DOE received comments from Atlas Copco that, due to the global nature of the industry, DOE should consider the findings in Lot 31 study. (Atlas-Copco, No. 0008 at p.2) And CAGI commented that it is important for regulations between the U.S. and EU to be similar given the global nature of the industry and many of its customers. (CAGI, No. 0030 at p. 1)

DOE recognizes that where applicable and justifiable it is beneficial to align with the Lot 31 study, because manufacturers have begun preparation for the Lot 31 proposal, the findings of the Lot 31 study can be useful, and it is important to have similar U.S. and EU regulations.

3. Representative Equipment

In the engineering analysis, DOE analyzed the MSP-efficiency relationships for the equipment classes specified in section IV.A.1. For both rotary and reciprocating equipment classes, DOE concluded, consistent with the EU Lot 31 study, that both incremental MSPs and attainable efficiency are independent of full-load

[48] For more information regarding CAGI's Performance Verification program, please see: *http://www.cagi.org/performance-verification/*

[49] See the Lot 31 Ecodesign Preparatory Study on Compressors Task 6 section 1.3.9, 1.3.10, and 1.3.11 here: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

[50] In developing standards, DOE may choose to contract with third party organizations who specialized in various functions.

[51] *http://www.grainger.com/.*

[52] *http://www.aircompressorsdirect.com/.*

[53] *http://www.compressorworld.com/.*

operating pressure.[54] However, DOE understands that absolute equipment MSP may vary by pressure. As such, DOE selected representative pressures as the basis for the development of their MSP-efficiency relationships. The representative pressures are 125 psig for rotary equipment classes, and 175 psig for reciprocating equipment classes. These pressures were selected because they represent the majority of equipment available in the CAGI database, and online retailer price database. Additionally, Chapter 5 of the NOPR TSD provides information regarding the distribution of pressures among available rotary and reciprocating models.

DOE requests comment on the use of 125 and 175 psig as representative pressures to establish absolute MSPs for rotary and reciprocating equipment classes, respectively. This is identified as Issue 13 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

As mentioned previously, DOE concluded, consistent with the EU Lot 31 study, that attainable efficiency is independent of full-load operating pressure.[55] Consequently, DOE used data from all full-load operating pressures represented in the CAGI database to establish efficiency levels for rotary air compressors. The CAGI database contains performance data for compressors ranging from 73 to 200 psig of full-load operating pressure and is representative of the full range of rotary compressor pressures available on the market. For reciprocating air compressors, DOE used a modified version of the EU Lot 31 regression and regulation curve for piston standard air compressors. The EU Lot 31 curves were recommended by the study author to be applicable to the full range of pressures proposed in the EU standard, ~101.5 − 203 psig (nominally: 7–14 bar (gauge)).[56] Section IV.C.5 contains complete details on the development of efficiency levels.

DOE requests comment on DOE's proposal to establish efficiency levels that are independent of pressure. This is identified as Issue 14 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

DOE also requests comment on DOE's proposal to establish incremental MSPs that are independent of pressure. This is identified as Issue 15 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

4. Design Options and Available Energy Efficiency Improvements

Section IV.A.2 identifies package redesign as the primary design option available to improve compressor efficiency. Multi-staging, air-end improvement, and auxiliary component improvement can be considered specialized cases of package redesign. In the first case, an additional air-end is introduced to the package, which affords the opportunity to dissipate heat after the first compression so that the second compression requires less work. Air-end improvement permits fine tuning of the air-end to the specific pressure and flow range in which it is expected to operate. The auxiliary component improvement option represents optimization of auxiliary components such as drives, motors, filters, valves, and piping. Ultimately, a manufacturer can implement a full package redesign to incrementally improve efficiency to any efficiency level, up to max-tech, as discussed in subsequent sections.

5. Efficiency Levels

For each equipment class, DOE established and analyzed six efficiency levels and a baseline to assess the relationship between MSP and package isentropic efficiency. As discussed previously, DOE's proposed efficiency levels are independent of full-load operating pressure. However, DOE concluded, consistent with the Lot 31 study,[57] that attainable package isentropic efficiency is a function of flow rate at full-load operating pressure. DOE notes that the test procedure NOPR proposed to define the term ''full-load actual volume flow rate'' to represent the actual volume flow rate of the compressor at the full-load operating pressure. As such, each efficiency level is defined by a mathematical relationship between full-load actual volume flow rate and package isentropic efficiency. Similarly to the Lot 31 study, DOE defines a regression curve (market average package isentropic efficiency, as a function of full-load actual volume flow rate) for each equipment class and uses specific ''d-values'' to shift the regression curve and establish efficiency levels for each equipment class, as discussed in section IV.C.1.b.

Similar to the approach used by the Lot 31 study, DOE defined the ''d-value,'' as a percentage reduction in losses from the regression curve to theoretical 100 percent package isentropic efficiency. The d-value is used as a metric to characterize compressor package isentropic efficiency with respect to the mean efficiency of the market (*i.e.,* the regression curve), and establish and evaluate various efficiency levels for all equipment classes. A positive d-value shifts the regression curve to a higher package isentropic efficiency for all full-load actual volume flow rates, and a negative d-value shifts the regression curve to lower package isentropic efficiency. A d-value of 100 would generate an efficiency level at 100 percent package isentropic efficiency for all full-load actual volume flow rates. Alternatively, a d-value of 50 would generate an efficiency level that falls halfway between the regression curve and 100 percent package isentropic efficiency for all full-load actual volume flow rates. And a d-value of zero would generate an efficiency level equal to the regression curve.

For each equipment class, DOE established efficiency levels at max-tech and a d-value of zero. DOE also established two intermediary efficiency levels between the baseline and a d-value of zero, and two efficiency levels between the d-value of zero level and max-tech.

For all equipment classes, efficiency level (EL) 6 represents the max-tech efficiency level. DOE considers technologies to be technologically feasible if they are incorporated in any currently available equipment or working prototypes. A max-tech level results from the combination of design options predicted to result in the highest efficiency level possible for an equipment class. DOE considers compressors a mature technology, with all available design options already existing in the marketplace. Therefore, for compressors, the max-tech efficiency level coincides with the maximum available efficiency already offered in the marketplace. As a result, DOE performed market-based analyses to determine max-tech/max-available levels. As with efficiency level, the max-tech/max-available levels are defined by d-values for each equipment class. Discussion of the process used to determine max-tech efficiency levels is in section IV.C.5 as well as chapter 5 of the NOPR TSD.

For all equipment classes, the baseline defines the lowest efficiency

[54] See the Lot 31 Ecodesign Preparatory Study on Compressors Task 6 section 1.2.2 and Task 7 section 2.4.1 here: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

[55] See the Lot 31 Ecodesign Preparatory Study on Compressors Task 6 section 1.2.2 here: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

[56] See the definition of standard air compressor in the working document here: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

[57] Discussed often, *e.g.,* Task 6 Section 1.3. See: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

equipment present in the market for each equipment class. DOE established baselines, represented by d-values, for each equipment class by reviewing available compressor performance data. Chapter 5 of the NOPR TSD provides additional information on the process used to select baseline efficiency levels.

Jenny commented that with the variety of air compressors available on the market, selecting baseline levels is difficult. Jenny added that larger manufacturers are more likely to test equipment efficiency—and as a result, Jenny cautioned that they may be unfairly represented in the baseline because smaller manufacturers are less likely to test equipment. (Jenny, No. 0005 at p. 4)

DOE recognizes that there are a variety of compressors available on the market that represent a range of efficiency levels. For this rulemaking, the baseline represents the lowest efficiency equipment commonly sold on the market; independent of the manufacturer. DOE used all available data to select the baseline. DOE requests additional data which can be used to refine its current baseline, max-tech, and efficiency level assumptions. This is identified as Issue 16 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

For all equipment classes, EL 3 corresponds to a d-value of zero, which represents the mean efficiency available on the market. The European Union draft regulation proposed a d-value of zero for a minimum energy efficiency requirement in 2020.[58] DOE notes that although the EU Lot 31 draft regulation proposes to cover only fixed-speed rotary standard air compressors, variable-speed rotary standard air compressors, and piston standard air compressors, DOE chose to evaluate a d-value of zero for all equipment classes.

EL 1 and EL 2 are established as intermediary efficiency levels one-third and two-thirds of the way, respectively, between the baseline and EL 3. EL 4 is an efficiency level established slightly above EL 3 to evaluate the sensitivity of going above the EU Lot 31 draft regulation. EL 5 is an intermediary efficiency level established approximately halfway between EL 3 and EL 6. The specific d-values for EL 1, 2, 4, and 5 vary for each equipment class.

As discussed in section IV.C.3, efficiency levels for each equipment class are independent of full-load operating pressure.

DOE pursued different analytical methods to establish efficiency levels for different equipment classes. These analytical methods can be grouped into three general categories presented in Table IV.4.

TABLE IV.4—EFFICIENCY LEVEL ANALYTICAL METHODS

Method	Applicable equipment classes
Direct from Lot 31	RP_FS_L_AC RP_VS_L_AC R3_FS_L_XX
Developed from CAGI Database	RP_FS_LF_AC RP_VS_LF_AC
Scaled from Other Equipment Classes, Using U.S. Data	RP_FS_L_WC RP_VS_L_WC RP_FS_LF_WC RP_VS_LF_WC R1_FS_L_XX

The following sections present the analytical methods used by DOE to develop the efficiency levels for each equipment class.

a. Direct From Lot 31

Table IV.5 shows the three equipment classes for which efficiency levels are derived from analogous EU Lot 31 regression curves.

TABLE IV.5—EQUIPMENT CLASS EFFICIENCY LEVELS DERIVED FROM LOT 31

Equipment Class	EU Lot 31 regression curve
RP_FS_L_AC	Fixed speed rotary standard air compressors.
RP_VS_L_AC	Variable-speed rotary standard air compressors.
R3_FS_L_XX	Piston standard air compressors.

The analogous EU Lot 31 regression curves for the RP_FS_L_AC and RP_VS_L_AC equipment classes are based on CAGI data for equipment sold in the United States at the time of the Lot 31 study.[59] DOE regressed the CAGI database data for these two equipment classes and compared the results to the analogous EU Lot 31 regression curves. DOE found that the shape of the new CAGI database curves were a close approximation to the Lot 31 regression curves and the magnitude (or y-axis scaling) of the curves were also a close fit with the EU curve. Generally, the RP_FS_L_AC CAGI database regression curve was within one efficiency point of the EU curve and the RP_VS_L_AC CAGI database curve was within two efficiency points of the EU curve for flow rates where CAGI data was available. Ultimately, due to the similarity of the regressions and the overall benefits of harmonizing with the European Union, DOE decided to use Lot 31 regressions, rather than the regressions obtained from the current CAGI database. DOE notes that differences between the CAGI database regression curves and the EU Lot 31

[58] For more information regarding the draft regulation see: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031*.

[59] See Task 6 Section 1.3: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031*.

regression curves can be compensated through use of d-values to scale to alternative efficiencies. Chapter 5 of the NOPR TSD provides complete details on the relationships between the EU Lot 31 regression curves and the current CAGI database regression curves.

Unlike rotary air compressors, DOE lacks publicly available performance data for reciprocating air compressors. Furthermore, discussions with industry experts indicate that the EU reciprocating air compressor markets may not be directly analogous or representative of the U.S. market. Specifically, industry experts indicate that EU reciprocating air compressors are predominantly single-stage units designed for lower operating pressures and duty cycles. Alternatively, industry experts indicate that U.S. reciprocating compressors are a more balanced mix of single- and two-stage units, typically designed for higher duty cycles. As described in section IV.A.3.a, single-stage units are inherently less efficient than two-stage units, and single-stage units tend to be designed for lower flow rates. These inherent differences in efficiency and flow rate make it difficult to use aggregated EU market data as a proxy for the U.S. market.

Ultimately, in the absence of sufficient U.S. efficiency data, DOE based efficiency levels for the R3_FS_L_XX equipment class on the EU Lot 31 regression curve for piston standard air compressors. However, DOE increased the max-tech level for R3_FS_L_XX beyond that of the Lot 31 study, based on limited confidential performance data collected by DOE's contractor. Chapter 5 of the NOPR TSD provides complete details on derivation of efficiency levels and max-tech for the R3_FS_L_XX equipment class.

DOE requests comment on the use of the EU Lot 31 regression curve for piston standard air compressors to define the regression curve of the R3_FS_L_XX equipment class. This is identified as Issue 17 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

i. RP_FS_L_AC Efficiency Levels

The proposed regression curve for the RP_FS_L_AC equipment class is as follows:

$$\eta_{Isen\_Regr}\text{\_RP\_FS\_L\_AC} = -0.00928 \times \ln(0.472 \times V_1)^2 + 0.139 \times \ln(0.472 \times V_1) + 0.271$$

Equation 3

Where:

- η_{Isen_Regr}_RP_FS_L_AC is the regression curve package isentropic efficiency for the RP_FS_L_AC equipment class, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

The proposed efficiency levels for the RP_FS_L_AC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.6.

$$\eta_{Isen\_STD}\text{\_RP\_FS\_L\_AC} = \eta_{Isen\_Regr}\text{\_RP\_FS\_L\_AC} + \left(1 - \eta_{Isen\_Regr}\text{\_RP\_FS\_L\_AC}\right) \times d/100$$

Equation 4

Where:

- η_{Ise_STD}_RP_FS_L_AC is package isentropic efficiency for the RP_FS_L_AC equipment class, for a selected efficiency level,
- η_{Isen_Regr}_RP_FS_L_AC is the regression curve package isentropic efficiency for the RP_FS_L_AC equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.6.

TABLE IV.6—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICATED, AIR-COOLED, FIXED-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−49
EL 1	−30
EL 2	−15
EL 3	0
EL 4	5
EL 5	13
EL 6	30

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 4 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, 5.1, 5.2, and 5.3. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

ii. RP_VS_L_AC Efficiency Levels

The proposed regression curve for the RP_VS_L_AC equipment is as follows:

$$\eta_{Isen\_Regr}\text{\_RP\_VS\_L\_AC} = -0.0155 \times \ln(0.472 \times V_1)^2 + 0.216 \times \ln(0.472 \times V_1) + 0.00905$$

Equation 5

Where:

- $\eta_{Isen\_Regr\_RP\_VS\_L\_AC}$ is the regression curve package isentropic efficiency for the RP_VS_L_AC equipment class, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

The proposed efficiency levels for the RP_VS_L_AC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.7.

$$\eta_{Isen\_STD\_RP\_VS\_L\_AC} = \eta_{Isen\_Regr\_RP\_VS\_L\_AC} + \left(1 - \eta_{Isen\_Regr\_RP\_VS\_L\_AC}\right) \times d/100$$

Equation 6

Where:

- $\eta_{Isen\_STD\_RP\_VS\_L\_AC}$ is package isentropic efficiency for the RP_VS_L_AC equipment class, for a selected efficiency level,
- $\eta_{Isen\_Regr\_RP\_VS\_L\_AC}$ is the regression curve package isentropic efficiency for the RP_VS_L_AC equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.7.

TABLE IV.7—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICATED, AIR-COOLED, VARIABLE-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−30
EL 1	−20
EL 2	−10
EL 3	0
EL 4	5
EL 5	15
EL 6	33

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 4 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, 5.1, 5.2, and 5.3. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

iii. R3_FS_L_XX Efficiency Levels

The proposed regression curve for the R3_FS_L_XX equipment class is as follows:

$$\eta_{Isen\_Regr\_R3\_FS\_L\_XX} = 0.0893 \times \ln(0.472 \times V_1) + 0.315$$

Equation 7

Where:

- $\eta_{Isen\_Regr\_R3\_FS\_L\_XX}$ is the regression curve package isentropic efficiency for the R3_FS_L_XX equipment class, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

The proposed efficiency levels for the R3_FS_L_XX equipment class are defined by the following equation, in conjunction with the d-values in Table IV.8.

$$\eta_{Isen\_STD\_R3\_FS\_L\_XX} = \eta_{Isen\_Regr\_R3\_FS\_L\_XX} + \left(1 - \eta_{Isen\_Regr\_R3\_FS\_L\_XX}\right) \times d/100$$

Equation 8

Where:

- $\eta_{Isen\_STD\_R3\_FS\_L\_XX}$ is package isentropic efficiency for the R3_FS_L_XX equipment class, for a selected efficiency level,
- $\eta_{Isen\_Regr\_R3\_FS\_L\_XX}$ is the regression curve package isentropic efficiency for the R3_FS_L_XX equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.8.

TABLE IV.8—EFFICIENCY LEVELS ANALYZED FOR RECIPROCATING, LUBRICATED, AIR-COOLED OR WATER-COOLED, FIXED-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−18
EL 1	−15
EL 2	−5
EL 3	0
EL 4	5
EL 5	20
EL 6	60

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 4 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, 5.1, 5.2, and 5.3. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

DOE requests comment and supporting data on the efficiency levels established for the RP_FS_L_AC, RP_VS_L_AC, and R3_FS_L_XX equipment classes. This is identified as Issue 18 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

b. Developed From CAGI Database

The proposed regression curve and efficiency levels for the RP_FS_LF_AC and RP_VS_LF_AC equipment classes are derived from data within the CAGI database. DOE notes that available CAGI data in each equipment class does not span the entire range of full-load actual volume flow rates evaluated. There was a lack of data at low and high full-load actual volume flow rates, so DOE based portions of the RP_FS_LF_AC and RP_VS_LF_AC equipment class regression curves on the analogous lubricated equipment classes. Consequently, the regression curves for the RP_FS_LF_AC and RP_VS_LF_AC equipment classes are composed of three piece-wise continuous functions. Chapter 5 of the NOPR TSD provides complete details on the curves developed based on the CAGI database.

i. RP_FS_LF_AC Efficiency Levels

The proposed regression curve for the RP_FS_LF_AC equipment class is as follows:

$$\eta_{Isen\_Regr}\text{RP\_FS\_LF\_AC} = a_{RP\_FS\_LF\_AC} \times \ln(0.472 \times V_1)^2 + b_{RP\_FS\_LF\_AC} \times \ln(0.472 \times V_1) + c_{RP\_FS\_LF\_AC}$$

Equation 9

Where:

- η_{Isen_Regr}RP_FS_LA is the regression curve package isentropic efficiency for the RP_FS_LF_AC equipment class,
- $a_{RP\_FS\_LF\_AC}$ is a coefficient from Table IV.9,
- $b_{RP\_FS\_LF\_AC}$ is a coefficient from Table IV.9,
- $c_{RP\_FS\_LF\_AC}$ is a coefficient from Table IV.9, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

TABLE IV.9—COEFFICIENTS FOR RP_FS_LF_AC REGRESSION CURVE

Full-load actual volume flow rate range (acfm)	$a_{RP\_FS\_LF\_AC}$	$b_{RP\_FS\_LF\_AC}$	$c_{RP\_FS\_LF\_AC}$
$0<V_1\leq161$	−0.00928	0.139	0.191
$161<V_1\leq2125$	0.00281	0.0344	0.417
$2125<V_1$	−0.00928	0.139	0.271

The proposed efficiency levels for the RP_FS_LF_AC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.10.

$$\eta_{Isen\_STD}\text{RP\_FS\_LF\_AC} = \eta_{Isen\_Regr}\text{RP\_FS\_LF\_AC} + \left(1 - \eta_{Isen\_Regr}\text{RP\_FS\_LF\_AC}\right) \times d/100$$

Equation 10

Where:

- η_{Isen_STD}RP_FS_LF_AC is package isentropic efficiency for the RP_FS_LF_AC equipment class, for a selected efficiency level,
- η_{Isen_Regr}RP_FS_LF_AC is the regression curve package isentropic efficiency for the RP_FS_LF_AC equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.10.

TABLE IV.10—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICANT-FREE, AIR-COOLED, FIXED-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−11
EL 1	−10
EL 2	−5
EL 3	0
EL 4	2.5
EL 5	7.5
EL 6	10

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 1 auxiliary efficiency level, beyond the primary efficiency levels listed in this table; this is EL 4.1. This auxiliary efficiency level was maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. To maintain a consistent analytical structure with other equipment classes the spreadsheets contain EL 5.1, 5.2, and 5.3 which are equal to EL 6. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

ii. RP_VS_LF_AC Efficiency Levels

The proposed regression curve for the RP_VS_LF_AC equipment class is as follows:

$$\eta_{Isen\_Regr}\text{\_RP\_VS\_LF\_AC} = a_{RP\_VS\_LF\_AC} \times \ln(0.472 \times V_1)^2 + b_{RP\_VS\_LF\_AC} \times \ln(0.472 \times V_1) + c_{RP\_VS\_LF\_AC}$$

Equation 11

Where:

- η_{Isen_Regr}_RP_VP_LF_AC is the regression curve package isentropic efficiency for the RP_VS_LF_AC equipment class,
- $\alpha_{RP\_VS\_LF\_AC}$ is a coefficient from Table IV.11,
- $b_{RP\_VS\_LF\_AC}$ is a coefficient from Table IV.11,
- $c_{RP\_VS\_LF\_AC}$ is a coefficient from Table IV.11, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

TABLE IV.11—COEFFICIENTS FOR RP_VS_LF_AC REGRESSION CURVE

Full-load actual volume flow rate range (acfm)	$\alpha_{RP\_VP\_LF\_AC}$	$b_{RP\_VP\_LF\_AC}$	$c_{RP\_VP\_LF\_AC}$
$0<V_1\leq102$	−0.0155	0.216	−0.0984
$102<V_1\leq1426$	0.000	0.0958	0.134
$1426<V_1$	−0.0155	0.216	0.00905

The proposed efficiency levels for the RP_VS_LF_AC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.12.

$$\eta_{Isen\_STD}\text{\_RP\_VS\_LF\_AC} = \eta_{Isen\_Regr}\text{\_RP\_VS\_LF\_AC} + \left(1 - \eta_{Isen\_Regr}\text{\_RP\_VS\_LF\_AC}\right) \times d/100$$

Equation 12

Where:

- η_{Isen_STD}_RP_VS_LF_AC is package isentropic efficiency for the RP_VS_LF_AC equipment class, for a selected efficiency level,
- η_{Isen_Regr}_RP_VS_LF_AC is the regression curve package isentropic efficiency for the RP_VS_LF_AC equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.12.

TABLE IV.12—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICANT-FREE, AIR-COOLED, VARIABLE-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−13
EL 1	−10
EL 2	−5
EL 3	0
EL 4	2.5
EL 5	7.5
EL 6	13

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 1 auxiliary efficiency level, beyond the primary efficiency levels listed in this table; this is EL 4.1. This auxiliary efficiency level was maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. To maintain a consistent analytical structure with other equipment classes the spreadsheets contain EL 5.1, 5.2, and 5.3 which are equal to EL 6. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

DOE notes that the proposed regression curve and efficiency levels for the RP_VS_LF_AC equipment class were established with a limited set of data from the CAGI database. Specifically, the CAGI database included data for 13 RP_VS_LF_AC air compressors as compared to 60 for RP_FS_LF_AC compressors, and 835 for RP_FS_L_AC compressors. Chapter 5 of the NOPR TSD contains complete details on the datasets and regression methodologies.

DOE requests comment on the proposed efficiency levels selected for the RP_VS_LF_AC equipment class regarding their representation of the market, and any data that could improve the analysis. This is identified as Issue 19 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

c. Scaled From Other Equipment Classes, Using U.S. Data

DOE scaled efficiency levels for water-cooled rotary from analogous air-cooled rotary equipment classes based on relationships developed from the CAGI database. Additionally, DOE scaled R1_FS_L_XX efficiency levels from R3_FS_L_XX efficiency levels based on motor data in the online retailer price database.

Many air-cooled rotary air compressors are also offered in a water-cooled variant. These variants are typically identical, except for the cooling method employed. The air-cooled variant will utilize one or more cooling fans and heat exchangers to remove heat from the compressed air. Alternatively, a water-cooled variant utilizes chilled water (from a separate chilled water system) and one or more heat exchanges to remove heat from the compressed air. Typically, both variants will remove the same amount of heat and offer the same output flow and pressure. The key difference is that the fan(s) used in the air-cooled unit are within the compressor package and cause the air-cooled unit to consume more energy than the water-cooled unit, which receives water pumped from a chiller external to the compressor package. This means that for water-cooled units the energy used to remove heat by external pumps and chillers is not accounted for in the test procedure and not reflected in package isentropic efficiency. Consequently, DOE established its proposed efficiency levels for water-cooled equipment classes by scaling analogous air-cooled efficiency levels to account for the lack of a fan motor. Specifically, for each equipment class, DOE developed a scaling relationship using the CAGI database and applied it to efficiency levels from the associated air-cooled equipment class.

Many reciprocating air compressors with motor power ≤7.5-hp are offered with both single- and three-phase induction motors. These variants are typically identical, except for the motor. Consequently, DOE established its proposed efficiency levels for single-phase equipment classes by scaling the analogous three-phase efficiency levels to account for inherent efficiency differences between single- and three-phase motors. DOE developed a scaling relationship using the online retailer price database and applied it to efficiency levels from R3_FS_L_XX. Ultimately, DOE established the proposed single- and three-phase equipment classes and efficiency levels, such that analogous single- and three-phase equipment would be rated at approximately the same efficiency level, when evaluated with the proposed DOE test procedure.

The following subsections provide the equations and d-values used to establish the proposed efficiency levels for the RP_FS_L_WC, RP_VS_L_WC, RP_FS_LF_WC, RP_VS_LF_WC, and R1_FS_L_XX equipment classes. Chapter 5 of the NOPR TSD provides complete details on the scaling relationships used to develop the proposed efficiency levels for equipment classes discussed in this section.

i. RP_FS_L_WC Efficiency Levels

The proposed efficiency levels for the RP_FS_L_WC equipment class are derived from the RP_FS_L_AC equipment class.

The proposed efficiency levels for the RP_FS_L_WC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.13.

$$\eta_{Isen\_STD\_}\text{RP\_FS\_L\_WC} = 0.0235 + \eta_{Isen\_Regr\_}\text{RP\_FS\_L\_AC} + \left(1 - \eta_{Isen\_Regr\_}\text{RP\_FS\_L\_AC}\right) \times d/100$$

Equation 13

Where:

- $\eta_{Isen_STD_}$RP_FS_L_WC is package isentropic efficiency for the RP_FS_L_WC equipment class, for a selected efficiency level,
- $\eta_{Isen_Regr_}$RP_FS_L_AC is the regression curve package isentropic efficiency for the RP_FS_L_AC equipment class, and
- *d* is the d-value for each proposed efficiency level, as specified in Table IV.13.

TABLE IV.13—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICATED, WATER-COOLED, FIXED-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−49
EL 1	−30
EL 2	−15
EL 3	0
EL 4	5
EL 5	13
EL 6	30

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 4 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, 5.1, 5.2, and 5.3. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

ii. RP_VS_L_WC Efficiency Levels

The proposed efficiency levels for the RP_VS_L_WC equipment class are derived from the RP_VS_L_AC equipment class.

The proposed efficiency levels for the RP_VS_L_WC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.14.

$$\eta_{Isen\_STD\_}\text{RP\_VS\_L\_WC} = 0.0235 + \eta_{Isen\_Regr\_}\text{RP\_VS\_L\_AC} + \left(1 - \eta_{Isen\_Regr\_}\text{RP\_VS\_L\_AC}\right) \times d/100$$

Equation 14

Where:

- $\eta_{Isen—STD_}$RP_VS_L_WC is package isentropic efficiency for the RP_VS_L_WC equipment class, for a selected efficiency level,
- $\eta_{Isen—Regr_}$RP_VS_L_AC is the regression curve package isentropic efficiency for the RP_VS_L_AC equipment class, and
- *d* is the d-value for each proposed efficiency level, as specified in Table IV.14.

TABLE IV.14—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICATED, WATER-COOLED, VARIABLE-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−45
EL 1	−30
EL 2	−15
EL 3	0
EL 4	5
EL 5	15
EL 6	34

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 4 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, 5.1, 5.2, and 5.3. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

iii. RP_FS_LF_WC Efficiency Levels

The proposed efficiency levels for the RP_FS_LF_WC equipment class are derived from the RP_FS_LF_AC equipment class.

The proposed efficiency levels for the RP_FS_LF_WC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.16.

$$\eta_{Isen\_STD}\text{RP\_FS\_LF\_WC} = a_{RP\_FS\_LF\_WC} \times \ln(0.472 \times V_1)^2 + b_{RP\_FS\_LF\_WC} \times \ln(0.472 \times V_1) + c_{RP\_FS\_LF\_WC} + \eta_{Isen\_Regr}\text{RP\_FS\_LF\_AC} + \left(1 - \eta_{Isen\_Regr}\text{RP\_FS\_LF\_AC}\right) \times d/100$$

Equation 15

Where:

- η_{Isen_STD}RP_FS_LF_WC is package isentropic efficiency for the RP_FS_LF_WC equipment class, for a selected efficiency level,
- $\alpha_{RP\_FS\_LF\_WC}$ is a coefficient from Table IV.15,
- $b_{RP\_FS\_LF\_WC}$ is a coefficient from Table IV.15,
- $c_{RP\_FS\_LF\_WC}$ is a coefficient from Table IV.15,
- V_1 is full-load actual volume flow rate (cubic feet per minute),
- η_{Isen_Regr}RP_FS_LF_AC is the regression curve package isentropic efficiency for the RP_FS_LF_AC equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.16.

TABLE IV.15—COEFFICIENTS FOR RP_FS_LF_WC EFFICIENCY LEVEL

Full-load actual volume flow rate range (acfm)	$\alpha_{RP\_FS\_LF\_WC}$	$b_{RP\_FS\_LF\_WC}$	$c_{RP\_FS\_LF\_WC}$
$0 < V_1 < 102$	0	0	0
$102 \leq V_1$	−0.00924	0.117	−0.315

TABLE IV.16—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICANT-FREE, WATER-COOLED, FIXED-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−11
EL 1	−10
EL 2	−5
EL 3	0
EL 4	2.5
EL 5	7.5
EL 6	10

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 2 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, and 5.1. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. To maintain a consistent analytical structure with other equipment classes the spreadsheets contain EL 5.2, and 5.3 which are equal to EL 6. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

iv. RP_VS_LF_WC Efficiency Levels

The proposed efficiency levels for the RP_VS_LF_WC equipment class are derived from the RP_VS_LF_AC equipment class.

The proposed efficiency levels for the RP_VS_LF_WC equipment class are defined by the following equation, in conjunction with the d-values in Table IV.18.

$$\eta_{Isen\_STD}\text{RP\_VS\_LF\_WC} = a_{RP\_VS\_LF\_WC} \times \ln(0.472 \times V_1)^2 + b_{RP\_VS\_LF\_WC} \times \ln(0.472 \times V_1) + c_{RP\_VS\_LF\_WC} + \eta_{Isen\_Regr}\text{RP\_VS\_LF\_AC} + \left(1 - \eta_{Isen\_Regr}\text{RP\_VS\_LF\_AC}\right) \times d/100$$

Equation 16

Where:

- η_{Isen_STD}RP_VS_LF_WC is package isentropic efficiency for the RP_VS_LF_WC equipment class, for a selected efficiency level,
- $\alpha_{RP\_VS\_LF\_WC}$ is a coefficient from Table IV.17,
- $b_{RP\_VS\_LF\_WC}$ is a coefficient from Table IV.17,
- $c_{RP\_VS\_LF\_WC}$ is a coefficient from Table IV.17,
- V_1 is full-load actual volume flow rate (cubic feet per minute),
- η_{Isen_Regr}RP_VS_LF_AC is the regression curve package isentropic efficiency for the RP_VS_LF_AC equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.18.

TABLE IV.17—COEFFICIENTS FOR RP_VS_LF_WC EFFICIENCY LEVEL

Full-load actual volume flow rate range (acfm)	$\alpha_{RP\_VS\_LF\_WC}$	$b_{RP\_VS\_LF\_WC}$	$c_{RP\_VS\_LF\_WC}$
$0 < V_1 < 74$	0	0	0
$74 \leq V_1$	0.000173	0.00783	−0.0300

TABLE IV.18—EFFICIENCY LEVELS ANALYZED FOR ROTARY, LUBRICANT-FREE, WATER-COOLED, VARIABLE-SPEED, THREE-PHASE

Efficiency level *	d-Value
Baseline	−13
EL 1	−10
EL 2	−5
EL 3	0
EL 4	2.5
EL 5	7.5
EL 6	13

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 2 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, and 5.1. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. To maintain a consistent analytical structure with other equipment classes the spreadsheets contain EL 5.2, and 5.3 which are equal to EL 6. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

DOE notes that the proposed regression curve and efficiency levels for the RP_VS_LF_WC equipment class were established with a limited set of data from the CAGI database. Specifically, the CAGI database included data for 13 RP_VS_LF_WC air compressors as compared to 63 for RP_FS_LF_WC compressors, and 440 for RP_FS_L_WC compressors. Chapter 5 of the NOPR TSD contains complete details on the datasets and regression methodologies.

DOE requests comment on the proposed efficiency levels selected for the RP_VS_LF_WC equipment class regarding their representation of the market, and any data that could improve the analysis. This is identified as Issue 20 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

v. R1_FS_L_XX Efficiency Levels

The proposed efficiency levels for the R1_FS_L_XX equipment class are defined by the following equation, in conjunction with the d-values in Table IV.19.

$$\eta_{Isen\_STD\_R1\_FS\_L\_XX} = (\eta_{Isen\_Regr\_R3\_FS\_L\_XX} + (1 - \eta_{Isen\_Regr\_R3\_FS\_L\_XX}) \times d/100)/1.091$$

Equation 17

Where:

- $\eta_{Isen\_STD\_R1\_FS\_L\_XX}$ is package isentropic efficiency for the R1_FS_L_XX equipment class, for a selected efficiency level,
- $\eta_{Isen\_Regr\_R3\_FS\_L\_XX}$ is the regression curve package isentropic efficiency for the R3_FS_L_XX equipment class, and
- d is the d-value for each proposed efficiency level, as specified in Table IV.19.

TABLE IV.19—EFFICIENCY LEVELS ANALYZED FOR RECIPROCATING, LUBRICATED, AIR-COOLED OR WATER-COOLED, FIXED-SPEED, SINGLE-PHASE

Efficiency level *	d-Value
Baseline	−18
EL 1	−15
EL 2	−5
EL 3	0
EL 4	5
EL 5	20
EL 6	60

* DOE notes that in this NOPR, the spreadsheets for the downstream economic analyses contain 4 auxiliary efficiency levels, beyond the primary efficiency levels listed in this table; these are EL 4.1, 5.1, 5.2, and 5.3. These auxiliary efficiency levels were maintained in the spreadsheets to increase the granularity and improve analytical accuracy of the economic analyses, however, they are not carried beyond the spreadsheets. Cost-efficiency relationships for these ELs are provided in Chapters 5 of the NOPR TSD.

DOE requests comment and supporting data on the proposed efficiency levels established for the R1_FS_L_XX equipment class. This is identified as Issue 21 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

6. Manufacturer Selling Price

This section presents the MSP-efficiency relationship for each equipment class and discusses the analytical methods used to develop these relationships. For all equipment classes, DOE defines MSP by a mathematical relationship between full-load actual volume flow rate and package isentropic efficiency. However, for the purposes of DOE's analysis, package isentropic efficiency is represented indirectly through the use of a d-value. For a complete discussion of the d-value, please refer to section IV.C.5.

DOE pursued different analytical methods to find the MSP-efficiency relationships for different equipment classes. These analytical methods can be grouped into four general categories, as presented in Table IV.20.

TABLE IV.20—MANUFACTURER SELLING PRICE ANALYTICAL METHODS

Method	Applicable equipment classes
Direct Scaling from Lot 31	RP_FS_L_AC RP_VS_L_AC
Scaling with U.S. MSP Data.	RP_FS_LF_AC RP_VS_LF_AC
MSPs for Water-Cooled Equipment.	RP_FS_L_WC RP_VS_L_WC RP_FS_LF_WC RP_VS_LF_WC
New Relationships from U.S. Data.	R3_FS_L_XX R1_FS_L_XX

Jenny commented that pricing information that is publicly available may not be accurate or contain consistent information between manufacturers. Specifically, key pricing and costing information such as labor may be inconsistent because manufacturers operate in different countries with different costs of labor. (Jenny, No. 0005 at p. 4)

DOE's analysis includes MSP information gathered from a variety of sources. These sources include publicly available data as well as confidential manufacturer data collected by a DOE contractor. Data collected under non-disclosure agreement was vetted by DOE's contractor for accuracy and consistency between manufacturers. DOE used all available datasets to establish MSP-efficiency relationships for each equipment class. The following sections present the analytical methods DOE applied to each equipment class to develop an MSP-efficiency relationship.

a. Direct Scaling From Lot 31

When possible, DOE used the Lot 31 study's MSP-Flow-Efficiency Relationships as a starting point to construct analogous MSP-Flow-Efficiency Relationships for U.S. equipment. To do so, DOE scaled Lot 31 MSP-Flow-Efficiency Relationships with analogous equipment classes (*i.e.,* RP_FS_L_AC, and RP_VS_L_AC) using confidential, U.S. MSP data. Specifically, DOE scaled the Lot 31 study's absolute equipment MSPs to a magnitude that represents MSPs offered in the U.S. market. Although MSP magnitudes were scaled, DOE maintained the incremental MSP trends established in the Lot 31 study. Chapter 5 of the NOPR TSD provides details on the calculation of MSP for each rotary equipment class.

DOE requests comment on the use of Lot 31 MSP-Flow-Efficiency Relationships to develop MSP-flow-efficiency relationships for the proposed RP_FS_L_AC and RP_VS_L_AC equipment classes. This is identified as Issue 22 in section VIII.E, "Issues on Which DOE Seeks Comment."

i. RP_FS_L_AC MSP-Flow-Efficiency Relationship

The MSP-flow-efficiency relationship for the RP_FS_L_AC equipment class is as follows:

$$MSP_{\mathrm{RP\_FS\_L\_AC}} = 0.820 \times \left[(4.72 \times V_1 + 2500) + (136.88 \times V_1 + 10000) \times \eta_{Isen\_STD\_\mathrm{RP\_FS\_L\_AC}}{}^{3}\right]$$

Equation 18

Where:

- $MSP_{\mathrm{RP\_FS\_L\_AC}}$ is the manufacturer selling price for the RP_FS_L_AC at a selected efficiency level and full-load actual volume flow rate,
- $\eta_{Isen\_STD\_\mathrm{RP\_FS\_L\_AC}}$ is package isentropic efficiency for the RP_FS_L_AC equipment class, for a selected efficiency level and full-load actual volume flow rate, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

MSP for each efficiency level for the RP_FS_L_AC equipment class is presented in Table IV.21 at representative full-load actual volume flow rates.

TABLE IV.21—REPRESENTATIVE MSPS FOR THE RP_FS_L_AC EQUIPMENT CLASS

Full-load actual volume flow rate (acfm)	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
10	$2,166	$2,351	$2,618	$3,024	$3,195	$3,510	$4,368
20	2,437	2,784	3,192	3,742	3,960	4,349	5,349
50	3,350	4,007	4,680	5,506	5,818	6,357	7,677
100	4,975	6,039	7,063	8,264	8,707	9,460	11,257
200	8,517	10,319	11,983	13,877	14,562	15,716	18,414
500	20,350	24,243	27,719	31,572	32,943	35,230	40,484
1000	41,492	48,764	55,158	62,159	64,633	68,739	78,091
2000	84,566	98,510	110,668	123,888	128,539	136,240	153,696
5000	208,211	242,244	271,856	304,004	315,302	333,997	376,324

ii. RP_VS_L_AC MSP-Flow-Efficiency Relationship

The MSP-flow-efficiency relationship for the RP_VS_L_AC equipment class is as follows:

$$MSP_{\mathrm{RP\_VS\_L\_AC}} = 1.302 \times \left[(4.72 \times V_1 + 2500) + (136.88 \times V_1 + 10000) \times \eta_{Isen\_STD\_\mathrm{RP\_VS\_L\_AC}}{}^3\right]$$

Equation 19

Where:

- $MSP_{\mathrm{RP\_VS\_L\_AC}}$ is the manufacturer selling price for the RP_VS_L_AC at a selected efficiency level and full-load actual volume flow rate,
- $\eta_{Isen\_STD\_\mathrm{RP\_VS\_L\_AC}}$ is package isentropic efficiency for the RP_VS_L_AC equipment class, for a selected efficiency level and full-load actual volume flow rate, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

MSP for each efficiency level for the RP_VS_L_AC equipment class is presented in Table IV.22 at representative full-load actual volume flow rates.

TABLE IV.22—REPRESENTATIVE MSPS FOR THE RP_VS_L_AC EQUIPMENT CLASS

Full-load actual volume flow rate (acfm)	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
10	$3,330	$3,386	$3,514	$3,742	$3,904	$4,340	$5,587
20	3,606	3,818	4,131	4,565	4,834	5,488	7,109
50	4,935	5,474	6,139	6,943	7,401	8,437	10,743
100	7,577	8,526	9,624	10,883	11,576	13,097	16,314
200	13,526	15,189	17,044	19,101	20,209	22,590	27,461
500	33,464	37,092	41,031	45,292	47,548	52,317	61,802
1000	68,234	75,013	82,293	90,093	94,193	102,806	119,743
2000	135,819	148,853	162,796	177,678	185,481	201,831	233,842
5000	312,284	344,330	378,745	415,616	434,998	475,708	555,762

b. Scaling With U.S. MSP Data

For rotary equipment classes with no Lot 31 study analogues (*i.e.,* RP_FS_LF_AC and RP_VS_LF_AC), DOE used confidential, U.S. MSP data from representative lubricant-free units to scale the lubricated MSP-flow-efficiency relationship, presented in section I.A.1.a, to represent the U.S. lubricant-free MSP-flow-efficiency relationship.

i. RP_FS_LF_AC MSP-Flow-Efficiency Relationship

DOE used MSP data from equipment of the same full-load actual volume flow rate and d-value to scale the RP_FS_L_AC MSP-flow-efficiency relationship to a new RP_FS_LF_AC MSP-flow-efficiency relationship. The new relationship resulted in significantly larger absolute MSP for RP_FS_LF_AC, as compared to RP_FS_L_AC. The new relationship also resulted in significantly larger incremental MSP for RP_FS_LF_AC, as compared to RP_FS_L_AC. Equation 20 provides the mathematical relationship between RP_FS_L_AC and RP_FS_LF_AC MSP for a given d-value and full-load actual volume flow rate. Chapter 5 of the NOPR TSD provides details on the calculation of MSP for each rotary equipment class.

DOE requests comment on the methods used to develop RP_FS_LF_AC (lubricant-free) incremental MSP. Specifically, DOE requests comment on the use of RP_FS_L_AC (lubricated) incremental MSP relationship to develop a lubricant-free incremental MSP relationship. This is identified as Issue 23 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

The MSP relationship for the RP_FS_LF_AC equipment class is as follows:

$$MSP_{\mathrm{RP\_FS\_LF\_AC}} = 1.410 \times MSP_{\mathrm{RP\_FS\_L\_AC}} + 33630$$

Equation 20

Where:

- $MSP_{\mathrm{RP\_FS\_LF\_AC}}$ is the manufacturer selling price for the RP_FS_LF_AC at a selected d-value and full-load actual volume flow rate, and
- $MSP_{\mathrm{RP\_FS\_L\_AC}}$ is the manufacturer selling price for the RP_FS_L_AC at the same d-value and full-load actual volume flow rate.

MSP for each efficiency level for the RP_FS_LF_AC equipment class is presented in Table IV.25 at representative full-load actual volume flow rates.

TABLE IV.23—REPRESENTATIVE MSPS FOR THE RP_FS_LF_AC EQUIPMENT CLASS

Full-load actual volume flow rate (acfm)	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
10	$37,453	$37,488	$37,678	$37,893	$38,010	$38,265	$38,403
20	38,316	38,365	38,623	38,905	39,055	39,376	39,547
50	40,516	40,591	40,978	41,392	41,608	42,061	42,298
100	44,013	44,122	44,686	45,280	45,588	46,227	46,558
200	51,202	51,376	52,265	53,193	53,671	54,656	55,163
500	74,101	74,456	76,266	78,137	79,095	81,060	82,066
1000	113,933	114,580	117,869	121,256	122,987	126,523	128,330
2000	194,459	195,681	201,892	208,275	211,531	218,175	221,563
5000	428,595	431,568	446,672	462,185	470,096	486,231	494,456

DOE requests comment and supporting data on the MSPs established for the RP_FS_LF_AC equipment class. This is identified as Issue 24 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

ii. RP_VS_LF_AC MSP-Flow-Efficiency Relationship

As with RP_FS_LF_AC, DOE used MSP data from equipment of the same full-load actual volume flow rate and d-value to scale the RP_VS_L_AC MSP-flow-efficiency relationship to a new RP_VS_LF_AC MSP-flow-efficiency relationship. The new relationship resulted in significantly larger absolute MSP for RP_VS_LF_AC, as compared to RP_VS_L_AC. The new relationship also resulted in significantly larger incremental MSP for RP_VS_LF_AC, as compared to RP_VS_L_AC. Equation 21 provides the mathematical relationship between RP_VS_L_AC and RP_FS_VF_AC MSP, for a given d-value and full-load actual volume flow rate. Chapter 5 of the NOPR TSD provides details on the calculation of MSP for each rotary equipment class.

DOE requests comment on the methods used to develop RP_VS_LF_AC (lubricant-free) incremental MSP. Specifically, DOE requests comment on the use of RP_VS_L_AC (lubricated) incremental MSP relationship to develop a lubricant-free incremental MSP relationship. This is identified as Issue 25 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

The MSP relationship for the RP_VS_LF_AC equipment class is as follows:

$$MSP_{\text{RP\_VS\_LF\_AC}} = MSP_{\text{RP\_FS\_LF\_AC}} + 26.7 \times V_1 + 98.7$$

Equation 21

Where:

- $MSP_{\text{RP\_VS\_LF\_AC}}$ is the manufacturer selling price for the RP_VS_LF_AC at a selected d-value and full-load actual volume flow rate,
- $MSP_{\text{RP\_FS\_LF\_AC}}$ is the manufacturer selling price for the RP_FS_LF_AC at the same d-value and full-load actual volume flow rate, and
- V_1 is full-load actual volume flow rate (cubic feet per minute).

MSP for each efficiency level for the RP_VS_LF_AC equipment class is presented in Table IV.24 at representative full-load actual volume flow rates.

TABLE IV.24—REPRESENTATIVE MSPS FOR THE RP_VS_LF_AC EQUIPMENT CLASS

Full-load actual volume flow rate (acfm)	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
10	$37,751	$37,854	$38,044	$38,259	$38,376	$38,631	$38,944
20	38,854	38,998	39,255	39,538	39,688	40,009	40,393
50	41,804	42,025	42,412	42,826	43,042	43,495	44,025
100	46,567	46,892	47,456	48,050	48,358	48,996	49,735
200	56,300	56,816	57,706	58,633	59,111	60,096	61,225
500	86,851	87,908	89,718	91,589	92,548	94,512	96,747
1000	139,459	141,386	144,676	148,063	149,794	153,330	157,338
2000	245,550	249,196	255,407	261,790	265,046	271,690	279,202
5000	556,337	565,206	580,311	595,824	603,735	619,870	638,105

DOE requests comment and supporting data on the MSPs established for the RP_VS_LF_AC equipment class. This is identified as Issue 26 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

c. MSPs for Water-Cooled Equipment

As discussed in section IV.C.5.c, many air-cooled rotary air compressors are also offered in a water-cooled variant. These variants are typically identical, except for the cooling method employed. The air-cooled variant will utilize one or more cooling fans and heat exchangers to remove heat from the compressed air. Alternatively, a water-cooled variant utilizes chilled water (from a separate chilled water system) and one or more heat exchanges to remove heat from the compressed air. As such, the MSP of analogous air- and water-cooled equipment, not factoring in the cooling system, is expected to be equivalent. Furthermore, DOE expects that any difference in incremental MSP between air- and water-cooled systems will not be significant, when compared to the incremental MSP of the greater package. Consequently, DOE concluded that the incremental cost and price of efficiency will be the same for both air-cooled and water-cooled equipment classes at each efficiency level. Thus, DOE did not develop unique MSP-flow-efficiency relationships for water-cooled equipment classes.

Specifically, for all water-cooled equipment classes, DOE used incremental MSPs equivalent to analogous air-cooled equipment classes.

DOE requests comment on the use of incremental MSP for air-cooled equipment classes to represent incremental MSP for water-cooled equipment classes. This is identified as Issue 27 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

d. New Relationships From U.S. Data

As discussed in section IV.C.5.a, DOE compared the Lot 31 study MSP-Flow-Efficiency Relationship for three-phase reciprocating air compressors to U.S. equipment data and concluded that the Lot 31 study relationship was not representative of the U.S. market. Consequently, DOE used the online retailer price database and confidential U.S. MSP data from representative units to establish a new relationship between MSP, d-value, and full-load actual volume flow rate for three-phase reciprocating air compressors. Chapter 5 of the NOPR TSD provides additional information on the calculation of MSP for each reciprocating equipment class.

i. R3_FS_L_XX MSP-Flow-Efficiency Relationship

The MSP-Flow-Efficiency Relationship for the R3_FS_L_XX equipment class is as follows:

$$MSP_{\mathrm{R3\_FS\_L\_XX}} = 175.51 \times \left(V_1^{0.751}\right) \times (0.015 \times d + 1)$$

Equation 22

Where:

- $MSP_{\mathrm{R3\_FS\_L\_XX}}$ is the manufacturer selling price for the R3_FS_L_XX at a selected efficiency level,
- V_1 is full-load actual volume flow rate (cubic feet per minute), and
- d is the d-value for each efficiency level.

MSP for each efficiency level for the R3_FS_L_XX equipment class is presented in Table IV.25 at representative full-load actual volume flow rates.

TABLE IV.25—REPRESENTATIVE MSPS FOR THE R3_FS_L_XX EQUIPMENT CLASS

Full-load actual volume flow rate (acfm)	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
5	$429	$456	$544	$588	$632	$764	$1,117
10	722	767	915	989	1,063	1,286	1,880
25	1,437	1,526	1,821	1,969	2,116	2,559	3,740
50	2,419	2,568	3,065	3,313	3,562	4,307	6,295
75	3,279	3,482	4,155	4,492	4,829	5,840	8,535
100	4,070	4,321	5,158	5,576	5,994	7,248	10,594

DOE requests comment and supporting data on the MSPs established for the R3_FS_L_XX equipment class. This is identified as Issue 28 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

ii. R1_FS_L_XX MSP-Flow-Efficiency Relationship

As discussed in section IV.C.5.c, many reciprocating air compressors with motor power ≤7.5-hp are offered with both single- and three-phase induction motors. These variants are typically identical, except for the motor. Consequently, the MSP of analogous single- and three-phase equipment, not factoring the motor price, is expected to be equivalent. Furthermore, DOE expects that any difference in incremental MSP between single- and three-phase motors will not be significant when compared to the incremental MSP of the greater package. Consequently, DOE concluded that the incremental cost and price of efficiency will be the same for single- and three-phase equipment classes at each efficiency level. DOE notes that the efficiency levels for single- and three-phase equipment are defined by the same d-values, but are scaled to account for the inherent differences in attainable efficiency between single- and three-phase equipment.

Specifically, DOE used the MSPs for the R3_FS_L_XX equipment class to directly represent the MSPs for the R1_FS_L_XX equipment class. This means that the incremental cost to move from one d-value (or efficiency level) to another, is identical between single- and three-phase units of the same full-load actual volume flow rate.

The MSP relationship for the R1_FS_L_XX equipment class is identical to the equation for the R3_FS_L_XX equipment class, and is as follows:

$$MSP_{\mathrm{R1\_FS\_L\_XX}} = 175.51 \times \left(V_1^{0.751}\right) \times (0.015 \times d + 1)$$

Equation 23

Where:

- $MSP_{\mathrm{R1\_FS\_L\_XX}}$ is the manufacturer selling price for the R1_FS_L_XX at a selected efficiency level,
- V_1 is full-load actual volume flow rate (cubic feet per minute), and
- d is the d-value for each efficiency level.

MSP for each efficiency level for the R1_FS_L_XX equipment class at representative full-load actual volume flow rates is equivalent to the MSPs in

Table IV.25 for the R3_FS_L_XX equipment class.

DOE requests comment on the use of incremental MSP for the R3_FS_L_XX equipment classes to represent incremental MSP for the R1_FS_L_XX equipment classes. This is identified as Issue 29 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

7. Manufacturer Production Cost

As discussed in the previous section, DOE developed MSP-flow-efficiency relationships for each equipment class. However, certain downstream analyses, such as the MIA, require DOE to also assess the relationship between manufacturer production costs (MPCs), flow, and efficiency. To determine the MPC-flow-efficiency relationship, DOE backed out manufacturer markups from each MSP-flow-efficiency relationship. The manufacturer markup is defined as the ratio of MSP to MPC and covers non-production costs such as selling, general and administrative expenses (SG&A); research and development expenses (R&D), interest expenses, and profit. DOE developed estimates of manufacturer markups based on confidential data obtained during confidential manufacturer interviews. DOE's estimates of markups are presented in Table IV.26.

TABLE IV.26—BASELINE MARKUP ESTIMATES

Equipment class	Markup
RP_FS_L_AC	1.35
RP_VS_L_AC	
RP_FS_L_WC	
RP_VS_L_WC	
RP_FS_LF_AC	1.40
RP_VS_LF_AC	
RP_FS_LF_WC	
RP_VS_LF_WC	
R3_FS_L_XX	1.26
R1_FS_L_XX	

The MIA also requires MPCs to be disaggregated the MPCs into material, labor, depreciation, and overhead costs. DOE estimated MPC breakdowns based on information gathered from consultants familiar with the compressor manufacturing industry. Table IV.27 presents DOE's estimates for material, labor, depreciation, and overhead breakdown.

TABLE IV.27—BREAKDOWN OF MPC FOR COMPRESSORS

Category	Percentage of total MPC
Materials	53.8
Labor	23.1
Depreciation	4.1
Overhead	19.0

DOE requests comment on its estimates for manufacturer markups, as well as material, labor, depreciation, and overhead breakdowns. This is identified as Issue 30 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

8. Other Analytical Outputs

In the engineering analysis DOE calculated values for full-load power and no load power for use in cost-benefit calculations for individual end users, manufacturers, and the Nation. Full-load power was calculated for each equipment classes using the formula proposed for package isentropic efficiency in the test procedure NOPR and the outputs of efficiency, full-load actual volume flow rate, and pressure from the engineering analysis. DOE used the CAGI database to establish a relationship and calculate values for no load power based on full-load power. Chapter 5 of the NOPR TSD provides additional information on these outputs.

D. Markups Analysis

The markups analysis develops appropriate markups (*e.g.,* retailer markups, distributor markups, contractor markups) in the distribution chain and sales taxes to convert the MSP estimates derived in the engineering analysis to end user prices, which are then used in the LCC and PBP analysis and in the manufacturer impact analysis. At each step in the distribution channel, companies mark up the price of the equipment to cover business costs and profit margin. For compressors, the main distribution channels are (1) manufacturers directly to end-users, (2) manufacturers to distributors to end-users, (3) manufacturers to contractors to end-users, and (4) manufacturers to end-users through other means. Table IV.28 shows the estimated market shares of each channel, based on air equipment type and capacity.

TABLE IV.28—COMPRESSORS DISTRIBUTION CHAIN

Channel structure				Rotary <500 ACFM (%)	Rotary ≥500 ACFM (%)	Reciprocating <100 ACFM (%)	Reciprocating ≥100 ACFM (%)
Manufacturer			User	7.5	20.0	5.0	20.0
Manufacturer	Distributor/Manufacturer Rep		User	85.0	77.5	75.0	75.0
Manufacturer	Distributor/Manufacturer Rep	Contractor	User	5.0	2.5	15.0	5.0
Manufacturer	Other		User	2.5	0.0	5.0	0.0
Total				100	100	100	100

DOE developed separate markups for baseline equipment (baseline markups) and for the incremental cost of more-efficient equipment (incremental markups). Incremental markups are coefficients that relate the change in the MSP of higher-efficiency models to the change in the retailer sales price.

To develop markups for the parties involved in the distribution of the equipment, DOE utilized several sources, including: (1) The U.S. Census Bureau 2007 *Economic Census Manufacturing Industry Series* (NAICS 33 Series)[60] to develop original equipment manufacturer markups; (2) the U.S. Census Bureau 2012 *Annual Wholesale Trade Survey,* Machinery,

[60] U.S. Census Bureau (2007). Economic Census Manufacturing Industry Series (NAICS 33 Series). *http://www.census.gov/manufacturing/asm.*

Equipment, and Supplies Merchant Wholesalers [61] to develop distributor markups; and (3) 2013 RS Means Electrical Cost Data [62] to develop mechanical contractor markups.

In addition to the markups, DOE derived State and local taxes from data provided by the Sales Tax Clearinghouse. These data represent weighted-average taxes that include county and city rates. DOE derived shipment-weighted-average tax values for each region considered in the analysis.

Chapter 6 of the NOPR TSD provides details on DOE's development of markups for compressors.

Because the identified market channels are complex and their characterization required a number of assumptions, DOE seeks input on its analysis of market channels listed above in Table IV.28, particularly related to whether the channels include all necessary intermediate steps, and the estimated market share of each channel. This is identified as Issue 31 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

E. Energy Use Analysis

The purpose of the energy use analysis is to determine the annual energy consumption of air compressors at different efficiencies in representative U.S. manufacturing and commercial facilities, and to assess the energy savings potential of increased air compressor efficiency. The energy use analysis estimates the range of energy use of air compressors in the field (*i.e.,* as they are actually used by end users). The energy use analysis provides the basis for other analyses DOE performed, particularly assessments of the energy savings and the savings in end user operating costs that could result from adoption of new standards.

Annual energy use of air compressors depends on the utilization of the equipment, which is influenced by air compressor application, annual hours of operation, load profiles, capacity controls, and compressor sizing. The annual energy use is calculated as the sum of input power at each load point multiplied by the annual operating hours at each respective load point.

1. Applications

DOE found that air compressors operate in response to system demands in three general ways, which were classified as applications. DOE determined these applications after examining available field assessment data from two database sources: (1) A database of motor nameplate and field data compiled by the Washington State University (WSU) Extension Energy Program, Applied Proactive Technologies (APT), and New York State Energy Research and Development Authority (NYSERDA) (''WSU/NYSERDA database'') [63] and (2) the Northwest Industrial Motor Database.[64] Based on the distribution of compressor-specific assessments found in these databases, DOE defined three application types to capture variations in air demand and control strategies. The three applications types are defined as:

Trim: Compressors equipped with controls configured to serve fluctuating air demand. The trim application is used to represent either the operation of an individual compressor, or a compressor within a compressor plant, that serves the fluctuating portion of the demand.

Base load: Compressors equipped with controls configured to serve steady-state air demands. The base-load application is used to represent a compressor within a compressor plant that serves the constant portion of fluctuating demand, while the remaining fluctuating portion of demand is covered by a trim application.[65]

Intermittent: Compressors equipped with controls configured to serve sporadic loads. For example, these could be operated as back-up compressors for either base-load or trim compressors, or as a dedicated air compressor to a specific process such as sand blasting or fermentation.

Table IV.29 shows the distribution of air compressor application for both rotary and reciprocating air compressors. DOE seeks comment on its distribution of air compressors application. This is identified as Issue 32 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

TABLE IV. 29—DISTRIBUTION OF AIR COMPRESSORS BY APPLICATION

Application	Probability (%)
Trim	50
Base-load	28
Intermittent	22

2. Annual Hours of Operation

DOE constructed a probability distribution of average annual hours of operation for each of the three application types based on NYSEDA and WSU system assessments data discussed previously and Ecodesign Preparatory Study on Electric motor systems/Compressors (Lot 31 Study).[66]

Table IV.30 shows the distribution of annual hours of operation for each application by equipment type, where each row is the probability of a compressor's annual operating hours when operated at a specific application.

TABLE IV. 30—DISTRIBUTION OF ANNUAL HOURS OF OPERATION BY APPLICATION

Probability * (%)	Rotary			Reciprocating		
	Base-load	Trim	Intermittent	Base-load	Trim	Intermittent
0	4,000	2,000	1,000	1,100	650	150
20	6,552	6,552	3,876	1,198	708	202
40	7,446	7,446	4,400	1,361	804	338
60	8,400	8,400	5,928	1,535	1,083	368
80	8,400	8,400	8,064	1,601	1,474	395

[61] U.S. Census Bureau (2012). Annual Wholesale Trade Survey, Machinery, Equipment, and Supplies Merchant Wholesalers (NAICS 4238). *http://www.census.gov/wholesale/index.html.*

[62] RS Means (2013), Electrical Cost Data, 36th Annual Edition (Available at: *http://www.rsmeans.com*).

[63] The motors database is composed of information gathered by WSU and APT during 123 industrial motor surveys or assessments: 11 motor assessments were conducted between 2005 and 2011 and occurred in industrial plants; 112 industrial motor surveys were conducted between 2005 and 2011 and were funded by NYSERDA and conducted in New York State.

[64] Northwest Industrial Motor Database Summary, 2009, Strategic Energy Group.

[65] Air demand (in cfm)) can vary considerably during plant operations. A portion of this air demand may be steady-state, driving equipment that is run constantly, while the remaining portion may be fluctuating.

[66] *Ecodesign Preparatory Study on Electric Motor Systems/Compressors;* 2014; Prepared for the European Commission by Van Holsteijn en Kemna B.V. (VHK); ENER/C3/413–2010–LOT 31–SI2.612161; *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

TABLE IV. 30—DISTRIBUTION OF ANNUAL HOURS OF OPERATION BY APPLICATION—Continued

Probability * (%)	Rotary			Reciprocating		
	Base-load	Trim	Intermittent	Base-load	Trim	Intermittent
100	8,400	8,400	8,400	1,601	1,601	731

* DOE assumes a uniform distribution between the listed values.

DOE requests comment and information on average annual operating hours for the compressor types and applications in the scope of this rulemaking. This is identified as Issue 33 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

3. Load Profiles

Information on typical load profiles for compressors is not available in the public domain. DOE reviewed resources provided by stakeholders, as well as sample compressed air system assessments of commercial and industrial customers. Given the lack of data, DOE developed several load profiles based on how typical compressor applications would likely be employed in the field. Each compressor load profile is approximated by weights that specify the percentage of time the compressor operates at one of four load points: 20, 40, 70, and 100 percent of its duty point airflow.[67] Load profiles are then mapped to each application type to capture compressor operation in the field; this mapping is shown in Table IV.32. The four load profile types are described below:

Flat-load profile: Represents a constant maximum airflow demand. All annual hours of operation are assigned to the duty point airflow. The flat-load profile is used for most base-load applications, and for intermittent applications to represent the event where a intermittent compressor is operating in a base-load role. It can also represent a situation where intermittent demand has been attenuated due to the inclusion of appropriately-sized secondary (demand) air receiver storage to the compressed air system.

High-load profile: Represents a high fraction of annual operating hours spent at, or near the maximum airflow demand. The annual hours of operation are distributed across the higher airflow load points. The high-load profile is used to represent most trim applications, and some base-load applications.

Low-load profile: Represents a low fraction of annual operating hours spent at maximum air flow. Annual hours of operation are distributed across the lower airflow load points. Low-load profile, although undesirable, occurs if a single compressor is supplying airflow to a range of tools, with only a small fraction of operating hours at which all of these tools are operating. This profile is also used with both trim and intermittent applications.

Even-load profile: Represents an even distribution of annual operating hours spent at each airflow load point. This load profile is a characteristic of trim or intermittent applications. Table IV.31 shows the percentage of annual operating hours at each of the load points described above for the four load profiles. Table IV.32 shows the assumed probability of each type of load profile being selected for each application type.

TABLE IV. 31—FRACTION OF ANNUAL OPERATING HOURS (%) AS A FRACTION OF RATED AIRFLOW

Load point (%)	Load profile			
	Flat (%)	High (%)	Low (%)	Even (%)
20	0	0	30	0
40	0	10	30	33.3
70	0	40	30	33.3
100	100	50	10	33.3

TABLE IV. 32—DISTRIBUTION OF LOAD PROFILES BY APPLICATION

Application	Load profile	Load profile probability
Trim	Flat.	
	Even	40
	Low	40
	High	20
Base-load	Flat	80
	Even.	
	Low.	
	High	20
Intermittent	Flat	30
	Even	20
	Low	20
	High	30

DOE requests comment and information on typical load profiles for the air compressor types and applications in the scope of this rulemaking. This is identified as Issue 34 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

4. Capacity Control Strategies

Facility demands for compressed air rarely match a compressor's rated air capacity. To account for this discrepancy, some form of compressed air control strategy is necessary. Some forms of capacity control only apply to certain compressor designs and are effective over a limited range of a compressor's capacity. In addition, some capacity controls can be used in combination. As the capacity is regulated, the power required for the compressor to meet the airflow demand will change depending on the chosen control strategy. Chapter 7 of the NOPR TSD describes the implemented control in detail with mathematical models for each of the following control strategies: Start/Stop, Load/Unload (2-step), Inlet Valve Modulation, Variable Displacement, and Multi-step. DOE also included the following combined control strategies: Inlet Valve Modulation/Unload, Variable Displacement/Unload, and Multi-step/Unload. DOE modeled these control strategies largely on the following

[67] DOE assumes that 20-percent is the lowest point at which a compressor will operate before being cycled by capacity controls into its Stop or Unload status. See chapter 7 of the TSD for more information on capacity controls.

sources: Analysis Methodology Manual for AIRMaster Compressed Air System Audit and Analysis Software,[68] CAGI's Compressed Air and Gas Handbook,[69] and Compressed Air System Controls.[70]

5. Compressor Sizing

In the Framework Document, DOE requested information on compressor sizing. CAGI noted that demand of operation dictates whether an installed system is adequate, inadequate, or oversized, but was unsure whether there are data available as to the number of systems that may be potentially oversized at the point of sale. (CAGI, No. 0014 at p. 210) Kaeser commented that they often see oversizing—specifically multiple units running at varying part-load levels. Kaeser stated that this is more of an issue of how compressors are controlled. (Kaeser Compressors, No. 0014 at p. 212–213) DOE was unable to find any information quantifying the degree of oversizing at the point of sale. In addition, DOE was unable to find information quantifying the frequency that compressors are misconfigured or oversized in the field, so DOE assumed that compressors were perfectly sized for this analysis.

DOE seeks data on the degree that compressors are over- or under-sized for an intended application. Specifically, DOE requests data on the degree that air compressors are operated at duty points other than their intended design point. This is identified as Issue 35 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

Additionally, Scales commented that air compressors are often set to operate at an elevated pressure, which increases input power as well as compressed air output. (W. Scales, No. 0020 at p. 1) DOE was unable to find any information quantifying the impacts of operating air compressors at pressures other than at their specified design point. DOE requests information and data on the degree that a compressor's pressure can be set above or below its design point. Additionally, DOE requests information and data on air compressor efficiency when it is operated above the design point pressure. This is identified as Issue 36 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

Chapter 7 of the NOPR TSD provides details on DOE's energy use analysis for air compressors.

F. Life-Cycle Cost and Payback Period Analysis

DOE conducted LCC and PBP analyses to evaluate the economic impacts on individual end users of potential energy conservation standards for air compressors. The effect of new or amended energy conservation standards on individual end users usually involves a reduction in operating cost and an increase in purchase cost. DOE used the following two metrics to measure end-user impacts:

- The LCC (life-cycle cost) is the total end user expense of an appliance or equipment over the life of that equipment, consisting of total installed cost (manufacturer selling price, distribution chain markups, sales tax, and installation costs) plus operating costs (expenses for energy use, maintenance, and repair). To compute the operating costs, DOE discounts future operating costs to the time of purchase and sums them over the lifetime of the equipment.
- The PBP (payback period) is the estimated amount of time (in years) it takes end users to recover the increased purchase cost (including installation) of more-efficient equipment through lower operating costs. DOE calculates the PBP by dividing the change in purchase cost at higher efficiency levels by the change in annual operating cost for the year that amended or new standards are assumed to take effect.

For any given efficiency level, DOE measures the change in LCC relative to the LCC in the no-standards case, which reflects the estimated efficiency distribution of air compressors in the absence of new or amended energy conservation standards. In contrast, the PBP for a given efficiency level is measured relative to the baseline equipment.

For each considered efficiency level in each equipment class, DOE calculated the LCC and PBP for a nationally representative set of air compressors. DOE used data from NYSERDA and NW databases, Lot 31 and acquired system assessments to define each air compressor's application, load profile, annual hours or operation, and combination of employed controls.[71] [72] [73] For each of these air compressors, DOE determined the energy consumption and the appropriate electricity price, thus capturing the variability in energy consumption and energy prices associated with the use of air compressors.

Inputs to the calculation of total installed cost include equipment costs—which includes MPCs, manufacturer markups, retailer and distributor markups, and sales taxes—and installation costs. Inputs to the calculation of operating expenses include annual energy consumption, energy prices and price projections, repair and maintenance costs, equipment lifetimes, and discount rates. DOE created distributions of values for equipment lifetime, discount rates, and sales taxes, with probabilities attached to each value, to account for their uncertainty and variability.

The computer model DOE uses to calculate the LCC and PBP relies on a Monte Carlo simulation to incorporate uncertainty and variability into the analysis. The Monte Carlo simulations randomly sample input values from the probability distributions and air compressor end user sample. The model calculated the LCC and PBP for equipment at each efficiency level for 10,000 end users per simulation run.

DOE calculated the LCC and PBP for all end users as if each were to purchase a new equipment in the expected year of compliance with a new standard. DOE has tentatively determined that any standards would apply to air compressors manufactured five years after the date on which any standard is published.[74] At this time, DOE estimates publication of a final rule in the second half of 2016. Therefore, for purposes of its analysis, DOE used 2022 as the first

[68] Wheeler, G. M., Bessey, E. G. & McGill, R. D. Analysis Methodology Manual for AIRMaster Compressed Air System Audit and Analysis Software, 1997.

[69] McCulloh, D. M. Compressed Air and Gas Handbook. Compressed Air and Gas Institute (CAGI), 2003. at <*http://www.cagi.org*>.

[70] Compressed Air Challenge, U.S. DOE, Compressed Air System Controls, 1998, at <*https://www.compressedairchallenge.org/library/factsheets/factsheet06.pdf*>.

[71] Washington State University Extension Energy Program (WSU) and Applied Proactive Technologies (APT). Database of Motor Nameplate and Field Measurement Data. New York State Energy Research and Development Authority (NYSERDA) (2011).

[72] Strategic Energy Group, Northwest Industrial Motor Database Summary (2009).

[73] Van Holsteijn en Kemna B.V. (VHK). *Ecodesign Preparatory Study on Electric Motor Systems/Compressors;* 2014; Prepared for the European Commission by Van Holsteijn en Kemna B.V. (VHK); ENER/C3/413–2010–LOT 31–SI2.612161, available at *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031*.

[74] EPCA specifies that the provisions of subsections (l) through (s) of section 42 U.S.C. 6295 shall apply to any other type of industrial equipment which the Secretary classifies as covered equipment, which includes compressors. (42 U.S.C. 6316(a)) Subsection (l)(2) of 42 U.S.C. 6295 states that any new or amended standard for any other type of consumer product which the Secretary classifies as a covered product shall not apply to products manufactured within five years after the publication of a final rule establishing such standard. DOE believes that this five-year lead time also applies to other types of industrial equipment, such as compressors.

full year of compliance with any standards for compressors.

Table IV. 33 summarizes the approach and data DOE used to derive inputs to the LCC and PBP calculations. The subsections that follow provide further discussion. Details of the spreadsheet model, and of all the inputs to the LCC and PBP analyses, are contained in chapter 8 of the NOPR TSD and its appendices.

TABLE IV. 33—SUMMARY OF INPUTS AND METHODS FOR THE LCC AND PBP ANALYSIS *

Inputs	Source/method
Equipment Cost	Derived by multiplying MPCs by manufacturer and retailer markups and sales tax, as appropriate. Used historical data to derive a price scaling index to forecast equipment costs.
Installation Costs	Baseline installation cost determined with data from stakeholders. Assumed no change with efficiency level.
Annual Energy Use	The total annual energy use multiplied by the hours per year. Average number of hours based on field data.
Energy Prices	Electricity: Marginal prices derived from EEI [75]
Energy Price Trends	Based on *AEO 2015* price forecasts.
Repair and Maintenance Costs	Assumed no change with efficiency level.
Equipment Lifetime	Assumed average life time of 12.5 years for rotary, and 8.4 for reciprocating air compressors.
Discount Rates	Approach involves identifying all possible debt or asset classes that might be used to purchase air compressors. Primary data source was the Damodaran Online.
Compliance Date	Late 2021.

* References for the data sources mentioned in this table are provided in the sections following the table or in chapter 8 of the NOPR TSD.

1. Equipment Cost

To calculate end user equipment costs, DOE multiplied the MPCs developed in the engineering analysis by the markups described in section IV.D (along with sales taxes). DOE used different markups for baseline equipment and higher-efficiency equipment because DOE applies an incremental markup to the increase in MSP associated with higher-efficiency equipment.

The markup is the percentage increase in price as the air compressor equipment passes through distribution channels. As explained in section IV.D, DOE assumed that compressors are delivered by the manufacturer through one of four distribution channels. The overall markups used in the LCC analysis are weighted averages of all of the relevant distribution channel markups.

To project an equipment price trend for the NOPR, DOE derived an inflation-adjusted index of the Producer Price Index for air and gas compressor equipment manufacturers over the period 1984–2013.[76] These data show a slight decrease from 1989 through 2004. Since 2004, however, there has been an increase in the price index. Given the relatively slow global economic activity in 2009 through 2013, the extent to which the future trend can be predicted based on the last decade is uncertain. Because the observed data do not provide a firm basis for projecting future cost trends for compressor equipment, DOE used a constant price assumption as the default trend to project future compressor prices from 2022. Thus, prices projected for the LCC and PBP analysis are equal to the 2014 values for each efficiency level in each equipment class.

DOE requests comments on the most appropriate trend to use for real (inflation-adjusted) compressor prices. This is identified as Issue 37 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

2. Installation Cost

Installation cost includes labor, overhead, and any miscellaneous materials and parts needed to install the equipment. In the Framework Document, DOE requested information on whether installation costs would be expected to change with efficiency. CAGI responded that there might be an added cost of installation related to efficiency (CAGI, No.0009 at p.8), but CAGI did not provide any rationale for this increase. In the absence of data to indicate at what efficiency level DOE may need to consider an increase in installation costs, or other drivers that would trigger higher installation costs for more efficient equipment, DOE has not included an estimate for installation costs for this analysis. DOE requests comment on whether any of the efficiency levels considered in this NOPR might lead to an increase in installation costs and, if so, data regarding the magnitude of the increased cost for each relevant efficiency level. This is identified as Issue 38 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

3. Annual Energy Consumption

For each sampled compressor, DOE determined the energy consumption for an air compressor at different efficiency levels using the approach described above in section IV.E of this document.

4. Energy Prices

DOE derived average and marginal annual non-residential (commercial and industrial) electricity prices using data from EIA's Form EIA–861 database (based on ''Annual Electric Power Industry Report''),[77] EEI Typical Bills and Average Rates Reports,[78] and information from utility tariffs. Electricity tariffs for non-residential end users can be very complex, with the principal difference from residential rates being the incorporation of demand charges. The presence of demand charges means that two end users with the same monthly electricity consumption may have very different bills, depending on their peak demand. For the NOPR analysis DOE used marginal electricity prices to estimate the impact of demand charges for end users of air compressors. The methodology of use to calculate the marginal electricity rates can be found in appendix 8B of the NOPR TSD.

To estimate energy prices in future years, DOE multiplied the average national energy prices by the forecast of annual change in national-average commercial and industrial energy price in the Reference case from *AEO 2015,*

[75] Edison Electric Institute (EEI), Typical Bills and Average Rates Report Summer, and Winger (2014).

[76] Series ID PCU333911333911; *http://www.bls.gov/ppi/.*

[77] Available at: *www.eia.doe.gov/cneaf/electricity/page/eia861.html.*

[78] Edison Electric Institute. *Typical Bills and Average Rates Report.* Winter 2014 published April 2014, Summer 2014 published October 2014: Washington, DC (Last accessed June 2, 2015.) *http://www.eei.org/resourcesandmedia/products/Pages/Products.aspx.*

which has an end-year of 2040.[79] To estimate price trends after 2040, DOE used the average annual rate of change in prices from 2020 to 2040.

5. Repair and Maintenance Costs

Commenting on the framework document, Kaeser stated that the cost of repair for more efficient compressors depends on whether it is fixed-speed or variable-speed, and that comparing more efficient fixed-speed to less efficient fixed-speed shows no variation in costs. (Kaeser Compressors, No. 0014 at p. 236–237) CAGI commented in response to the Framework document that VSDs can have higher repair and troubleshooting costs based on issues of cleanliness of the operating site and electrical noise/interference. (CAGI, No. 0006 at p. 8)

For this analysis DOE is considering separate equipment classes for compressors using fixed-speed drives and VSDs, so they are not considered as potential replacements for one another in the LCC analysis. Based on the comments from Kaeser, DOE does not expect repair or maintenance costs to change with increased efficiency, so DOE did not estimate either repair or maintenance costs.

6. Equipment Lifetime

DOE defines ''equipment lifetime'' as the age when a given air compressor is retired from service. DOE presented several average equipment lifetimes estimates in the framework document. In response, CAGI commented that well-cared-for compressors can have lifetimes spanning decades, while Kaeser commented that very old equipment exists, but some equipment may experience much shorter lifetimes. (CAGI, No. 0009 at p.8; Kaeser Compressors, No. 0014 at p. 228) CAGI further noted that there are many variables that could affect equipment lifetime, such as quality of installation, operating environment, quality of replacement parts, and qualifications of maintenance technicians. (CAGI, No. 0014 at p. 238) While no stakeholder directly commented on the lifetimes presented, Kaeser stated they were reasonable as an average over the entire market. (Kaeser Compressors, No. 0014 at p. 229)

For the NOPR, DOE based equipment lifetimes on new information published in the Lot31 study.[80] DOE calculated a distribution of lifetimes shown in Table IV.34. DOE also used a distribution of mechanical lifetime in hours to allow a negative correlation between annual operating hours and lifetime in years—air compressors with more annual operating hours tend to have shorter lifetimes. Chapter 8 of the NOPR TSD contains a detailed discussion of equipment lifetimes.

TABLE IV. 34—AIR COMPRESSOR LIFETIMES (YEARS)

	Minimum	Average	Maximum
Rotary	4	12.5	36
Reciprocating	1	8.4	25

DOE seeks comment on these minimum, average, and maximum equipment lifetimes, and whether or not they are appropriate for all equipment classes. This is identified as Issue 39 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

7. Discount Rates

The discount rate is the rate at which future expenditures are discounted to estimate their present value. The weighted average cost of capital is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so the cost of capital is the weighted-average cost to the firm of equity and debt financing. DOE estimated the cost of equity using the capital asset pricing model, which assumes that the cost of equity for a particular company is proportional to the systematic risk faced by that company.

The primary source of data for this analysis was Damodaran Online, a widely used source of information about company debt and equity financing for most types of firms.[81] DOE estimated a separate weighted average cost of capital for each business sector that purchases compressors. More details regarding DOE's estimates of end user discount rates are provided in chapter 8 of the NOPR TSD.

8. Efficiency Distribution in the No-New-Standards Case

To accurately estimate the share of end users that would be affected by a potential energy conservation standard at a particular efficiency level, DOE's LCC analysis considered the projected distribution (*i.e.,* market shares) of equipment efficiencies that end users purchase in the no-new-standards case (*i.e.,* the case without new energy conservation standards). To estimate the efficiency distribution of air compressors for 2021, DOE examined the frequency of efficiencies made available under CAGI's voluntary testing program for each equipment class (CAGI database), and the distribution of efficiencies of shipments of commercial and industrial pumps provided,[82] scaled to the capacity range of compressors. DOE found the distribution for both samples to be similar, with the distribution of efficiencies of shipments for pumps skewed slightly toward higher efficiencies. For the NOPR analysis, DOE used the re-scaled distribution of pump efficiencies, as it is based on the efficiencies of shipments of a durable industrial product, rather than the frequency of efficiency of an entry in a catalog, and thus better reflects end user choice. The estimated market shares for the no-new-standards case efficiency distribution for air compressors are shown in Table IV.35. See chapter 8 of the NOPR TSD for further information on the derivation of the efficiency distributions.

[79] U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 2015 with Projections to 2040* (Available at: <*http://www.eia.gov/forecasts/aeo/*>).

[80] *Ecodesign Preparatory Study on Electric Motor Systems/Compressors;* 2014; Prepared for the European Commission by Van Holsteijn en Kemna B.V. (VHK); ENER/C3/413–2010–LOT 31–SI2.612161; *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

[81] Damodaran Online, The Data Page: Cost of Capital by Industry Sector, 2001–2013. (Last accessed March, 2014.) See: *http://pages.stern.nyu.edu/~adamodar/.*

[82] U.S. Department of Energy. Energy Efficiency and Renewable Energy Office. Energy Conservation Program: Energy Conservation Standards for Pumps; Notice of proposed rulemaking (NOPR), 2015. See: *http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0031-0040.*

TABLE IV. 35—DISTRIBUTION OF EFFICIENCIES IN THE NO-NEW-STANDARDS CASE

EL	Average of probability (%)
0	11.50
1	15.50
2	15.90
3	18.40
4	11.30
5	22.40
6	5.10

9. Payback Period Analysis

The payback period is the amount of time it takes the end user to recover the additional installed cost of more-efficient equipment, compared to baseline equipment, through energy cost savings. Payback periods are expressed in years. Payback periods that exceed the life of the equipment mean that the increased total installed cost is not recovered in reduced operating expenses.

The inputs to the PBP calculation for each efficiency level are the change in total installed cost of the equipment and the change in the first-year annual operating expenditures relative to the baseline. The PBP calculation uses the same inputs as the LCC analysis, except that discount rates are not needed.

As noted above, EPCA, as amended, establishes a rebuttable presumption that a standard is economically justified if the Secretary finds that the additional cost to the end user of purchasing equipment complying with an energy conservation standard level will be less than three times the value of the first year's energy savings resulting from the standard, as calculated under the applicable test procedure. (42 U.S.C. 6295(o)(2)(B)(iii) and 6316(a)) For each considered efficiency level, DOE determined the value of the first year's energy savings by calculating the energy savings in accordance with the applicable DOE test procedure, and multiplying those savings by the average energy price forecast for the year in which compliance with the new standards would be required.

G. Shipments Analysis

DOE uses forecasts of annual equipment shipments to calculate the national impacts of potential energy conservation standards on energy use, NPV, and future manufacturer cash flows.[83] The shipments model takes an accounting approach, tracking market shares of each equipment class and the vintage of units in the stock. Stock accounting uses equipment shipments as inputs to estimate the age distribution of in-service equipment stocks for all years. The age distribution of in-service equipment stocks is a key input to calculations of both the NES and NPV, because operating costs for any year depend on the age distribution of the stock.

In its proposed Coverage Determination and subsequent Framework Document, DOE considered using the shipment data available from the U.S. Census Bureau. In reference to the shipments found in the Census data, CAGI commented that air compressors used for actual commercial and industrial applications are significantly lower, being a fraction of the referenced number (CAGI, EERE–2012–BT–DET–0033–0003, pg. 7). In response, DOE sought, and received, recent shipments data for rotary compressors from a number of stakeholders and subject matter experts. DOE was able to find only limited shipments data for reciprocating compressors, so DOE continued to use the data from the U.S. Census Bureau.[84] DOE aggregated these data into its shipments estimate for 2013 (see chapter 9 of the NOPR TSD).

DOE seeks comment on the total 2013 shipments by equipment class. This is identified as Issue 40 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

The 2013 shipments estimates were disaggregated by compressor capacity in actual cubic feet per minute (ACFM). To project future shipments of air compressors, DOE scaled the 2013 values using particular forecasts from *AEO 2015*. DOE understands that air compressors are used widely in both commercial, and manufacturing and industrial sectors. However, DOE was not able to locate and information indication what fraction of equipment was used in either sector. For this analysis DOE assumed that industrial/manufacturing processes will require a greater volume of compressed air than commercial processes. With higher electrical loads in the industrial/manufacturing sector than the commercial sector, DOE assumed that compressors greater than 50 ACFM capacity are mainly used in manufacturing, so DOE used the forecast for value of manufacturing shipments for this category. DOE assumed compressors equal to or less than 50 ACFM capacity are mainly used in commercial buildings, so DOE used the forecast for commercial floor space for this category.

DOE seeks comment on its assumption that air compressors with a capacity of no more than 50 ACFM are used in commercial applications, and air compressors greater than 50 ACFM are used in industrial applications. This is identified as Issue 41 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

For rotary equipment classes DOE then used CAGI test data for air compressors collected directly from manufacturers to distribute shipments into the different lubrication and cooling type equipment classes. For reciprocating compressors DOE was unable to locate any information on the fractions of equipment shipped that are single-phase or three-phase. DOE assumed an equal division of shipments between single-phase and three-phase reciprocating compressors for equipment rated less than or equal to 10-hp,[85] while any reciprocating shipments above 10-hp were considered to be three-phase equipment. The equipment classes and their estimated market shares are shown in Table IV.36. DOE used the same shares for all years in the projection.

TABLE IV. 36—SHARE OF SHIPMENTS BY EQUIPMENT CLASS

Equipment class	Description	Market share (%)
RP_FS_L_AC	Rotary Screw, Fixed-Speed, Lubricated, Air Cooled	1.62
RP_FS_L_WC	Rotary Screw, Fixed-Speed, Lubricated, Water-Cooled	0.29
RP_FS_LF_AC	Rotary Screw, Fixed-Speed, Lubricant Free, Air Cooled	0.06

[83] DOE uses data on manufacturer shipments as a proxy for national sales, as aggregate data on sales are lacking. In general one would expect a close correspondence between shipments and sales.

[84] U.S. Department of Commerce, Census Bureau, Manufacturing and Construction Division, Series MA333P(10)–1, Stationary Air Compressors, Reciprocating, Single and Double Acting (333912110T), 2011.

[85] For this analysis DOE considers 10-hp is the upper nominal power limit for single-phase electric motors and air compressors driven by these motors, For this analysis DOE approximated as 10-hp as 50 ACFM to match available shipment data to the equipment class capacities defined in the engineering analysis. Equipment class capacities are chapter 5 of the TSD.

TABLE IV. 36—SHARE OF SHIPMENTS BY EQUIPMENT CLASS—Continued

Equipment class	Description	Market share (%)
RP_FS_LF_WC	Rotary Screw, Fixed-Speed, Lubricant Free, Water-Cooled	0.04
RP_VS_L_AC	Rotary Screw, Variable-speed, Lubricated, Air Cooled	0.34
RP_VS_L_WC	Rotary Screw, Variable-speed, Lubricated, Water-Cooled	0.06
RP_VS_LF_AC	Rotary Screw, Variable-speed, Lubricant Free, Air Cooled	0.01
RP_VS_LF_WC	Rotary Screw, Variable-speed, Lubricant Free, Water-Cooled	0.02
R1_FS_L_XX	Reciprocating 1-phase, Fixed-Speed, Lubricated, Air Cooled	44.02
R3_FS_L_XX	Reciprocating 3-phase, Fixed-Speed, Lubricated, Air Cooled	53.54

DOE seeks comment on the share of shipments by equipment class, and how these shares may change over time. This is identified as Issue 42 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

DOE recognizes that an increase in equipment price resulting from energy efficiency standards may affect end user decision-making regarding whether to purchase a new compressor, a refurbished one, or repair the existing failed unit. DOE has not found any information in the literature that indicates a demand price elasticity for commercial and industrial firms. For the NOPR, it used a medium elasticity of −0.5 for commercial customers, and a lower elasticity (−0.25) for industrial customers.[86] DOE used a lower elasticity for industrial customers because these customers are likely to place greater value on the reliability and efficiency provided by new equipment, over the alternative of purchasing used equipment.

DOE seeks comment on whether the assumed price elasticities are reasonable for air compressors. This is identified as Issue 43 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

H. National Impact Analysis

The NIA assesses the national energy savings (NES) and the national net present value (NPV) from a national perspective of total consumer costs and savings that would be expected to result from new or amended standards at specific efficiency levels. (''Consumer'' in this context refers to consumers of the equipment being regulated.) DOE calculates the NES and NPV for the potential standard levels considered based on projections of annual equipment shipments, along with the annual energy consumption and total installed cost data from the energy use and LCC analyses.[87] For the present analysis, DOE forecasted the energy savings, operating cost savings, equipment costs, and NPV of consumer benefits over the lifetime of air compressors sold from 2022 through 2051.

DOE evaluates the impacts of potential standards for compressors by comparing a case without such standards with standards-case projections. For the no-new-standards case, DOE considers historical trends in efficiency and various forces that are likely to affect the mix of efficiencies over time. For the standards cases, DOE considers how a given standard would likely affect the market shares of equipment with efficiencies greater than the standard.

DOE uses a spreadsheet model to calculate the energy savings and the national consumer costs and savings from each TSL. Interested parties can review DOE's analyses by changing various input quantities within the spreadsheet. The NIA spreadsheet model uses typical values (as opposed to probability distributions) as inputs.

Table IV.37 summarizes the inputs and methods DOE used for the NIA analysis for the NOPR. Discussion of these inputs and methods follows the table. See chapter 10 of the NOPR TSD for further details.

TABLE IV. 37—SUMMARY OF INPUTS AND METHODS FOR THE NATIONAL IMPACT ANALYSIS

Inputs	Method
Shipments	Annual shipments from shipments model.
Compliance Date of Standard	Late 2021.
Efficiency Trends	No-new-standards case: constant market shares.
Annual Energy Consumption per Unit	Annual weighted-average values are a function of energy use at each TSL.
Total Installed Cost per Unit	Annual weighted-average values are a function of cost at each TSL. Incorporates projection of future equipment prices based on historical data.
Annual Energy Cost per Unit	Annual weighted-average values as a function of the annual energy consumption per unit and energy prices.
Repair and Maintenance Cost per Unit	Annual values do not change with efficiency level.
Energy Prices	AEO 2015 forecasts (to 2040) and extrapolation thereafter.
Energy Site-to-Primary Conversion	A time-series conversion factor based on AEO 2015.
Discount Rate	Three and seven percent.
Present Year	2015.

1. Equipment Efficiency Trends

A key component of the NIA is the trend in energy efficiency projected for the no-new-standards case and each of the standards cases. Section IV.F.8 of this document describes how DOE developed an energy efficiency distribution for the no-new-standards case (which yields a shipment-weighted average efficiency) for each of the considered equipment classes for the

[86] A price elasticity of -0.5 means that for every 1 percent increase in price, the demand for the product (*i.e.,* shipments) would decline by 0.5 percent. An elasticity of 1 indicates very high elasticity of demand, whereas an elasticity of zero indicates no elasticity of demand. Elasticities are considered constant over time.

[87] For the NIA, DOE adjusts the installed cost data from the LCC analysis to exclude sales tax, which is a transfer.

first full year of anticipated compliance with an amended standard.

Several stakeholders commented that manufacturers will continue to increase the efficiency of air compressors in the absence of standards. (CAGI, No. 0014 at p. 247–251; Kaeser Compressors, No. 0014 at p. 252–253; Ingersoll-Rand, No. 0014 at p. 254) Data on the number of air compressor designs by efficiency is available for 2006 through 2014 from manufacturer performance test reports. These data show that in some years the number of higher-efficiency designs increases, indicating a potential average improvement in efficiency. However, DOE has no data indicating what percentage of shipments are attributed to these more-efficient air compressors, so no clear trend toward more efficient air compressors could be determined. Thus, DOE assumed no change in efficiency in the no-new-standards case.

DOE seeks comment on its assumption of no change over time in the market share of more efficient equipment in the no-new-standards case. This is identified as Issue 44 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

For each standards case, DOE used a ''roll-up'' scenario to establish the market shares by efficiency level for the year that compliance would be required with new standards (*i.e.,* late 2021). In this case, equipment efficiencies in the no-new-standards case that were above the standard level under consideration would not be affected. After the compliance year, DOE maintained consistency with the no-new-standards case and assumed no change in efficiency.

DOE seeks information on any projected change in equipment efficiencies over time, specifically whether or not the market shares of air compressors by efficiency would change after the publication of a new standard. This is identified as Issue 45 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

2. National Energy Savings

The national energy savings analysis involves a comparison of national energy consumption of the considered equipment between each potential standards case (TSL) and the no-new-standards case. DOE calculated the national energy consumption by multiplying the number of units (stock) of each product (by vintage or age) by the unit energy consumption (also by vintage). DOE calculated annual NES based on the difference in national energy consumption for the no-new-standards case and for each higher efficiency standard. DOE estimated energy consumption and savings based on site energy and converted the electricity consumption and savings to primary energy (*i.e.,* the energy consumed by power plants to generate site electricity) using annual conversion factors derived from *AEO 2015.* Cumulative energy savings are the sum of the NES for each year over the timeframe of the analysis.

In 2011, in response to the recommendations of a committee on ''Point-of-Use and Full-Fuel-Cycle Measurement Approaches to Energy Efficiency Standards'' appointed by the National Academy of Sciences, DOE announced its intention to use full-fuel-cycle (FFC) measures of energy use and greenhouse gas and other emissions in the national impact analyses and emissions analyses included in future energy conservation standards rulemakings. 76 FR 51281 (August 18, 2011). After evaluating the approaches discussed in the August 18, 2011 notice, DOE published a statement of amended policy in which DOE explained its determination that EIA's National Energy Modeling System (NEMS) is the most appropriate tool for its FFC analysis and its intention to use NEMS for that purpose. 77 FR 49701 (August 17, 2012). NEMS is a public domain, multi-sector, partial equilibrium model of the U.S. energy sector [88] that EIA uses to prepare its *Annual Energy Outlook.* The approach used for deriving FFC measures of energy use and emissions is described in appendix 10A of the NOPR TSD.

3. Net Present Value Analysis

The inputs for determining the NPV of the total costs and benefits experienced by consumers are: (1) Total annual installed cost; (2) total annual operating costs; and (3) a discount factor to calculate the present value of costs and savings. DOE calculates net savings each year as the difference between the no-new-standards case and each standards case in terms of total savings in operating costs versus total increases in installed costs. DOE calculates operating cost savings over the lifetime of each product shipped during the forecast period. DOE used a discount factor based on real discount rates of 3 percent and 7 percent to discount future costs and savings to present values.

As discussed in section IV.F.1of this document, DOE did not find a firm bases to project a trend in air compressor prices, so DOE used constant real prices as the default. To evaluate the effect of uncertainty regarding the price trend estimates, DOE investigated the impact of different product price forecasts on the consumer NPV for the considered TSLs for air compressors. In addition to the default price trend, DOE considered two equipment price sensitivity cases—(1) a high price decline case based on Air and Gas Compressor Manufacturer historical Producer Price Index (PPI) series [89] and (2) a low price decline case based on *AEO 2015* industrial equipment price trend. The derivation of these price trends and the results of these sensitivity cases are described in appendix 10C of the NOPR TSD.

The operating cost savings are energy cost savings, which are calculated using the estimated energy savings in each year and the projected price of the appropriate form of energy. To estimate energy prices in future years, DOE multiplied the average regional energy prices by the forecast of annual national-average residential energy price changes in the Reference case from *AEO 2015,* which has an end year of 2040. To estimate price trends after 2040, DOE used the average annual rate of change in prices from 2020 to 2040. As part of the NIA, DOE also analyzed scenarios that used inputs from the *AEO 2015* Low Economic Growth and High Economic Growth cases. Those cases have higher and lower energy price trends compared to the Reference case. NIA results based on these cases are presented in appendix 10C of the NOPR TSD.

In calculating the NPV, DOE multiplies the net savings in future years by a discount factor to determine their present value. DOE uses discount factors based on both a 3-percent and a 7-percent real discount rate, in accordance with guidance provided by the Office of Management and Budget (OMB) to Federal agencies on the development of regulatory analysis.[90] The discount rates for the determination of NPV are in contrast to the discount rates used in the LCC analysis, which are designed to reflect a consumer's perspective. The 7-percent real value is an estimate of the average before-tax rate of return to private capital in the U.S. economy. The 3-percent real value represents the ''social rate of time

[88] For more information on NEMS, refer to *The National Energy Modeling System: An Overview,* DOE/EIA–0581 (98) (Feb.1998) (Available at: *http://www.eia.gov/oiaf/aeo/overview/).*

[89] U.S. Department of Labour, Bureau of Labor Statistics, Air & gas compressors, ex. compressors for ice making, refrigeration, or a/c equipment, Series ID: PCU33391233391211Z

[90] United States Office of Management and Budget. Circular A–4: Regulatory Analysis,'' (Sept. 17, 2003), section E (Available at: *www.whitehouse.gov/omb/memoranda/m03–21.html*).

preference,'' which is the rate at which society discounts future consumption flows to their present value.

I. Consumer Subgroup Analysis

In analyzing the potential impact of new or amended energy conservation standards on consumers, DOE evaluates the impact on identifiable subgroups of consumers that may be disproportionately affected by a new or amended national standard. The purpose of a subgroup analysis is to determine the extent of any such disproportional impacts. DOE evaluates impacts on particular subgroups of consumers by analyzing the LCC impacts and PBP for those particular consumers from alternative standard levels. For this NOPR, DOE analyzed the impacts of the considered standard levels on small business consumers. DOE used the LCC and PBP spreadsheet model to estimate the impacts of the considered efficiency levels on this subgroup. Chapter 11 in the NOPR TSD describes the consumer subgroup analysis.

J. Manufacturer Impact Analysis

1. Overview

DOE performed an MIA to estimate the financial impacts of energy conservation standards on manufacturers of compressors and to estimate the potential impacts of such standards on employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects and includes analyses of forecasted industry cash flows, the industry net present value (INPV), investments in research and development (R&D) and manufacturing capital, and domestic manufacturing employment. Additionally, the MIA seeks to determine how new energy conservation standards might affect manufacturing capacity and industry competition, as well as how standards contribute to the overall regulatory burden facing manufacturers. Finally, the MIA serves to identify any disproportionate impacts on manufacturer subgroups, including small business manufacturers.

The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash flow model with inputs specific to this rulemaking. The key GRIM inputs include data on the industry cost structure, unit production costs, equipment shipments, manufacturer markups, and investments in R&D and manufacturing capital required to produce compliant equipment. The key GRIM output is the INPV, which is the sum of industry annual cash flows over the analysis period, discounted using the industry-weighted average cost of capital. The model uses standard accounting principles to estimate the impacts of new energy conservation standards on a given industry by comparing changes in INPV between a base case and the various standards cases (TSLs). To capture the uncertainty relating to manufacturer pricing strategy following amended standards, the GRIM estimates a range of possible impacts under different markup scenarios.

The qualitative part of the MIA addresses manufacturer characteristics and market trends. Specifically, the MIA considers such factors as a potential standard's impact on manufacturing capacity, R&D capacity, competition within the industry, cumulative impact of other regulations, and impacts on manufacturer subgroups. The complete MIA is outlined in chapter 12 of the NOPR TSD.

DOE conducted the MIA for this rulemaking in three-phases. In Phase 1 of the MIA, DOE prepared a profile of the compressor industry using publicly available information, such as Securities and Exchange Commission (SEC) 10–K reports,[91] market research tools (*e.g.,* Hoovers [92]), corporate annual reports, the U.S. Census Bureau's 2013 Annual Survey of Manufacturers (ASM),[93] and industry trade association membership directories (*e.g.,* CAGI), as well as information obtained through DOE's engineering analysis and market and technology assessment prepared for this rulemaking.

In Phase 2 of the MIA, DOE prepared a framework industry cash-flow analysis to quantify the potential impacts of new energy conservation standards on manufacturers. In general, energy conservation standards can affect manufacturer cash flow in three distinct ways: (1) Creating a need for increased investment; (2) raising production costs per unit; and (3) altering revenue due to higher per-unit prices and changes in sales volumes. To quantify these impacts, DOE uses the GRIM to estimate a series of annual cash flows starting with the announcement of the standard and extending over a 30-year period following the compliance date of the standard. Inputs to the GRIM include annual expected revenues, costs of sales, SG&A expenses, R&D expenses, taxes, and capital expenditures.

In addition, DOE developed interview guides to distribute to manufacturers of compressors in order to develop and refine key GRIM inputs, including product and capital conversion costs, and to gather additional information on the anticipated effects of energy conservation standards on revenues, direct employment, capital assets, industry competitiveness, and subgroup impacts.

In Phase 3 of the MIA, DOE conducted structured, detailed interviews with manufacturers. During these interviews, DOE discussed engineering, manufacturing, procurement, and financial topics to validate assumptions used in the GRIM and to identify key issues or concerns. A copy of the manufacturer interview guide is provided in appendix 12B of NOPR TSD. Additionally, see section IV.J.3 for a description of the key issues raised by manufacturers during the interviews. As part of Phase 3, DOE also evaluated subgroups of manufacturers that may be disproportionately impacted by amended standards or that may not be accurately represented by the average cost assumptions used to develop the industry cash flow analysis. Such manufacturer subgroups may include small business manufacturers, niche players, and/or manufacturers exhibiting a cost structure that largely differs from the industry average. DOE identified one compressor manufacturer subgroup for which average cost assumptions may not hold: small businesses. The small business subgroup is discussed in section VII.B, ''Review under the Regulatory Flexibility Act,'' and in chapter 12 of the NOPR TSD.

2. GRIM Analysis

As discussed previously, DOE uses the GRIM to quantify the changes in cash flow that result in a higher or lower industry value due to energy conservation standards. The GRIM analysis uses a discounted cash-flow methodology that incorporates manufacturer costs, markups, shipments, and industry financial information as inputs. The GRIM models changes in MPCs, distributions of shipments, investments, and manufacturer margins that could result from new energy conservation standards. The GRIM spreadsheet uses the inputs to arrive at a series of annual cash flows, beginning in 2015 (the base year of the analysis) and continuing to 2051. DOE calculated INPVs by

[91] U.S. Securities and Exchange Commission, Annual 10–K Reports (Various Years) (Available at: *www.sec.gov*).

[92] Hoovers Inc., Company Profiles, Various Companies (Available at: *www.hoovers.com/*).

[93] U.S. Census Bureau, Annual Survey of Manufacturers: General Statistics: Statistics for Industry Groups and Industries (2013) (Available at: *http://www.census.gov/manufacturing/asm/index.html*).

summing the stream of annual discounted cash flows during this period. DOE applied a discount rate of 8.7 percent, derived from industry financials and then modified according to feedback received during manufacturer interviews.

In the GRIM, DOE calculates cash flows using standard accounting principles and compares changes in INPV between the base case and each TSL (the standards case). The difference in INPV between the base case and a standards case represents the financial impact of the energy conservation standard on manufacturers. Additional details about the GRIM, the discount rate, and other financial parameters can be found in chapter 12 of the NOPR TSD.

a. GRIM Key Inputs

i. Manufacturer Production Costs

Manufacturer production costs (MPCs) are those incurred by the manufacturer to produce a covered compressor. The cost includes raw materials and purchased components, production labor, factory overhead, and production equipment depreciation. Changes in the MPCs of the analyzed equipment can affect revenues, gross margins, and industry cash flows. In the MIA, DOE used the MPCs for each efficiency level calculated in the engineering analysis, as described in section IV.C.7 and further detailed in chapter 5 of the NOPR TSD.

ii. Manufacturer Markups

Manufacturer selling prices (MSPs) include direct manufacturing production costs and all non-production costs (*i.e.,* SG&A, R&D, and interest), along with profit. To calculate the MSPs in the GRIM, DOE applied non-production cost markups to the MPCs estimated in the engineering analysis for each equipment class and efficiency level. For the MIA, DOE modeled a baseline markup for the compressor industry in both the base case and the standards case.

With a baseline markup, DOE applied a uniform ''gross margin percentage'' for each equipment class, across all efficiency levels. This assumes that manufacturers would be able to maintain the same amount of profit as a percentage of revenues at all efficiency levels within an equipment class. As production costs increase with efficiency, the absolute dollar markup will increase as well. As discussed in section IV.C.7, DOE estimated the average non-production cost baseline markup—which includes SG&A expenses, R&D expenses, interest, and profit—to be 1.35 for lubricated rotary compressors, 1.40 for lubricant-free rotary compressors, and 1.26 for reciprocating compressors.

Jenny commented that markups data only based on publicly available information may not be accurate and may not contain key pricing and costing information. (Jenny, No. 0005 at p. 4) DOE agrees. To develop its estimated baseline markups, DOE used both publicly available financial information as well as comments and data received directly from manufacturers during confidential interviews.

iii. Shipments Forecast

The GRIM estimates manufacturer revenues based on total unit shipment forecasts and the distribution of shipments by equipment class. Changes in sales volumes and efficiency mix over time can significantly affect manufacturer finances. For this analysis, the GRIM uses the NIA's annual shipment forecasts derived from the shipments analysis from 2015 (the base year) to 2051 (the end year of the analysis period). See chapter 9 of the NOPR TSD for additional details.

iv. Product and Capital Conversion Costs

Energy conservation standards can cause manufacturers to incur conversion costs to make necessary changes to their production facilities and bring equipment designs into compliance. DOE evaluated the level of conversion-related expenditures that would be needed to comply with each considered efficiency level in each equipment class. For the purpose of the MIA, DOE classified these conversion costs into two major groups: (1) Product conversion costs; and (2) capital conversion costs. Product conversion costs are investments in research, development, testing, and marketing, focused on making equipment designs comply with the energy conservation standard. Capital conversion costs are investments in property, plant, and equipment to adapt or change existing production facilities so that compliant equipment designs can be fabricated and assembled. Ultimately, for the MIA, DOE modeled two standards-case conversion cost scenarios to represent uncertainty regarding the potential impacts on manufacturers following the implementation of energy conservation standards. These scenarios are discussed further in section IV.J.2.b.

v. Financial Parameters

DOE estimated eight key financial parameters for use in the GRIM. Table IV.38 describes these parameters and summarizes DOE's estimated values. DOE notes that each estimate represents an industry average value.

Jenny commented that ''deriving baseline information from publicly traded companies is problematic at best . . . a very high percentage of compressors sold in the US come from small, privately held companies.'' (Jenny, No. 0005 at p. 5)

To estimate the financial parameters outlined in Table IV.38, DOE first created estimates based on publicly available financial information for manufacturers of compressors. DOE then revised its initial estimates based on discussions with both private and public compressor companies. Table IV.38 presents the financial parameters incorporated into the GRIM, which reflect data from both public and private compressor manufacturing companies.

TABLE IV.38—INDUSTRY AVERAGE FINANCIAL PARAMETERS FOR ROTARY AND RECIPROCATING COMPRESSOR MANUFACTURERS

Financial parameter	Definition	Estimated industry average value %
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes, EBT)	25.0
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity).	8.7
Working Capital	Current assets less current liabilities (percentage of revenues)	17.3
Net Property, Plant & Equipment	Fixed assets, or long-lived assets, including building, machinery, and equipment less accumulated depreciation (percentage of revenues).	11.4
SG&A	Selling, general, and administrative expenses (percentage of revenues)	17.2
R&D	Research and development expenses (percentage of revenues)	2.1
Depreciation	Amortization of fixed assets (percentage of revenues)	3.0

TABLE IV.38—INDUSTRY AVERAGE FINANCIAL PARAMETERS FOR ROTARY AND RECIPROCATING COMPRESSOR MANUFACTURERS—Continued

Financial parameter	Definition	Estimated industry average value %
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units).	3.2

DOE requests comment on its estimates of average industry financial parameters. This is identified as Issue 46 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

b. GRIM Scenarios

i. Conversion Cost Scenarios

As mentioned previously, DOE modeled two standards-case conversion cost scenarios to represent uncertainty regarding the potential impacts on manufacturers following the implementation of energy conservation standards: (1) A low conversion cost scenario; and (2) a high conversion cost scenario.

Specifically, the two scenarios explore uncertainty in conversion cost, as it relates to the draft EU minimum energy efficiency standards for compressors. During confidential interviews, multiple manufactures indicated that they sell similar equipment in the U.S. and the EU. They also indicated that if the EU adopted the draft standard for compressors, the efficiency of some equipment sold in the U.S. would be improved by windfall. As such, if the EU adopts its draft standard, which would be phased in from 2018 to 2020,[94] a significant amount of globally marketed equipment would already exhibit improved efficiency, regardless of a DOE standard. However, because the EU standard is currently in draft stage, and is not yet adopted, DOE chose to use a scenario analysis to evaluate its potential impacts on conversion cost.

DOE notes that conversion costs only vary between the scenarios for lubricated rotary equipment, as lubricant-free rotary equipment is not proposed for coverage in the EU (but may be evaluated for future coverage—see section IV.A.2.b), and DOE is unaware of any reciprocating compressor models sold in both the EU and the United States.

The low conversion cost scenario assumes that manufacturers active in the EU market will not face additional product conversion costs to adapt to a U.S. standard that is at or below the draft EU level (EL 3 and TSL 3). If the U.S. standard is above the draft EU level, these manufacturers would still incur full redesign costs. In the high conversion cost scenario, all manufacturers face full product conversion costs, regardless of an EU regulation. DOE notes that Manufacturers that are not active in the EU market will face the same conversion costs, regardless of the scenario.

To evaluate the magnitude of each product and capital conversion cost scenario, DOE relied on cost estimates provided by representative manufacturers as well as estimates and appraisals provided by consultants familiar with compressor and general industrial manufacturing.

DOE first determined conversion costs for the high scenario. To find industry-wide conversion costs for each equipment class, DOE first estimated the average cost per manufacturer to redesign all covered equipment in its portfolio; this corresponds to the conversion costs needed to reach the max-tech efficiency level. For each equipment class, DOE then multiplied the per-manufacturer conversion costs by the number of manufacturers active in the equipment class with a market share greater than three percent. DOE believes its per-manufacturer conversion cost estimates were sufficiently conservative such that this method yields an estimate of total industry conversion costs to reach the max-tech efficiency level for each equipment class.

Next, DOE scaled the max-tech conversion costs down to each efficiency level considered in this NOPR. To do this, DOE multiplied the max-tech conversion costs by the percentage of models in each equipment class that fail at each efficiency level. For rotary equipment classes, DOE estimated the percentage of models failing at each efficiency level using the CAGI database.

For reciprocating equipment classes, no product data was available to help estimate the percentage of models failing at each efficiency level. In the absence of direct data, failure rates for rotary compressor equipment were used as a proxy. DOE selected this approach as efficiency levels for reciprocating and rotary compressors were established using similar methods, and each efficiency level represents the same relative efficiency, with respect to baseline and max-tech (as discussed in section IV.C.5). Specifically, for all equipment classes, DOE established efficiency levels at baseline (EL 0), max-tech (EL 6), and a d-value of zero (EL 3). DOE also established two intermediary efficiency levels between the baseline and a d-value of zero (ELs 1 and EL 2), and two efficiency levels between the d-value of zero level and max-tech (ELs 4 and 5). Furthermore, DOE believes that rotary and reciprocating equipment may have similar distributions of efficiency, with respect to baseline and max-tech, as indicated by graphical data presented in the Lot 31 study.[95]

DOE requests comment on the use of failure rates for rotary compressor equipment as a proxy for reciprocating equipment failure rates. This is identified as Issue 47 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

To estimate conversion costs for the low scenario, DOE reduced the lubricated rotary product conversion costs by 31.25-percent at each efficiency level at or below the draft EU level. The value of 31.25-percent represents DOE's estimate of the percentage of U.S. lubricated rotary models that are offered for sale in the EU and may be redesigned to meet the draft EU level.

Table IV.39 and Table IV.40 present the resulting product and capital conversion costs at each efficiency level, for three major groupings of equipment classes. Due to commonality in design and components, DOE is presenting the conversion costs for the following equipment classes in aggregate: (1) Rotary, lubricated, fixed-speed and variable-speed, air and water cooled; (2) rotary, lubricant-free, VSD, fixed-speed and variable-speed, air and water cooled; and (3) reciprocating, 1- and 3-

[94] See Draft EU Compressors Regulation, Article 3 at p. 4, available at: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031*.

[95] See Lot 31 Study, figures 1–1 through 1–3 at pp. 26–28 available at: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031*.

phase. Complete results by equipment class, as well as details on the calculation of industry aggregate product and capital conversion costs are found in chapter 12 of the NOPR TSD. A comparison of industry financial impacts under the two conversion cost scenarios is presented in section V.B.2.a of this document.

TABLE IV.39—AGGREGATE INDUSTRY PRODUCT CONVERSION COST, EXCLUDING COMPLIANCE AND TESTING COSTS,** AT EACH EFFICIENCY LEVEL

[In $Millions]

All values in millions of dollars	Scenario	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
RP_FS_L_AC RP_VS_L_AC RP_FS_L_WC RP_VS_L_WC	Low	16	57	144	269	333	424
	High	24	84	210	269	333	424
RP_FS_LF_AC RP_VS_LF_AC RP_FS_LF_WC RP_VS_LF_WC	Not Applicable	10	27	59	75	92	112
R3_FS_L_XX R1_FS_L_XX	Not Applicable	2	5	13	17	21	27

* Due to commonality in design and components, DOE is presenting conversion costs in three aggregated equipment class groups. Complete results by equipment class are available in chapter 12 of the NOPR TSD.

** Note that compliance and testing cost estimates are presented separately, later in this section.

TABLE IV.40—AGGREGATE INDUSTRY CAPITAL CONVERSION COST AT EACH EFFICIENCY LEVEL

All values in millions of dollars	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
RP_FS_L_AC RP_VS_L_AC RP_FS_L_WC RP_VS_L_WC	8	29	73	92	113	143
Rotary, Non-Lubricated, FS & VSD, AC & WC*	3	9	20	26	32	38
RP_FS_LF_AC RP_VS_LF_AC RP_FS_LF_WC RP_VS_LF_WC	1	3	8	10	12	16

* Due to commonality in design and components, DOE is presenting conversion costs in three aggregated equipment class groups. Complete results by equipment class are available in chapter 12 of the NOPR TSD.

DOE also estimated the magnitude of the aggregate industry compliance testing costs needed to conform to new energy conservation standards. Although compliance testing costs are a subset of product conversion costs, DOE estimated these costs separately. DOE pursued this approach because no energy conservation standards currently exist for compressors; as such, all basic models[96] will be required to be tested and certified to comply with new energy conservation standards regardless of the level of such a standard. As a result, the industry-wide magnitude of these compliance testing costs will be constant, regardless of the selected standard level.

DOE notes that new energy conservation standards will require every model offered for sale to be tested according to the sampling plan proposed in the test procedure NOPR. This proposed sampling plan specifies that a minimum of two units must be tested to certify a basic model as compliant.

DOE estimated the industry-wide magnitude of compliance testing by multiplying the estimated number of models currently in each equipment class by the cost to test each model, and doubling this value to account for the minimum sample size of two units per basic model. DOE estimated the total number of rotary models in the industry by scaling the model counts in the CAGI database by CAGI's estimated market share. The number of reciprocating models was estimated using data collected from manufacturer Web sites. DOE estimated the cost to test each model to the method proposed in the test procedure NOPR from discussions with third-party compressor test labs as well as information gathered during confidential manufacturer interviews. Table IV.41 presents DOE's estimates of aggregate industry compliance testing costs for each equipment class. Complete details on the calculation of aggregate industry compliance testing costs are found in chapter 12 of the NOPR TSD.

TABLE IV.41—AGGREGATE INDUSTRY COMPLIANCE TESTING COST

Equipment class	Aggregate industry compliance testing cost ($Millions)
RP_FS_L_AC	4.72
RP_VS_L_AC	2.48
RP_FS_L_WC	0.95
RP_VS_L_WC	0.50
RP_FS_LF_AC	2.16

[96] In the test procedure NOPR, DOE proposes to define the term "basic model" as "all units of a class of compressors manufactured by one manufacturer, having the same primary energy source, the same compressor motor nominal horsepower, and essentially identical electrical, physical, and functional (or pneumatic) characteristics that affect energy consumption and energy efficiency."

TABLE IV.41—AGGREGATE INDUSTRY COMPLIANCE TESTING COST—Continued

Equipment class	Aggregate industry compliance testing cost ($Millions)
RP_VS_LF_AC	1.34
RP_FS_LF_WC	0.46
RP_VS_LF_WC	0.24
R1_FS_L_XX	5.57
R3_FS_L_XX	25.1

In general, DOE assumes that all conversion-related investments occur between the year of publication of the final rule and the year by which manufacturers must comply with the standard.

DOE requests feedback on its conversion cost methodology, including quantitative estimates and qualitative descriptions of the capital and product conversion costs manufacturers would incur in order to comply with amended energy conservation standards. This is identified as Issue 48 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

3. Manufacturer Interviews

As part of the MIA, DOE discussed potential impacts of standards with nine compressor manufacturers. The interviewed manufacturers account for approximately 70 percent of the domestic rotary compressor market and approximately 20 percent of the domestic reciprocating compressor market. In interviews, DOE asked manufacturers to describe their major concerns about this rulemaking. This section highlights manufacturer statements that helped shaped DOE's understanding of the potential impacts of an energy conservation standard on the industry.

a. Conversion Requirements

Manufacturers raised concerns over potentially significant conversion costs, particularly at higher efficiency levels. Several manufacturers of rotary equipment indicated that if U.S. standards exceed the levels proposed in the draft EU Lot 31 compressors standards, adequate capital may not be available to fund the redesigns and manufacturing equipment needed to maintain their current product portfolios. At higher efficiency levels, namely those that remove more than 75-percent of models from the market, many indicated they would consider closing manufacturing facilities rather than make the investments necessary to comply with such efficiency standards.

b. Engineering Constraints and Development Cycle Times

The primary efficiency-improving technology option discussed in this NOPR is compressor package redesign. A compressor package redesign relies on the expertise of many highly trained engineers to redesign a compressor to higher efficiency levels, while still meeting other performance and reliability criteria. Many manufacturers of rotary equipment expressed concern surrounding insufficient availability of engineering resources required to redesign a high volume of compressor packages during a short time period. Manufacturers indicated that most experienced compressor design engineers are already employed within the industry, which limits their ability to rapidly expand their research and development teams if faced with a high volume of required compressor redesigns. Consequently, manufacturers typically commented that at standard levels at or above the equivalent of TSL 3, these engineering constraints could create time delays in complying with new standards. DOE notes that manufacturers typically discussed this constraint with respect to a three-year compliance period.

Some manufacturers indicated that a longer compliance period, such as the five-year compliance period proposed in this document, may ease their concern over engineering constraints, as their existing engineering teams would be able to accomplish more redesigns if given more time. Under business-as-usual conditions most manufacturers indicated that a typical lubricated rotary compressor redesign would last between 18 and 24 months. This timeframe is expected to extend if R&D teams are faced with large numbers of concurrent redesigns.

c. Relationship to the Draft European Union Energy Efficiency Standards

Some manufacturers emphasized the importance of harmonizing U.S. energy conservation standards with proposed EU standards for compressors. Some manufacturers have already begun preparations for the proposed EU standard. These manufacturers stated that harmonized standards would promote regulatory consistency and would enable them to better coordinate product redesigns and reduce conversion costs. If U.S. and EU standards are not harmonized, these manufacturers noted they would either have to carry a greater number of equipment lines to comply with efficiency standards in both domestic and European markets, or sell a single set of high efficiency equipment in both markets. The former adds complexity and cost. The latter may put the manufacturer at a competitive disadvantage in the market regulated to a lower efficiency.

Conversely, some manufacturers expressed concern that the proposed EU standard levels are too aggressive, and they indicated that such a level in the U.S. could result in adverse impacts to manufacturers.

d. Unfair Advantages for Replacement Technologies

Many manufacturers of rotary equipment expressed concerns that energy conservation standards on rotary compressors of 200-hp or greater may provide unfair advantages to competing technologies such as dynamic compressors (also known as centrifugal compressors). These manufacturers contend that both technologies are already competitive above 200-hp and both offer certain advantages to the end user. Increased prices resulting from a standard on only rotary equipment could push more end users to choose dynamic compressors, which would remain unregulated and unchanged in price. Furthermore, these manufacturers believe that coverage of only rotary compressors will unfairly burden them with costs and expenses not seen by their dynamic compressor competition.

e. Uncertainty of Compliance Cost for Reciprocating Equipment

Some manufacturers of reciprocating equipment indicated that most reciprocating equipment in the U.S. market are not currently tested or labeled for efficiency. These manufacturers expressed two concerns related to this issue: (1) Many manufacturers do not currently know the efficiency of their equipment, and therefore cannot estimate the impact of the standard and the cost to their organization; and (2) many manufacturers do not currently have test facilities and will be required to either build facilities or utilize third-party test labs, both of which are new and unfamiliar costs to them.

K. Emissions Analysis

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site (where applicable) combustion emissions of CO_2, NO_X, SO_2, and Hg. The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, CH_4 and N_2O, as well as the reductions to emissions of all species due to ''upstream'' activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions.

The analysis of power sector emissions uses marginal emissions factors that were derived from data in *AEO 2015,* as described in section IV.M. The methodology is described in chapter 13 and chapter 15 of the NOPR TSD.

Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors from the EPA GHG Emissions Factors Hub.[97] The FFC upstream emissions are estimated based on the methodology described in chapter 15 of the NOPR TSD. The upstream emissions include both emissions from fuel combustion during extraction, processing, and transportation of fuel, and ''fugitive'' emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The emissions intensity factors are expressed in terms of physical units per megawatt hour (MWh) or million British thermal units (MMBtu) of site energy savings. Total emissions reductions are estimated using the energy savings calculated in the national impact analysis.

The *AEO 2015* projections incorporate the projected impacts of existing air quality regulations on emissions. *AEO 2015* generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of October 31, 2014. DOE's estimation of impacts accounts for the presence of the emissions control programs discussed in the following paragraphs.

SO_2 emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap-and-trade programs. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous States and the District of Columbia (DC). (42 U.S.C. 7651 *et seq.*) SO_2 emissions from 28 eastern States and DC were also limited under the Clean Air Interstate Rule (CAIR). 70 FR 25162 (May 12, 2005). CAIR created an allowance-based trading program that operates along with the Title IV program. In 2008, CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit, but it remained in effect.[98] In 2011, EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (August 8, 2011). On August 21, 2012, the DC Circuit issued a decision to vacate CSAPR,[99] and the court ordered EPA to continue administering CAIR. On April 29, 2014, the U.S. Supreme Court reversed the judgment of the DC Circuit and remanded the case for further proceedings consistent with the Supreme Court's opinion.[100] On October 23, 2014, the DC Circuit lifted the stay of CSAPR.[101] Pursuant to this action, CSAPR went into effect (and CAIR ceased to be in effect) as of January 1, 2015.

EIA was not able to incorporate CSAPR into *AEO 2015,* so it assumes implementation of CAIR. Although DOE's analysis used emissions factors that assume that CAIR, not CSAPR, is the regulation in force, the difference between CAIR and CSAPR is not significant for the purpose of DOE's analysis of emissions impacts from energy conservation standards.

The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the adoption of an efficiency standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of efficiency standards on SO_2 emissions covered by the existing cap-and-trade system, but it concluded that negligible reductions in power sector SO_2 emissions would occur as a result of standards.

Beginning in 2016, however, SO_2 emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants. 77 FR 9304 (Feb. 16, 2012). In the MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO_2 (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, SO_2 emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2015* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce SO_2 emissions. Under the MATS, emissions will be far below the cap established by CAIR, so it is unlikely that excess SO_2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO_2 emissions by any regulated EGU.[102] Therefore, DOE believes that energy conservation standards will generally reduce SO_2 emissions in 2016 and beyond.

CAIR established a cap on NO_X emissions in 28 eastern States and the District of Columbia.[103] Energy conservation standards are expected to have little effect on NO_X emissions in those States covered by CAIR because excess NO_X emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NO_X emissions from other facilities. However, standards would be expected to reduce NO_X emissions in the States not affected by the caps, so DOE estimated NO_X emissions reductions from the standards considered in this NOPR for these States.

The MATS limit mercury emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated mercury emissions reduction

[97] Available at: *http://www2.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub.*

[98] See *North Carolina* v. *EPA,* 550 F.3d 1176 (D.C. Cir. 2008); *North Carolina* v. *EPA,* 531 F.3d 896 (D.C. Cir. 2008).

[99] See *EME Homer City Generation, LP* v. *EPA,* 696 F.3d 7, 38 (D.C. Cir. 2012), *cert. granted,* 81 U.S.L.W. 3567, 81 U.S.L.W. 3696, 81 U.S.L.W. 3702 (U.S. June 24, 2013) (No. 12–1182).

[100] See *EPA* v. *EME Homer City Generation,* 134 S.Ct. 1584, 1610 (2014). The Supreme Court held in part that EPA's methodology for quantifying emissions that must be eliminated in certain States due to their impacts in other downwind States was based on a permissible, workable, and equitable interpretation of the Clean Air Act provision that provides statutory authority for CSAPR.

[101] See Georgia v. EPA, Order (D.C. Cir. filed October 23, 2014) (No. 11–1302).

[102] DOE notes that the Supreme Court recently remanded EPA's 2012 rule regarding national emission standards for hazardous air pollutants from certain electric utility steam generating units. See *Michigan* v. *EPA* (Case No. 14–46, 2015). DOE has tentatively determined that the remand of the MATS rule does not change the assumptions regarding the impact of energy efficiency standards on SO_2 emissions. Further, while the remand of the MATS rule may have an impact on the overall amount of mercury emitted by power plants, it does not change the impact of the energy efficiency standards on mercury emissions. DOE will continue to monitor developments related to this case and respond to them as appropriate.

[103] CSAPR also applies to NO_X and it supersedes the regulation of NO_X under CAIR. As stated previously, the current analysis assumes that CAIR, not CSAPR, is the regulation in force. The difference between CAIR and CSAPR with regard to DOE's analysis of NO_X emissions is slight.

using emissions factors based on *AEO 2015,* which incorporates the MATS.

L. Monetizing Carbon Dioxide and Other Emissions Impacts

As part of the development of this proposed rule, DOE considered the estimated monetary benefits from the reduced emissions of CO_2 and NO_X that are expected to result from each of the TSLs considered. In order to make this calculation analogous to the calculation of the NPV of consumer benefit, DOE considered the reduced emissions expected to result over the lifetime of equipment shipped in the forecast period for each TSL. This section summarizes the basis for the monetary values used for CO_2 and NO_X emissions and presents the values considered in this NOPR.

1. Social Cost of Carbon

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. Estimates of the SCC are provided in dollars per metric ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in CO_2 emissions, while a global SCC value is meant to reflect the value of damages worldwide.

Under section 1(b)(6) of Executive Order 12866, ''Regulatory Planning and Review,'' 58 FR 51735 (Oct. 4, 1993), agencies must, to the extent permitted by law, ''assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.'' The purpose of the SCC estimates presented here is to allow agencies to incorporate the monetized social benefits of reducing CO_2 emissions into cost-benefit analyses of regulatory actions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed these SCC estimates, technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

a. Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of CO_2 emissions, the analyst faces a number of challenges. A report from the National Research Council [104] points out that any assessment will suffer from uncertainty, speculation, and lack of information about: (1) Future emissions of GHGs; (2) the effects of past and future emissions on the climate system; (3) the impact of changes in climate on the physical and biological environment; and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise questions of science, economics, and ethics and should be viewed as provisional.

Despite the limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing CO_2 emissions. The agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC values appropriate for that year. The NPV of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. In the meantime, the interagency group will continue to explore the issues raised by this analysis and consider public comments as part of the ongoing interagency process.

b. Development of Social Cost of Carbon Values

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To ensure consistency in how benefits are evaluated across Federal agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment by the interagency group was a set of five interim values: Global SCC estimates for 2007 (in 2006$) of $55, $33, $19, $10, and $5 per metric ton of CO_2. These interim values represented the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules.

c. Current Approach and Key Assumptions

After the release of the interim values, the interagency group reconvened on a regular basis to generate improved SCC estimates. Specially, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models commonly used to estimate the SCC: The FUND, DICE, and PAGE models. These models are frequently cited in the peer-reviewed literature and were used in the last assessment of the Intergovernmental Panel on Climate Change (IPCC). Each model was given equal weight in the SCC values that were developed.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models, while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: Climate sensitivity, socio-economic and emissions trajectories, and discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the socio-economic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments.

[104] National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use,* National Academies Press: Washington, DC (2009).

In 2010, the interagency group selected four sets of SCC values for use in regulatory analyses. Three sets of values are based on the average SCC from the three integrated assessment models, at discount rates of 2.5-, 3-, and 5-percent. The fourth set, which represents the 95th percentile SCC estimate across all three models at a 3-percent discount rate, was included to represent higher-than-expected impacts from climate change further out in the tails of the SCC distribution. The values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7-percent to 23-percent should be used to adjust the global SCC to calculate domestic effects,[105] although preference is given to consideration of the global benefits of reducing CO_2 emissions. Table IV.42 presents the values in the 2010 interagency group report,[106] which is reproduced in appendix 14A of the NOPR TSD.

TABLE IV.42—ANNUAL SCC VALUES FROM 2010 INTERAGENCY REPORT, 2010–2050

[2007$ per metric ton CO_2]

Year	Discount rate			
	5%	3%	2.5%	3%
	Average	Average	Average	95th percentile
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC values used for this document were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature, as described in the 2013 update from the interagency working group (revised July 2015).[107] Table IV.43 shows the updated sets of SCC estimates from the latest interagency update in 5-year increments from 2010 to 2050. The full set of annual SCC values between 2010 and 2050 is reported in appendix 14B of the NOPR TSD. The central value that emerges is the average SCC across models at the 3-percent discount rate. However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SCC values.

TABLE IV.43—ANNUAL SCC VALUES FROM 2013 INTERAGENCY UPDATE (REVISED JULY 2015), 2010–2050

[2007$ per metric ton CO_2]

Year	Discount rate			
	5%	3%	2.5%	3%
	Average	Average	Average	95th percentile
2010	10	31	50	86
2015	11	36	56	105
2020	12	42	62	123
2025	14	46	68	138
2030	16	50	73	152
2035	18	55	78	168
2040	21	60	84	183
2045	23	64	89	197
2050	26	69	95	212

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable because they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Research Council report mentioned previously points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. There are a number of analytical challenges that are being addressed by the research community, including

[105] It is recognized that this calculation for domestic values is approximate, provisional, and highly speculative. There is no *a priori* reason why domestic benefits should be a constant fraction of net global damages over time.

[106] *Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.* Interagency Working Group on Social Cost of Carbon, United States Government (February 2010) (Available at: *www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf*).

[107] *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866,* Interagency Working Group on Social Cost of Carbon, United States Government (May 2013; revised July 2015) (Available at: *http://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf*).

research programs housed in many of the Federal agencies participating in the interagency process to estimate the SCC. The interagency group intends to periodically review and reconsider those estimates to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling.[108]

In summary, in considering the potential global benefits resulting from reduced CO_2 emissions, DOE used the values from the 2013 interagency report (revised July 2015), adjusted to 2015$ using the implicit price deflator for gross domestic product (GDP) from the Bureau of Economic Analysis. For each of the four sets of SCC cases specified, the values for emissions in 2015 were $12.2, $40.0, $62.3, and $117 per metric ton avoided (values expressed in 2015$). DOE derived values after 2050 based on the trend in 2010–2050 in each of the four cases.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SCC value for that year in each of the four cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SCC values in each case.

2. Social Cost of Other Air Pollutants

As noted previously, DOE has estimated how the considered energy conservation standards would decrease power sector NO_X emissions in those 22 States not affected by the CAIR.

DOE estimated the monetized value of net NO_X emissions reductions using benefit per ton estimates from the *Regulatory Impact Analysis for the Clean Power Plan Final Rule,* published in August 2015 by EPA's Office of Air Quality Planning and Standards.[109] The report includes high and low values for NO_X (as $PM_{2.5}$) for 2020, 2025, and 2030 discounted at 3 percent and 7 percent; these values are presented in chapter 14 of the NOPR TSD. DOE primarily relied on the low estimates to be conservative.[110] DOE assigned values for 2021–2024 and 2026–2029 using, respectively, the values for 2020 and 2025. DOE assigned values after 2030 using the value for 2030. DOE developed values specific to the end-use category for compressors using a method described in appendix 14–C.

DOE multiplied the emissions reduction (tons) in each year by the associated $/ton values, and then discounted each series using discount rates of 3-percent and 7-percent as appropriate. DOE will continue to evaluate the monetization of avoided NO_X emissions and will make any appropriate updates of the current analysis for the final rulemaking.

DOE is evaluating appropriate monetization of avoided SO_2 and Hg emissions in energy conservation standards rulemakings. DOE has not included monetization of those emissions in the current analysis.

M. Utility Impact Analysis

The utility impact analysis estimates several effects on the electric power generation industry that would result from the adoption of new or amended energy conservation standards. The utility impact analysis DOE estimates the changes in installed electrical capacity and generation that would result for each TSL. The analysis is based on published output from the NEMS, associated with *AEO 2015.* NEMS produces the *AEO* Reference case, as well as a number of side cases that estimate the economy-wide impacts of changes to energy supply and demand. DOE uses published side cases that incorporate efficiency-related policies to estimate the marginal impacts of reduced energy demand on the utility sector. These marginal factors are estimated based on the changes to electricity sector generation, installed capacity, fuel consumption and emissions in the *AEO* Reference case and various side cases. Details of the methodology are provided in the appendices to Chapters 13 and 15 of the NOPR TSD.

The output of this analysis is a set of time-dependent coefficients that capture the change in electricity generation, primary fuel consumption, installed capacity and power sector emissions due to a unit reduction in demand for a given end use. These coefficients are multiplied by the stream of electricity savings calculated in the NIA to provide estimates of selected utility impacts of new or amended energy conservation standards.

N. Employment Impact Analysis

DOE considers employment impacts in the domestic economy as one factor in selecting a proposed standard. Employment impacts from new or amended energy conservation standards include both direct and indirect impacts. Direct employment impacts are any changes in the number of employees of manufacturers of the equipment subject to standards, their suppliers, and related service firms. The MIA addresses those impacts. Indirect employment impacts are changes in national employment that occur due to the shift in expenditures and capital investment caused by the purchase and operation of more-efficient appliances. Indirect employment impacts from standards consist of the net jobs created or eliminated in the national economy, other than in the manufacturing sector being regulated, caused by: (1) Reduced spending by end users on energy; (2) reduced spending on new energy supply by the utility industry; (3) increased consumer spending on new equipment to which the new standards apply; and (4) the effects of those three factors throughout the economy.

One method for assessing the possible effects on the demand for labor of such shifts in economic activity is to compare sector employment statistics developed by the Labor Department's Bureau of Labor Statistics (BLS).[111] BLS regularly publishes its estimates of the number of jobs per million dollars of economic activity in different sectors of the economy, as well as the jobs created elsewhere in the economy by this same economic activity. Data from BLS indicate that expenditures in the utility sector generally create fewer jobs (both directly and indirectly) than expenditures in other sectors of the economy.[112] There are many reasons for these differences, including wage differences and the fact that the utility sector is more capital-intensive and less

[108] In November 2013, OMB announced a new opportunity for public comment on the interagency technical support document underlying the revised SCC estimates. 78 FR 70586. In July 2015 OMB published a detailed summary and formal response to the many comments that were received. *https://www.whitehouse.gov/blog/2015/07/02/estimating-benefits-carbon-dioxide-emissions-reductions.* It also stated its intention to seek independent expert advice on opportunities to improve the estimates, including many of the approaches suggested by commenters.

[109] Available at: *http://www.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.* See Tables 4A–3, 4A–4, and 4A–5 in the report.

[110] For the monetized NO_X benefits associated with $PM_{2.5}$, the related benefits are primarily based on an estimate of premature mortality derived from the ACS study (Krewski et al. 2009), which is the lower of the two EPA central tendencies. Using the lower value is more conservative when making the policy decision concerning whether a particular standard level is economically justified. If the benefit-per-ton estimates were based on the Six Cities study (Lepuele et al. 2012), the values would be nearly two-and-a-half times larger. (See chapter 14 of the NOPR TSD for citations for the studies mentioned above.)

[111] Data on industry employment, hours, labor compensation, value of production, and the implicit price deflator for output for these industries are available upon request by calling the Division of Industry Productivity Studies (202–691–5618) or by sending a request by email to *dipsweb@bls.gov.*

[112] See Bureau of Economic Analysis, Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II), U.S. Department of Commerce (1992).

labor-intensive than other sectors. Energy conservation standards have the effect of reducing consumer utility bills. Because reduced consumer expenditures for energy likely lead to increased expenditures in other sectors of the economy, the general effect of efficiency standards is to shift economic activity from a less labor-intensive sector (*i.e.,* the utility sector) to more labor-intensive sectors (*e.g.,* the retail and service sectors). Thus, the BLS data suggest that net national employment may increase due to shifts in economic activity resulting from energy conservation standards.

DOE estimated indirect national employment impacts for the standard levels considered in this NOPR using an input/output model of the U.S. economy called Impact of Sector Energy Technologies version 3.1.1 (ImSET).[113] ImSET is a special-purpose version of the ''U.S. Benchmark National Input-Output'' (I–O) model, which was designed to estimate the national employment and income effects of energy-saving technologies. The ImSET software includes a computer-based I–O model having structural coefficients that characterize economic flows among 187 sectors most relevant to industrial, commercial, and residential building energy use.

DOE notes that ImSET is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis. Because ImSET does not incorporate price changes, the employment effects predicted by ImSET may over-estimate actual job impacts over the long run for this rule. Therefore, DOE generated results for near-term timeframes, where these uncertainties are reduced. For more details on the employment impact analysis, see chapter 16 of the NOPR TSD.

V. Analytical Results and Conclusions

The following section addresses the results from DOE's analyses with respect to the considered energy conservation standards for compressors. It addresses the TSLs examined by DOE, the projected impacts of each of these levels if adopted as energy conservation standards for compressors, and the standards levels that DOE is proposing to adopt in this NOPR. Additional details regarding DOE's analyses are contained in the NOPR TSD supporting this document.

A. Trial Standard Levels

DOE analyzed the benefits and burdens of six TSLs for compressors. These TSLs were developed by combining specific efficiency levels for each of the equipment classes analyzed by DOE. Table V.1 presents the TSLs and the corresponding efficiency levels for compressors. DOE presents the results for the TSLs in this document, while the results for all efficiency levels that DOE analyzed are in the NOPR TSD.

For the rotary lubricated equipment classes, the TSLs increase directly with the analyzed ELs, from EL 1 through max-tech (EL 6). TSL 3 is of significance for these equipment classes because it represents a combination of efficiency levels that are equivalent to the draft EU second tier minimum energy efficiency requirement for rotary lubricated compressors.[114]

For rotary lubricant-free equipment classes, DOE evaluated an efficiency levels at the baseline for TSLs 1 through 5. This equipment exhibits low potential for national energy savings, which is demonstrated at TSL 6, the max-tech TSL for lubricant free equipment. At this TSL, the equipment contributes 0.1 quad of energy savings, which is less than 5-percent of the total energy savings for the TSL. Low potential national energy savings were compounded by significant burden to manufacturers at this TSL. Complete economic results for lubricant free equipment are discussed further in section V.B of this document and the TSD.

At the ''new standards at baseline'' efficiency level for rotary lubricant-free equipment classes, which is evaluated in TSLs 1 through 5, DOE analyzed the impacts of establishing new standards for this equipment at the baseline efficiency levels discussed and established in section IV.C.5 of this document and chapter 5 of the NOPR TSD. In a ''new standards at baseline'' scenario, DOE expects no impacts to the end user and no product redesign or capital conversion costs to the manufacturing industry. DOE accounts for the testing and compliance costs encountered by the manufacturers of this equipment in the MIA. These costs are reflected in the results presented in section V.B.2 of this document.

DOE notes that the ''new standards at baseline'' scenario will not result in national energy savings that can be captured in the NIA. A standard at baseline will, however, prevent potential new, less efficient equipment from the entering the market and potentially increasing future national energy consumption. As discussed previously, the burdens on the manufacturing industry that result from such a standard are assessed in the MIA.

For reciprocating equipment classes, the NPV of consumer benefits was negligible or negative for at least one of the classes[115] at all efficiency levels; as such, DOE chose not to evaluate new standards for this equipment in TSLs 1 through 5, and evaluated new standards only at TSL 6, the max-tech level. Complete economic results for reciprocating compressors are discussed further in section V.B, and chapters eight and ten of the NOPR TSD.

DOE notes that unlike rotary lubricant free, DOE did not evaluate a ''new standards at baseline'' scenario for its reciprocating TSLs. DOE determined that a standard, regardless of level, would not be economically justified because of the significant testing and compliance burdens encountered by the manufacturers of this equipment. Unlike rotary lubricant free, the overwhelming majority of reciprocating compressors in the market do not currently make public representation of efficiency, nor are they currently tested for efficiency. As such, many manufacturers in the reciprocating industry expressed concern over the availability and cost of third party test labs. These concerns were discussed in detail in section IV.J.3.e. Furthermore, DOE estimated that compared to rotary lubricant free, there are significantly more reciprocating basic models in the market. This results in significantly higher estimated industry testing and compliance cost for reciprocating versus rotary lubricant free; $30.7 versus $2.2 million, respectively. These estimates are detailed in section IV.J.2.b.i. In addition, whereas DOE is aware of only 1 domestic small manufacturer of rotary lubricant free compressors (out of seven total), DOE is aware of 13 domestic small manufacturers of reciprocating compressors (out of 33 total). Assuming

[113] J.M. Roop, M.J. Scott, and R.W. Schultz, *ImSET 3.1: Impact of Sector Energy Technologies,* PNNL–18412, Pacific Northwest National Laboratory (2009) (Available at: *www.pnl.gov/main/publications/external/technical_reports/PNNL–18412.pdf*).

[114] For more information regarding the draft regulation see: *http://www.regulations.gov/#!documentDetail;D=EERE-2013-BT-STD-0040-0031.*

[115] When developing TSLs for reciprocating compressors, DOE tied the efficiency levels of single-phase and three-phase equipment classes together to avoid potential unnecessary market impacts. Single- and three-phase reciprocating equipment are typically identical, except for their motor; any changes made to one equipment class will be pass through to the other. A standard established at disparate ELs would essentially result in economic impacts similar to the case where both equipment class are tied together at the higher EL. As such, DOE found it appropriate to tie the efficiency levels together when developing TSLs.

equal distribution of basic models per manufacturer, this equates to $0.93 million in testing and compliance costs per reciprocating manufacturer (including small manufacturers), versus $0.32 million per rotary lubricant free manufacturer.

When DOE proposes to adopt a new standard for a type or class of covered product, it must determine the maximum improvement in energy efficiency or maximum reduction in energy use that is technologically feasible for such product. (42 U.S.C. 6295(p)(1) and 6316(a)) As discussed above, TSL 6 reflects that max-tech level for all product classes.

TABLE V.1—TRIAL STANDARD LEVEL TO EFFICIENCY LEVEL MAPPING

Equipment class (EC)	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
RP_FS_L_AC	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
RP_FS_L_WC	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
RP_FS_LF_AC	* EL 0	* EL 0	* EL 0	* EL 0	* EL 0	EL 6
RP_FS_LF_WC	* EL 0	* EL 0	* EL 0	* EL 0	* EL 0	EL 6
RP_VS_L_AC	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
RP_VS_L_WC	EL 1	EL 2	EL 3	EL 4	EL 5	EL 6
RP_VS_LF_AC	* EL 0	* EL 0	* EL 0	* EL 0	* EL 0	EL 6
RP_VS_LF_WC	* EL 0	* EL 0	* EL 0	* EL 0	* EL 0	EL 6
R1_FS_L_XX	** EL 0	** EL 0	** EL 0	** EL 0	** EL 0	EL 6
R3_FS_L_XX	** EL 0	** EL 0	** EL 0	** EL 0	** EL 0	EL 6

* For the RP_FS_LF_AC, RP_FS_LF_WC, RP_VS_LF_AC, and RP_VS_LF_WC equipment classes, EL 0 represents a scenario in which a standard is set at the baseline efficiency level.

** For R1_FS_L_XX, and R3_FS_L_XX, EL 0 represents a scenario in which no new standards are established.

B. Economic Justification and Energy Savings

1. Economic Impacts on Individual Consumers

DOE analyzed the economic impacts on compressor consumers by looking at the effects potential standards at each TSL would have on the LCC and PBP. DOE also examined the impacts of potential standards on consumer subgroups. These analyses are discussed below.

a. Life-Cycle Cost and Payback Period

In general, higher-efficiency equipment affect consumers in two ways: (1) Purchase price increases, and (2) annual operating costs decrease. Inputs used for calculating the LCC and PBP include total installed costs (*i.e.,* product price plus installation costs), and operating costs (*i.e.,* annual energy use, energy prices, energy price trends, repair costs, and maintenance costs). The LCC calculation also uses equipment lifetime and a discount rate. Chapter 8 of the NOPR TSD provides detailed information on the LCC and PBP analyses.

Table V.2 through Table V.21 show the LCC and PBP results for the TSL efficiency levels considered for each compressor equipment class. In the first of each pair of tables, the simple payback is measured relative to the baseline equipment (EL 0). In the second table, the impacts are measured relative to the efficiency distribution in the no-new-standards case in the compliance year (see section IV.F.8 of this document). Because some consumers purchase equipment with higher efficiency in the no-new-standards case, the average savings are less than the difference between the average LCC of EL 0 and the average LCC at each TSL. The savings refer only to consumers who are affected by a standard at a given TSL. Those who already purchase equipment with efficiency at or above a given TSL are not affected. Consumers for whom the LCC increases at a given TSL experience a net cost.

TABLE V.2—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, FIXED-SPEED, LUBRICATED, AIR-COOLED COMPRESSORS

[RP_FS_L_AC]

TSL	EL	Average costs (2015$)				Simple payback *(years)*	Average Lifetime *(years)*
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$14,808	$11,280	$88,269	$103,077		11.8
1	1	15,022	11,115	87,028	102,050	1.3	11.8
2	2	15,494	10,877	85,202	100,696	1.7	11.8
3	3	16,379	10,547	82,673	99,052	2.1	11.8
4	4	16,842	10,405	81,582	98,424	2.3	11.8
5	5	17,725	10,165	79,732	97,457	2.6	11.8
6	6	20,399	9,586	75,253	95,652	3.3	11.8

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

TABLE V.3—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, FIXED-SPEED, LUBRICATED, AIR-COOLED COMPRESSORS

[RP_FS_L_AC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings * (2015$)
1	1	0	$9,056
2	2	0	8,902
3	3	1	9,443
4	4	3	7,579
5	5	5	7,748
6	6	14	7,817

* The savings represent the average LCC for affected consumers.

TABLE V.4—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, FIXED-SPEED, LUBRICATED, WATER-COOLED COMPRESSORS

[RP_FS_L_WC]

TSL	EL	Average costs (2015$)				Simple payback (years)	Average Lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$37,958	$29,953	$248,854	$286,813		12.8
1	1	38,504	29,685	246,653	285,157	2.0	12.8
2	2	39,658	29,250	243,055	282,713	2.4	12.8
3	3	41,699	28,622	237,909	279,608	2.8	12.8
4	4	42,752	28,340	235,590	278,342	3.0	12.8
5	5	44,716	27,856	231,614	276,330	3.2	12.8
6	6	50,482	26,644	221,619	272,101	3.8	12.8

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

TABLE V.5—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, FIXED-SPEED, LUBRICATED, WATER-COOLED COMPRESSORS

[RP_FS_L_WC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings * (2015$)
1	1	0	$14,396
2	2	1	15,011
3	3	3	16,538
4	4	5	13,649
5	5	7	14,397
6	6	15	15,512

* The savings represent the average LCC for affected consumers.

TABLE V.6—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, FIXED-SPEED, LUBRICANT FREE, AIR-COOLED COMPRESSORS

[RP_FS_LF_AC]

TSL	EL	Average costs (2015$)				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$88,182	$21,714	$177,081	$265,263	n.a.	12.5
1	0	88,182	21,714	177,081	265,263	n.a.	12.5
2	0	88,182	21,714	177,081	265,263	n.a.	12.5

TABLE V.6—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, FIXED-SPEED, LUBRICANT FREE, AIR-COOLED COMPRESSORS—Continued

[RP_FS_LF_AC]

TSL	EL	Average costs (2015$)				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
3	0	88,182	21,714	177,081	265,263	n.a.	12.5
4	0	88,182	21,714	177,081	265,263	n.a.	12.5
5	0	88,182	21,714	177,081	265,263	n.a.	12.5
6	6	92,064	20,622	168,270	260,334	3.6	12.5

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

TABLE V.7—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, FIXED-SPEED, LUBRICANT FREE, AIR-COOLED COMPRESSORS

[RP_FS_LF_AC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
1	0	n.a.	n.a.
2	0	n.a.	n.a.
3	0	n.a.	n.a.
4	0	n.a.	n.a.
5	0	n.a.	n.a.
6	6	8	$5,182

Note: n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

*The savings represent the average LCC for affected consumers.

TABLE V.8—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, FIXED-SPEED, LUBRICANT FREE, WATER-COOLED COMPRESSORS

[RP_FS_LF_WC]

TSL	EL	Average costs (2015$)				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$103,931	$29,608	$246,435	$350,366	n.a.	13.0
1	0	103,931	29,608	246,435	350,366	n.a.	13.0
2	0	103,931	29,608	246,435	350,366	n.a.	13.0
3	0	103,931	29,608	246,435	350,366	n.a.	13.0
4	0	103,931	29,608	246,435	350,366	n.a.	13.0
5	0	103,931	29,608	246,435	350,366	n.a.	13.0
6	6	109,110	28,324	235,882	344,992	4.0	13.0

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

"n.a." indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

TABLE V.9—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, FIXED-SPEED, LUBRICANT FREE, WATER-COOLED COMPRESSORS

[RP_FS_LF_WC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
1	0	n.a.	n.a.

TABLE V.9—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, FIXED-SPEED, LUBRICANT FREE, WATER-COOLED COMPRESSORS—Continued

[RP_FS_LF_WC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
2	0	n.a.	n.a.
3	0	n.a.	n.a.
4	0	n.a.	n.a.
5	0	n.a.	n.a.
6	6	10	$5,686

Note: n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

*The savings represent the average LCC for affected consumers.

TABLE V.10—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, VARIABLE-SPEED, LUBRICATED, AIR-COOLED COMPRESSORS

[RP_VS_L_AC]

TSL	EL	Average costs 2015$				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$24,181	$12,574	$97,620	$121,801		11.8
1	1	24,398	12,473	96,845	121,243	2.1	11.8
2	2	24,981	12,258	95,215	120,196	2.5	11.8
3	3	26,025	11,955	92,920	118,945	3.0	11.8
4	4	26,843	11,757	91,415	118,258	3.3	11.8
5	5	28,864	11,344	88,263	117,128	3.8	11.8
6	6	34,034	10,559	82,265	116,299	4.9	11.8

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

"n.a." indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

TABLE V.11—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, VARIABLE-SPEED, LUBRICATED, AIR-COOLED COMPRESSORS

[RP_VS_L_AC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
1	1	0	$5,073
2	2	1	6,061
3	3	4	6,746
4	4	8	5,732
5	5	13	6,408
6	6	31	5,784

*The savings represent the average LCC for affected consumers.

TABLE V.12—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, VARIABLE-SPEED, LUBRICATED, WATER-COOLED COMPRESSORS

(RPp_VS_L_WC)

TSL	EL	Average costs 2015$				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$61,242	$31,544	$259,506	$320,748	....	13.0
1	1	61,990	31,281	257,385	319,375	2.8	13.0
2	2	64,077	30,717	252,831	316,908	3.4	13.0
3	3	67,766	29,945	246,533	314,299	4.1	13.0
4	4	69,662	29,605	243,752	313,414	4.3	13.0
5	5	74,247	28,872	237,732	311,979	4.9	13.0
6	6	86,230	27,315	224,949	311,179	5.9	13.0

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

TABLE V.13—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, VARIABLE-SPEED, LUBRICATED, WATER-COOLED COMPRESSORS

[RP_VS_L_WC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
1	1	1	$12,017
2	2	3	13,865
3	3	8	14,922
4	4	14	11,996
5	5	21	12,055
6	6	40	10,082

* The savings represent the average LCC for affected consumers.

TABLE V.14—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, VARIABLE-SPEED, LUBRICANT-FREE, AIR-COOLED COMPRESSORS

[RP_VS_lf_ac]

TSL	EL	Average costs (2015$)				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$115,579	$29,125	$238,450	$354,029	n.a.	13.0
1	0	115,579	29,125	238,450	354,029	n.a.	13.0
2	0	115,579	29,125	238,450	354,029	n.a.	13.0
3	0	115,579	29,125	238,450	354,029	n.a.	13.0
4	0	115,579	29,125	238,450	354,029	n.a.	13.0
5	0	115,579	29,125	238,450	354,029	n.a.	13.0
6	6	121,730	27,060	221,747	343,478	3.0	13.0

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

" n.a." indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

TABLE V.15—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, VARIABLE-SPEED, LUBRICANT-FREE, AIR-COOLED COMPRESSORS

[RP_VS_Lf_AC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
1	0	n.a.	n.a.
2	0	n.a.	n.a.
3	0	n.a.	n.a.
4	0	n.a.	n.a.
5	0	n.a.	n.a.
6	6	6	$11,104

Note: n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

* The calculation excludes households with zero LCC savings (no impact).

TABLE V.16—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR ROTARY, VARIABLE-SPEED, LUBRICANT-FREE, WATER-COOLED COMPRESSORS

[RP_VS_LF_WC]

TSL	EL	Average costs (2015$)				Simple payback (years)	Average lifetime (years)
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$93,159	$19,555	$155,255	$248,414	n.a.	12.2
1	0	93,159	19,555	155,255	248,414	n.a.	12.2
2	0	93,159	19,555	155,255	248,414	n.a.	12.2
3	0	93,159	19,555	155,255	248,414	n.a.	12.2
4	0	93,159	19,555	155,255	248,414	n.a.	12.2
5	0	93,159	19,555	155,255	248,414	n.a.	12.2
6	6	97,524	17,922	142,583	240,107	2.7	12.2

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

"n.a." indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

TABLE V.17—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR ROTARY, VARIABLE-SPEED, LUBRICANT-FREE, WATER-COOLED COMPRESSORS

[RP_VS_LFf_WC]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
1	0	n.a.	n.a.
2	0	n.a.	n.a.
3	0	n.a.	n.a.
4	0	n.a.	n.a.
5	0	n.a.	n.a.
6	6	5	$8,748

Note: n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

* The calculation excludes households with zero LCC savings (no impact).

TABLE V.18—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR RECIPROCATING, SINGLE-PHASE, FIXED-SPEED, LUBRICATED COMPRESSORS

[R1_FS_L_XX]

TSL	EL	Average costs (2015$)				Simple payback *(years)*	Average lifetime *(years)*
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$1,281	$240	$1,606	$2,888	n.a.	9.5
1	0	1,281	240	1,606	2,888	n.a.	9.5
2	0	1,281	240	1,606	2,888	n.a.	9.5
3	0	1,281	240	1,606	2,888	n.a.	9.5
4	0	1,281	240	1,606	2,888	n.a.	9.5
5	0	1,281	240	1,606	2,888	n.a.	9.5
6	6	2,209	139	946	3,155	9.2	9.5

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

"n.a." indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

TABLE V.19—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR RECIPROCATING, SINGLE-PHASE, FIXED-SPEED, LUBRICATED COMPRESSORS

[R1_FS_L_XX]

TSL	EL	Life-cycle cost savings	
		% of consumers that experience (net cost)	Average savings* (2015$)
1	0	n.a.	n.a.
2	0	n.a.	n.a.
3	0	n.a.	n.a.
4	0	n.a.	n.a.
5	0	n.a.	n.a.
6	6	78	−$282

Note: n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

*The calculation excludes households with zero LCC savings (no impact).

TABLE V.20—AVERAGE LCC AND PBP RESULTS BY EFFICIENCY LEVEL FOR RECIPROCATING, THREE-PHASE, FIXED-SPEED, LUBRICATED COMPRESSORS

[R3_FS_L_XX]

TSL	EL	Average costs (2015$)				Simple payback *(years)*	Average lifetime *(years)*
		Installed cost	First year's operating cost	Lifetime operating cost	LCC		
	0	$2,200	$406	$2,997	$5,197	n.a.	9.8
1	0	2,200	406	2,997	5,197	n.a.	9.8
2	0	2,200	406	2,997	5,197	n.a.	9.8
3	0	2,200	406	2,997	5,197	n.a.	9.8
4	0	2,200	406	2,997	5,197	n.a.	9.8
5	0	2,200	406	2,997	5,197	n.a.	9.8
6	6	3,802	274	2,055	5,857	12.1	9.8

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.

"n.a." indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

TABLE V.21—AVERAGE LCC SAVINGS RELATIVE TO THE NO-NEW-STANDARDS CASE FOR RECIPROCATING, THREE-PHASE, FIXED-SPEED, LUBRICATED COMPRESSORS

[RP_FS_L_XX]

TSL	EL	Life-cycle cost savings: % of consumers that experience (net cost)	Life-cycle cost savings: Average savings * (2015$)
1	0	n.a.	n.a.
2	0	n.a.	n.a.
3	0	n.a.	n.a.
4	0	n.a.	n.a.
5	0	n.a.	n.a.
6	6	83	−$693

* The calculation excludes households with zero LCC savings (no impact).

* n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

b. Consumer Subgroup Analysis

In the consumer subgroup analysis, described in section IV.I of this document, DOE estimated the impact of the considered TSLs on small businesses that purchase compressors. Table V.22 and Table V.23 compares the average LCC savings and PBP at each efficiency level for the ''small business'' consumer subgroup, along with the average LCC savings for the entire sample. In most cases, the average LCC savings and PBP for the small business consumer subgroup at the considered efficiency levels are not substantially different from the average for all consumers. Chapter 11 of the NOPR TSD presents the complete LCC and PBP results for the subgroups.

TABLE V.22—COMPARISON OF LCC SAVINGS FOR THE SMALL BUSINESS SUBGROUP AND ALL CONSUMERS

Equipment class	Scenario	Average life-cycle cost savings (2015$)					
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
RP_FS_L_AC	All Consumers	$9,056	$8,902	$9,443	$7,579	$7,748	$7,817
	Small Businesses	7,837	7,577	7,939	6,341	6,421	6,309
RP_FS_L_WC	All Consumers	14,396	15,011	16,538	13,649	14,397	15,512
	Small Businesses	12,046	12,498	13,601	11,160	11,677	12,194
RP_FS_LF_AC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	5,182
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	4,098
RP_FS_LF_WC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	5,686
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	4,386
RP_VS_L_AC	All Consumers	5,073	6,061	6,746	5,732	6,408	5,784
	Small Businesses	4,438	5,141	5,591	4,703	5,108	4,181
RP_VS_L_WC	All Consumers	12,017	13,865	14,922	11,996	12,055	10,082
	Small Businesses	9,975	11,269	11,717	9,253	8,841	6,130
RP_VS_LF_AC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	11,104
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	9,185
RP_VS_LF_WC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	8,748
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	7,317
R1_FS_L_XX	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	(282)
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	(332)
R3_FS_L_XX	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	(693)
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	(790)

* n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

TABLE V.23—COMPARISON OF SIMPLE PAYBACK PERIOD FOR THE SMALL BUSINESS SUBGROUP AND ALL CONSUMERS

Equipment class	Scenario	Average simple payback period (years)					
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
RP_FS_L_AC	All Consumers	1.3	1.7	2.1	2.3	2.6	3.3
	Small Businesses	1.3	1.7	2.2	2.4	2.7	3.3
RP_FS_L_WC	All Consumers	2.0	2.4	2.8	3.0	3.2	3.8
	Small Businesses	2.0	2.4	2.8	3.0	3.2	3.8
RP_FS_LF_AC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	3.6
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	3.6
RP_FS_LF_WC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	4.0
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	4.0
RP_VS_L_AC	All Consumers	2.1	2.5	3.0	3.3	3.8	4.9

TABLE V.23—COMPARISON OF SIMPLE PAYBACK PERIOD FOR THE SMALL BUSINESS SUBGROUP AND ALL CONSUMERS—Continued

Equipment class	Scenario	Average simple payback period (years)					
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
	Small Businesses	2.1	2.5	3.0	3.3	3.8	4.9
RP_VS_L_WC	All Consumers	2.8	3.4	4.1	4.3	4.9	5.9
	Small Businesses	2.9	3.5	4.1	4.4	4.9	5.9
RP_VS_LF_AC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	3.0
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	3.0
RP_VS_LF_WC	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	2.7
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	2.7
R1_FS_L_XX	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	9.2
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	9.2
R3_FS_L_XX	All Consumers	n.a.	n.a.	n.a.	n.a.	n.a.	12.1
	Small Businesses	n.a.	n.a.	n.a.	n.a.	n.a.	12.2

Note: The results for each TSL are calculated assuming that all consumers use equipment at that efficiency level. The PBP is measured relative to the baseline (EL 0) equipment.
* n.a. indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

c. Rebuttable Presumption Payback

As discussed in section III.G.2, EPCA establishes a rebuttable presumption that an energy conservation standard is economically justified if the increased purchase cost for equipment that meets the standard is less than three times the value of the first-year energy savings resulting from the standard. In calculating a rebuttable presumption payback period for each of the considered TSLs, DOE used discrete values, and, as required by EPCA, based the energy use calculation on the DOE test procedure for compressors. In contrast, the PBPs presented in section V.B.1.a were calculated using distributions for input values, with energy use based on the methodology described in section IV.E.

Notwithstanding this more limited analysis, DOE routinely conducts a full economic analysis that considers the full range of impacts to the consumer, manufacturer, Nation, and environment. See 42 U.S.C. 6295(o)(2)(B)(i) and 6316(a). The results of that analysis serve as the basis for DOE to definitively evaluate the economic justification for a potential standard level, thereby supporting or rebutting the results of any preliminary determination of economic justification. Table V.24 shows the rebuttable presumption PBPs for the considered TSLs for the considered compressors equipment classes.

TABLE V.24—REBUTTABLE PRESUMPTION PAYBACK PERIODS BY TSL

Equipment class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
RP_FS_L_AC	1.1	1.5	1.9	2.0	2.3	2.8
RP_FS_L_WC	1.7	2.0	2.4	2.5	2.7	3.2
RP_FS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	3.0
RP_FS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	3.4
RP_VS_L_AC	2.3	2.8	3.3	3.6	4.2	5.4
RP_VS_L_WC	3.2	3.8	4.5	4.8	5.4	6.5
RP_VS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	3.3
RP_VS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	3.0
R1_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	7.2
R3_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	9.4

Note: "n.a." indicates that there is no increased in efficiency in the proposed standards case, therefore there are no LCC Savings or Simple Payback.

2. Economic Impacts on Manufacturers

As noted previously, DOE performed an MIA to estimate the impact of energy conservation standards on manufacturers of compressors. The following section summarizes the expected impacts on manufacturers at each considered TSL. Chapter 12 of the NOPR TSD explains the analysis in further detail.

a. Industry Cash Flow Analysis Results

Table V.25 depicts the estimated financial impacts (represented by changes in industry net present value, or INPV) of amended energy conservation standards on manufacturers of compressors, as well as the conversion costs that DOE expects manufacturers would incur for all equipment classes at each TSL. DOE notes that the GRIM and resulting industry cash flow analysis considered only rotary equipment classes, as DOE is proposing not to establish standards for reciprocating equipment. For further discussion on DOE's proposal for reciprocating compressors, see section V.C.

As discussed in section IV.J.2, DOE modeled two different conversion cost scenarios to evaluate the range of cash flow impacts on the compressor industry: (1) A low conversion cost scenario; and (2) a high conversion cost scenario.

The low conversion cost scenario assumes that manufacturers active in the EU market will not face additional product conversion costs to adapt to a U.S. standard that is at or below the draft EU level (EL 3 and TSL 3). If the U.S. standard is above the draft EU level, these manufacturers would still incur full redesign costs. In the high conversion cost scenario, all manufacturers face full product conversion costs, regardless of an EU regulation. DOE notes that these scenarios only impact lubricated rotary equipment, as lubricant-free rotary equipment is not proposed for coverage in the EU. Each of the conversion cost scenarios result in a unique set of cash flows and corresponding industry values at each TSL.

In the following discussion, the INPV results refer to the difference in industry value between the base case ''business as usual'' and each standards case resulting from the sum of discounted cash flows from the base year (2015) through the end of the analysis period (2051). To provide perspective on the short-run cash flow impact, DOE includes in the discussion of results a comparison of free cash flow between the no-standards case and the standards case at each TSL in the year before amended standards would take effect. This figure provides an understanding of the magnitude of required conversion costs relative to cash flows generated by the industry in the base case.

Table V.25 and Table V.26 present INPV results under the low and high conversion cost scenarios. The low conversion cost scenario represents the least severe set of impacts while the high conversion cost scenario represents the most severe sets of impacts. Markups do not vary with conversion cost scenario.

TABLE V.25—MANUFACTURER IMPACT ANALYSIS RESULTS FOR COMPRESSORS: LOW CONVERSION COST SCENARIO

	Units	No new standard case	Trial standard level*					
			1	2	3	4	5	6
INPV	2014$M	497.1	480.4	451.9	385.7	301.8	256.0	105.3
Change in INPV	2014$M		(16.7)	(45.2)	(111.4)	(195.3)	(241.1)	(391.8)
	%		(3.4)	(9.1)	(22.4)	(39.3)	(48.5)	(78.8)
Product Conversion Costs	2014$M		29.2	70.3	157.1	281.5	345.9	548.8
Capital Conversion Costs	2014$M		7.6	28.7	72.9	92.4	112.7	181.3
Total Conversion Costs	2014$M		36.8	99.1	230.0	373.9	458.6	730.1
Free Cash Flow	2014$M	33.0	19.9	(3.2)	(57.1)	(120.7)	(158.2)	(278.6)
	%Change		(39.7)	(109.7)	(273.1)	(465.9)	(579.7)	(944.5)

* Parentheses indicate negative values.

TABLE V.26—MANUFACTURER IMPACT ANALYSIS RESULTS FOR COMPRESSORS: HIGH CONVERSION COST SCENARIO

	Units	No new standard case	Trial standard level*					
			1	2	3	4	5	6
INPV	2014$M	497.1	476.8	439.3	345.8	301.8	256.0	105.3
Change in INPV	2014$M		(20.3)	(57.8)	(151.3)	(195.3)	(241.1)	(391.8)
	%		(4.1)	(11.6)	(30.4)	(39.3)	(48.5)	(78.8)
Product Conversion Costs	2014$M		36.6	96.4	222.7	281.5	345.9	548.8
Capital Conversion Costs	2014$M		7.6	28.7	72.9	92.4	112.7	181.3
Total Conversion Costs	2014$M		44.3	125.2	295.6	373.9	458.6	730.1
Free Cash Flow	2014$M	33.0	17.4	(11.8)	(86.0)	(120.7)	(158.2)	(278.6)
	%Change		(47.1)	(135.9)	(360.7)	(465.9)	(579.7)	(944.5)

* Parentheses indicate negative values.

At TSL 1, DOE estimates the impacts on INPV to range from −$20.3 million to −$16.7 million, or a change of −4.1 to −3.4 percent. Industry free cash flow is estimated to decrease by $13.1 to $15.5 million, or a change of −47.1 to −39.7 percent compared to the base case value of $33.0 million in the year before the compliance date (2021).[116] DOE estimates industry conversion costs of $36.8 to 44.3 million at TSL 1.

At TSL 2, DOE estimates impacts on INPV to range from −$57.8 million to −$45.2 million, or a change in INPV of −11.6 percent to −9.1 percent. At this level, industry free cash flow is estimated to decrease by $36.2 to 44.8 million, or a change of −135.9 to −109.7 percent compared to the base case value of $33.0 million in the year before the compliance date (2021). DOE estimates industry conversion costs of $99.1 to 125.2 million at TSL 2.

At TSL 3, DOE estimates impacts on INPV to range from −$151.3 to −$111.4 million, or a change in INPV of −30.4 to −22.4 percent. At this level, industry free cash flow is estimated to decrease by $90.1 to 119.0 million, or a change of −360.7 to −273.1 percent compared to the base case value of $33.0 million in the year before the compliance date (2021). DOE estimates industry conversion costs of $230.0 to 295.6 million at TSL 3.

At TSL 4, DOE estimates impacts on INPV of −$195.3 million, or a change in INPV of −39.3 percent. At this level, industry free cash flow is estimated to decrease by $153.7 million, or a change of 465.9 percent compared to the base case value of $33.0 million in the year before the compliance date (2021). DOE estimates industry conversion costs of $373.9 million at TSL 4.

At TSL 5, DOE estimates impacts on INPV of −$241.1 million, or a change in INPV of −48.5 percent. Industry free cash flow is estimated to decrease by $191.2 million, or a change of −579.7 percent compared to the base case value of $33.0 million in the year before the compliance date (2021). DOE estimates industry conversion costs of $458.6 million at TSL 5.

At TSL 6, DOE estimates impacts on INPV of −$391.8 million, or a change in INPV of −78.8 percent. Industry free cash flow is estimated to decrease by $311.6 million, or a change of −944.5 percent compared to the base case value of $33.0 million in the year before the compliance date (2021). DOE estimates industry conversion costs of $730.1 million at TSL 6.

[116] As noted previously, DOE estimates that a Final Rule will publish in late 2016, and compliance would be required starting in late 2021. As such, DOE's analysis begins in the first full year of compliance with new standards, 2022. So for the purposes of DOE's analysis, 2021 is considered the year before the compliance date.

b. Impacts on Employment

To quantitatively assess the potential impacts of energy conservation standards on direct employment, DOE used the GRIM to estimate the domestic labor expenditures and number of direct employees in the base case and at each TSL from 2015 through 2051. DOE used statistical data from the U.S. Census Bureau's 2013 Annual Survey of Manufacturers,[117] the results of the engineering analysis, and interviews with manufacturers to determine the inputs necessary to calculate industry-wide labor expenditures and domestic direct employment levels. Labor expenditures related to producing the equipment are a function of the labor intensity of producing the equipment, the sales volume, and an assumption that wages remain fixed in real terms over time. The total labor expenditures in each year are calculated by multiplying the MPCs by the labor percentage of MPCs. DOE estimates that 50 percent of rotary air compressors are produced domestically.

The total labor expenditures in the GRIM were then converted to domestic production employment levels by dividing production labor expenditures by the annual payment per production worker (production worker hours multiplied by the labor rate found in the U.S. Census Bureau's 2013 Annual Survey of Manufacturers). The production worker estimates in this section only cover workers up to the line-supervisor level who are directly involved in fabricating and assembling equipment within an OEM facility. Workers performing services that are closely associated with production operations, such as materials handling tasks using forklifts, are also included as production labor. DOE's estimates only account for production workers who manufacture the specific equipment covered by this rulemaking.

To estimate an upper bound to employment change, DOE assumes all domestic manufacturers would choose to continue producing equipment in the U.S. and would not move production to foreign countries. To estimate a lower bound to employment, DOE considers the case where all manufacturers choose to relocate production of failing rotary compressors under 50-hp overseas rather than make the necessary conversions at domestic production facilities. A complete description of the assumptions used to generate these upper and lower bounds can be found in chapter 12 of the NOPR TSD.

In the absence of energy conservation standards, DOE estimates that the rotary air compressors industry would employ 1,417 domestic production workers in 2022. Table V.27 shows the range of impacts of potential energy conservation standards on U.S. production workers of air compressors.

TABLE V.27—POTENTIAL CHANGES IN THE TOTAL NUMBER OF ROTARY AIR COMPRESSOR PRODUCTION WORKERS IN 2022

	Trial standard level *					
	1	2	3	4	5	6
Potential Changes in Domestic Production Workers in 2022.	(113) to 14	(179) to 45	(265) to 95	(288) to 121	(345) to 169	(477) to 293.

* Parentheses indicate negative values.
† No-new-standards case assumes 1,417 domestic production workers in the rotary air compressor industry in 2022.

The upper end of the range estimates the maximum increase in the estimated number of domestic production workers in the compressor industry after implementation of amended energy conservation standards. It assumes manufacturers would continue to produce the same scope of covered equipment within the United States.

The lower end of the range represents the maximum decrease in the total number of U.S. production workers that could result from an energy conservation standard. In interviews, manufacturers stated that the domestic compressor industry has seen limited migration to foreign production facilities. While many compressors are currently manufactured in foreign production facilities, this is more often the result of the global operations of many manufacturers, rather than off-shoring of former U.S. production. However, manufacturers that currently produce in the U.S. have indicated they could potentially shift some production of some covered equipment to foreign facilities in order to take advantage of lower labor costs and/or global economies of scale, if standards erode the economic benefits of manufacturing domestically. Manufacturers also stated that smaller, lower horsepower compressors, rather than larger, higher horsepower compressors, are more likely to shift to foreign production. Given the uncertainty surrounding potential off-shoring decisions, manufacturers were unable to pinpoint a specific horsepower cutoff for ''lower horsepower compressors.'' However, based on qualitative discussions with manufacturers, DOE estimates that 50 horsepower is an appropriate cutoff to represent ''lower horsepower compressors.'' As a result, the lower bound of direct employment impacts assumes manufacturers choose to relocate production of failing rotary compressors under 50-hp overseas rather than make the necessary conversions at domestic production facilities.

This conclusion is independent of any conclusions regarding indirect employment impacts in the broader U.S. economy, which are documented in chapter 15 of the TSD

DOE requests comments on the total annual direct employment levels in the industry. This is identified as Issue 49 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

c. Impacts on Manufacturing Capacity

In interviews, manufacturers of compressors did not indicate that new energy conservation standards would significantly constrain manufacturing production capacity. However, as discussed in section IV.J.3.b, manufacturers expressed concern that they may face a bottleneck in the redesign process. In other words, manufacturers felt that if they could complete their redesigns within the compliance period, then they would not have a problem obtaining sufficient floor space, equipment, and manufacturing labor to meet the shipment demands of the market, following an energy conservation standard.

[117] Annual Survey of Manufacturers: General Statistics: Statistics for Industry Groups and Industries, U.S. Census Bureau, 2011. Available at *http://www.census.gov/manufacturing/asm/index.html.*

Manufacturers indicated that most experienced compressor design engineers are already employed within the industry, which limits their ability to rapidly expand their research and development teams if faced with a high volume of required compressor redesigns. Consequently, manufacturers typically commented that standard levels at or above the equivalent of TSL 3 could cause engineering constraints which might create time delays in complying with new standards. DOE notes that manufacturers typically discussed this constraint with respect to a three-year compliance period. In this NOPR, however, DOE is proposing a standard level at TSL 2, in conjunction with a five-year compliance period.

DOE requests comment on potential bottlenecks in manufacturing capacity or constraints in engineering resources that could result from a new standard. This is identified as Issue 50 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

d. Impacts on Subgroups of Manufacturers

As discussed previously, using average cost assumptions to develop an industry cash flow estimate is not adequate for assessing differential impacts among subgroups of manufacturers. Small manufacturers, niche players, or manufacturers exhibiting a cost structure that differs largely from the industry average could be affected differently. DOE used the results of the industry characterization to group manufacturers exhibiting similar characteristics. Specifically, DOE identified small business manufacturers as a subgroup for a separate impact analysis.

For the small business subgroup analysis, DOE applied the small business size standards published by the Small Business Administration (SBA) to determine whether a company is considered a small business. (65 FR 30840, 30849 (May 15, 2000), as amended at 65 FR 53533, 53544 (September 5, 2000), and codified at 13 CFR part 121.) To be categorized as a small business manufacturer of compressors under North American Industry Classification System (NAICS) code 333912, ''Air and Gas Compressor Manufacturing,'' a compressor manufacturer and its affiliates may employ a maximum of 500 employees. The 500-employee threshold includes all employees in a business's parent company and any other subsidiaries. Based on this classification, DOE identified three manufacturers of rotary air compressors and thirteen manufacturers of reciprocating equipment that qualify as small businesses. The small business subgroup analysis is discussed in section VII.B of this document and in chapter 12 of the NOPR TSD.

e. Cumulative Regulatory Burden

While any one regulation may not impose a significant burden on manufacturers, the combined effects of recent or impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. In addition to energy conservation standards, other regulations can significantly affect manufacturers' financial operations. Multiple regulations affecting the same manufacturer can strain profits and lead companies to abandon product lines or markets with lower expected future returns than competing equipment. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to appliance efficiency.

For the cumulative regulatory burden analysis, DOE looks at equipment-specific Federal regulations that could affect compressor manufacturers and with which compliance is required approximately three years before or after the 2021 compliance date of the standard proposed in this document. The Department was not able to identify any additional regulatory burdens that meet these criteria.

DOE requests comments on the cumulative regulatory burden facing compressor manufacturers. Specifically, DOE seeks input on any equipment-specific Federal regulations with which compliance is required within three years of the proposed compliance date for any final compressor standards, as well as on recommendations on how DOE may be able to align varying regulations to mitigate cumulative burden. This is identified as Issue 51 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

3. National Impact Analysis

a. Significance of Energy Savings

To estimate the energy savings attributable to potential standards for compressors, DOE compared the energy consumption of those equipment under the no-new-standards case to their anticipated energy consumption under each TSL. The savings are measured over the entire lifetime of equipment purchased in the 30-year period that begins in the year of anticipated compliance with amended standards (2022–2051). Table V.28 present DOE's projections of the national energy savings for each TSL considered for compressors. The savings were calculated using the approach described in section IV.H of this document.

TABLE V.28—CUMULATIVE NATIONAL ENERGY SAVINGS FOR COMPRESSORS SHIPPED IN 2022–2051

	Trial standard level					
	1	2	3	4	5	6
Primary energy (quads)	0.04	0.17	0.47	0.67	1.06	4.37
FFC energy (quads)	0.04	0.18	0.49	0.70	1.11	4.57

OMB Circular A–4 [118] requires agencies to present analytical results, including separate schedules of the monetized benefits and costs that show the type and timing of benefits and costs. Circular A–4 also directs agencies to consider the variability of key elements underlying the estimates of benefits and costs. For this rulemaking, DOE undertook a sensitivity analysis using nine, rather than 30, years of equipment shipments. The choice of a nine-year period is a proxy for the timeline in EPCA for the review of certain energy conservation standards and potential revision of, and compliance with, such revised standards.[119] The review timeframe

[118] U.S. Office of Management and Budget, ''Circular A–4: Regulatory Analysis'' (Sept. 17, 2003) (Available at: *http://www.whitehouse.gov/omb/circulars_a004_a-4/*).

[119] Section 325(m) of EPCA requires DOE to review its standards at least once every 6 years, and requires, for certain products, a 3-year period after any new standard is promulgated before compliance is required, except that in no case may any new standards be required within 6 years of the compliance date of the previous standards. While adding a 6-year review to the 3-year compliance period adds up to 9 years, DOE notes that it may

established in EPCA is generally not synchronized with the equipment lifetime, equipment manufacturing cycles, or other factors specific to compressors. Thus, such results are presented for informational purposes only and are not indicative of any change in DOE's analytical methodology. The NES sensitivity analysis results based on a nine-year analytical period are presented in Table V.29. The impacts are counted over the lifetime of compressors purchased in 2022–2030.

TABLE V.29—CUMULATIVE NATIONAL ENERGY SAVINGS FOR COMPRESSORS; NINE YEARS OF SHIPMENTS (2022–2030)

	Trial standard level					
	1	2	3	4	5	6
Primary energy (quads)	0.01	0.04	0.12	0.17	0.27	1.15
FFC energy (quads)	0.01	0.05	0.13	0.18	0.28	1.20

b. Net Present Value of Consumer Costs and Benefits

DOE estimated the cumulative NPV of the total costs and savings for consumers that would result from the TSLs considered for compressors. In accordance with OMB's guidelines on regulatory analysis,[120] DOE calculated NPV using both a 7-percent and a 3-percent real discount rate.

Table V.30 shows the consumer NPV results for each TSL DOE considered for compressors. The impacts are counted over the lifetime of products purchased in 2022–2051.

TABLE V.30—CUMULATIVE NET PRESENT VALUE OF CONSUMER BENEFITS FOR COMPRESSORS SHIPPED IN 2022–2051

Discount rate	Trial standard level (billion 2015$)					
	1	2	3	4	1	6
3 percent	0.14	0.63	1.62	2.21	3.28	−4.94
7 percent	0.05	0.23	0.56	0.75	1.07	−4.71

The NPV results based on the aforementioned 9-year analytical period are presented in Table V.31. The impacts are counted over the lifetime of equipment purchased in 2022–2030. As mentioned previously, such results are presented for informational purposes only and are not indicative of any change in DOE's analytical methodology or decision criteria.

TABLE V.31—CUMULATIVE NET PRESENT VALUE OF CONSUMER BENEFITS FOR COMPRESSORS; NINE YEARS OF SHIPMENTS (2022–2030)

Discount rate	Trial standard level (billion 2015$)					
	1	2	3	4	5	6
3 percent	0.04	0.20	0.50	0.67	0.99	−2.19
7 percent	0.02	0.09	0.23	0.31	0.44	−2.32

The above results reflect the use of a default trend to estimate the change in price for compressors over the analysis period (see section IV.F.1 of this document). DOE also conducted a sensitivity analysis that considered one scenario with a lower rate of price decline than the reference case and one scenario with a higher rate of price decline than the reference case. The results of these alternative cases are presented in appendix 10B of the NOPR TSD. In the high-price-decline case, the NPV of consumer benefits is higher than in the default case. In the low-price-decline case, the NPV of consumer benefits is lower than in the default case.

c. Indirect Impacts on Employment

DOE expects energy conservation standards for compressors to reduce energy bills for consumers of those equipment, with the resulting net savings being redirected to other forms of economic activity. These expected shifts in spending and economic activity could affect the demand for labor. As described in section IV.N of this document, DOE used an input/output model of the U.S. economy to estimate indirect employment impacts of the TSLs that DOE considered in this rulemaking. DOE understands that there are uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis. Therefore, DOE generated results for near-term timeframes (2022–2027), where these uncertainties are reduced.

The results suggest that the proposed standards are likely to have a negligible impact on the net demand for labor in the economy. The net change in jobs is so small that it would be imperceptible in national labor statistics and might be offset by other, unanticipated effects on

undertake reviews at any time within the 6 year period and that the 3-year compliance date may yield to the 6-year backstop. A 9-year analysis period may not be appropriate given the variability that occurs in the timing of standards reviews and the fact that for some consumer products, the compliance period is 5 years rather than 3 years.

[120] U.S. Office of Management and Budget, "Circular A–4: Regulatory Analysis," section E, (Sept. 17, 2003) (Available at: *http://www.whitehouse.gov/omb/circulars_a004_a-4/*).

employment. Chapter 16 of the NOPR TSD presents detailed results regarding anticipated indirect employment impacts.

4. Impact on Utility or Performance of Equipment

Based on testing conducted in support of this proposed rule, discussed in section IV.C.1.b of this document, DOE has tentatively concluded that the standards proposed in this NOPR would not reduce the utility or performance of the compressors under consideration in this rulemaking. This view is largely based on the fact that compressor manufacturers currently offer units that meet or exceed the proposed standards.

5. Impact of Any Lessening of Competition

As discussed in section III.G.1.e, the Attorney General determines the impact, if any, of any lessening of competition likely to result from a proposed standard, and transmits such determination in writing to the Secretary, together with an analysis of the nature and extent of such impact. To assist the Attorney General in making such determination, DOE has provided DOJ with copies of this NOPR and the accompanying TSD for review. DOE will consider DOJ's comments on the proposed rule in determining whether to proceed to a final rule. DOE will publish and respond to DOJ's comments in that document. DOE invites comment from the public regarding the competitive impacts that are likely to result from this proposed rule. In addition, interested members of the public may also provide comments separately to DOJ regarding these potential impacts. See the **ADDRESSES** section for information on how to send comments to DOJ.

6. Need of the Nation To Conserve Energy

Enhanced energy efficiency, where economically justified, improves the Nation's energy security, strengthens the economy, and reduces the environmental impacts (costs) of energy production. Reduced electricity demand due to energy conservation standards is also likely to reduce the cost of maintaining the reliability of the electricity system, particularly during peak-load periods. As a measure of this reduced demand, chapter 15 in the NOPR TSD presents the estimated reduction in generating capacity, relative to the no-new-standards case, for the TSLs that DOE considered in this rulemaking.

Energy conservation from potential standards for compressors are expected to yield environmental benefits in the form of reduced emissions of air pollutants and greenhouse gases. Table V.32 provides DOE's estimate of cumulative emissions reductions expected to result from the TSLs considered in this rulemaking. The table includes both power sector emissions and upstream emissions. The emissions were calculated using the multipliers discussed in section IV.L. DOE reports annual emissions reductions for each TSL in chapter 13 of the NOPR TSD.

TABLE V.32—CUMULATIVE EMISSIONS REDUCTION FOR COMPRESSORS SHIPPED IN 2022–2051

	Trial standard level					
	1	2	3	4	5	6
Power Sector Emissions						
CO_2 (million metric tons)	2.1	10.0	27.6	39.1	62.0	256.5
SO_2 (thousand tons)	1.2	5.7	15.7	22.3	35.3	146.9
NO_X (thousand tons)	2.3	11.2	30.8	43.7	69.4	286.5
Hg (tons)	0.004	0.02	0.1	0.1	0.1	0.5
CH_4 (thousand tons)	0.2	0.8	2.3	3.2	5.1	21.2
N_2O (thousand tons)	0.0	0.1	0.3	0.5	0.7	3.0
Upstream Emissions						
CO_2 (million metric tons)	0.1	0.6	1.6	2.3	3.6	14.8
SO_2 (thousand tons)	0.0	0.1	0.3	0.4	0.7	2.7
NO_X (thousand tons)	1.7	8.3	22.9	32.5	51.6	211.9
Hg (tons)	0.0	0.0	0.0	0.0	0.0	0.0
CH_4 (thousand tons)	9.6	45.9	126.7	179.5	285.0	1170.9
N_2O (thousand tons)	0.0	0.0	0.0	0.0	0.0	0.1
Total FFC Emissions						
CO_2 (million metric tons)	2.2	10.6	29.2	41.3	65.6	271.3
SO_2 (thousand tons)	1.2	5.8	16.0	22.7	36.0	149.6
NO_X (thousand tons)	4.1	19.5	53.8	76.2	121.0	498.4
Hg (tons)	0.004	0.02	0.1	0.1	0.1	0.6
CH_4 (thousand tons)	9.8	46.7	128.9	182.7	290.1	1192.1
CH_4 (thousand tons CO_2eq)*	275.0	1308.7	3609.9	5116.0	8123.3	33378.7
N_2O (thousand tons)	0.0	0.1	0.3	0.5	0.8	3.1
N_2O (thousand tons CO_2eq)*	6.8	32.2	88.8	125.8	199.8	829.3

* CO_2eq is the quantity of CO_2 that would have the same global warming potential (GWP).

As part of the analysis for this proposed rule, DOE estimated monetary benefits likely to result from the reduced emissions of CO_2 and NO_X that DOE estimated for each of the considered TSLs for compressors. As discussed in section IV.L of this document, for CO_2, DOE used the most recent values for the SCC developed by an interagency process. The four sets of SCC values for CO_2 emissions reductions in 2015 resulting from that process (expressed in 2015$) are represented by $12.2/metric ton (the average value from a distribution that uses a 5-percent discount rate), $40.0/metric ton (the average value from a distribution that uses a 3-percent discount rate), $62.3/metric ton (the average value from a distribution that uses a 2.5-percent discount rate), and $117/metric ton (the 95th-percentile value from a distribution that uses a 3-percent discount rate). The values for later years are higher due to increasing damages (public health, economic and environmental) as the projected magnitude of climate change increases.

Table V.33 presents the global value of CO_2 emissions reductions at each TSL. For each of the four cases, DOE calculated a present value of the stream of annual values using the same discount rate as was used in the studies upon which the dollar-per-ton values are based. DOE calculated domestic values as a range from 7 percent to 23 percent of the global values; these results are presented in chapter 14 of the NOPR TSD.

TABLE V.33—ESTIMATES OF GLOBAL PRESENT VALUE OF CO_2 EMISSIONS REDUCTION FOR EQUIPMENT SHIPPED IN 2022–2051

TSL	SCC case* (million 2015$)			
	5% discount rate, average	3% discount rate, average	2.5% discount rate, average	3% discount rate, 95th percentile
Power Sector Emissions				
1	13.7	64.5	103.2	196.6
2	65.1	306.8	491.0	935.4
3	179.6	846.2	1354.1	2579.7
4	254.5	1199.1	1919.0	3655.7
5	404.1	1903.8	3046.7	5803.9
6	1738.1	8071.6	12866.2	24609.9
Upstream Emissions				
1	0.8	3.7	5.9	11.3
2	3.7	17.6	28.3	53.8
3	10.3	48.6	77.9	148.3
4	14.5	68.9	110.5	210.2
5	23.1	109.4	175.4	333.7
6	98.6	461.0	735.9	1406.3
Total FFC Emissions				
1	14.5	68.2	109.1	207.9
2	68.9	324.5	519.3	989.2
3	189.9	894.8	1432.1	2728.0
4	269.1	1268.1	2029.4	3865.9
5	427.2	2013.3	3222.1	6137.7
6	1836.7	8532.6	13602.1	26016.2

* For each of the four cases, the corresponding SCC value for emissions in 2015 is $12.2, $40.0, $62.3, and $117 per metric ton (2015$). The values are for CO_2 only (*i.e.,* not CO_{2eq} of other greenhouse gases).

DOE is well aware that scientific and economic knowledge about the contribution of CO_2 and other GHG emissions to changes in the future global climate and the potential resulting damages to the world economy continues to evolve rapidly. Thus, any value placed on reduced CO_2 emissions in this rulemaking is subject to change. DOE, together with other Federal agencies, will continue to review various methodologies for estimating the monetary value of reductions in CO_2 and other GHG emissions. This ongoing review will consider the comments on this subject that are part of the public record for this and other rulemakings, as well as other methodological assumptions and issues. However, consistent with DOE's legal obligations, and taking into account the uncertainty involved with this particular issue, DOE has included in this proposed rule the most recent values and analyses resulting from the interagency review process.

DOE also estimated the cumulative monetary value of the economic benefits associated with NO_X emissions reductions anticipated to result from the considered TSLs for compressors. The dollar-per-ton values that DOE used are discussed in section IV.L of this document.

Table V.34 presents the cumulative present values for NO_X emissions for each TSL calculated using 7-percent and 3-percent discount rates. This table presents values that use the low dollar-per-ton values, which reflect DOE's primary estimate. Results that reflect the range of NO_X dollar-per-ton values are presented in Table V.36.

TABLE V.34—ESTIMATES OF PRESENT VALUE OF NO_X EMISSIONS REDUCTION FOR COMPRESSORS SHIPPED IN 2022–2051

TSL	(Million 2015$)	
	3% discount rate	7% discount rate
Power Sector Emissions		
1	4.1	1.5
2	19.3	7.2
3	53.1	19.8
4	75.3	28.0
5	119.5	44.5
6	515.8	200.4
Upstream Emissions		
1	3.0	1.1
2	14.1	5.1
3	38.9	14.2
4	55.2	20.1
5	87.6	31.9

TABLE V.34—ESTIMATES OF PRESENT VALUE OF NO_X EMISSIONS REDUCTION FOR COMPRESSORS SHIPPED IN 2022–2051—Continued

TSL	(Million 2015$)	
	3% discount rate	7% discount rate
6	376.0	143.0
Total FFC Emissions		
1	7.0	2.6
2	33.4	12.3
3	92.1	34.0
4	130.5	48.1
5	207.2	76.4
6	891.8	343.4

7. Other Factors

The Secretary of Energy, in determining whether a standard is economically justified, may consider any other factors that the Secretary deems to be relevant. (42 U.S.C. 6295(o)(2)(B)(i)(VII) and 6316(a)) No other factors were considered in this analysis.

8. Summary of National Economic Impacts

The NPV of the monetized benefits associated with emissions reductions can be viewed as a complement to the NPV of the consumer savings calculated for each TSL considered in this rulemaking. Table V.35 presents the NPV values that result from adding the estimates of the potential economic benefits resulting from reduced CO_2 and NO_X emissions in each of four valuation scenarios to the NPV of consumer savings calculated for each TSL considered in this rulemaking, at both a 7-percent and 3-percent discount rate. The CO_2 values used in the columns of each table correspond to the four sets of SCC values discussed above.

TABLE V.35—NET PRESENT VALUE OF CONSUMER SAVINGS COMBINED WITH PRESENT VALUE OF MONETIZED BENEFITS FROM CO_2 AND NO_X EMISSIONS REDUCTIONS

TSL	Consumer NPV at 3% discount rate added with: (billion 2015$)			
	SCC Case $12.2/metric ton and 3% low NO_X values	SCC Case $12.2/metric ton and 3% low NO_X values	SCC Case $12.2/metric ton and 3% low NO_X values	SCC Case $12.2/metric ton and 3% low NO_X values
1	0.2	0.2	0.3	0.4
2	0.7	1.0	1.2	1.7
3	1.9	2.6	3.1	4.4
4	2.6	3.6	4.4	6.2
5	3.9	5.5	6.7	9.6
6	−2.2	4.5	9.6	22.0
1	0.1	0.1	0.2	0.3
2	0.3	0.6	0.8	1.2
3	0.8	1.5	2.0	3.3
4	1.1	2.1	2.8	4.7
5	1.6	3.2	4.4	7.3
6	−2.5	4.2	9.2	21.6

Note: The SCC case values represent the global SCC in 2015, in 2015$, for each case.

In considering the above results, two issues are relevant. First, the national operating cost savings are domestic U.S. monetary savings that occur as a result of market transactions, while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and the SCC are performed with different methods that use different time frames for analysis. The national operating cost savings is measured for the lifetime of equipment shipped in 2022 to 2051. Because CO_2 emissions have a very long residence time in the atmosphere,[121] the SCC values in future years reflect future CO_2-emissions impacts that continue beyond 2100.

[121] The atmospheric lifetime of CO_2 is estimated of the order of 30–95 years. Jacobson, MZ, ''Correction to 'Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming,' '' *J. Geophys. Res.* 110. pp. D14105 (2005).

C. Conclusion

When considering new or amended energy conservation standards, the standards that DOE adopts for any type (or class) of covered product must be designed to achieve the maximum improvement in energy efficiency that the Secretary determines is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A) and 6316(a)) In determining whether a standard is economically justified, the Secretary must determine whether the benefits of the standard exceed its burdens by, to the greatest extent practicable, considering the seven statutory factors discussed previously. (42 U.S.C. 6295(o)(2)(B)(i) and 6316(a).) The new or amended standard must also result in the significant conservation of energy. (42 U.S.C. 6295(o)(3)(B) and 6316(a).)

For this NOPR, DOE considered the impacts of new standards for compressors at each TSL, beginning with the maximum technologically feasible level, to determine whether that level was economically justified. Where the max-tech level was not justified, DOE then considered the next most efficient level and undertook the same evaluation until it reached the highest efficiency level that is both technologically feasible and economically justified and saves a significant amount of energy.

To aid the reader as DOE discusses the benefits and/or burdens of each TSL, tables in this section present a summary of the results of DOE's quantitative analysis for each TSL. In addition to the quantitative results presented in the tables, DOE also considers other burdens and benefits that affect economic justification. These include the impacts on identifiable subgroups of consumers who may be disproportionately affected by a national standard and impacts on employment.

1. Benefits and Burdens of TSLs Considered for Compressor Standards

Table V.36 and Table V.37 summarize the quantitative impacts estimated for each TSL for compressors. The national impacts are measured over the lifetime of compressors purchased in the 30-year period that begins in the anticipated first full year of compliance with amended standards (2022–2051). The energy savings, emissions reductions, and value of emissions reductions refer to full-fuel-cycle results. The efficiency levels contained in each TSL are described in section V.A of this document.

TABLE V.36—SUMMARY OF ANALYTICAL RESULTS FOR COMPRESSOR TSLS: NATIONAL IMPACTS

Category	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Cumulative FFC National Energy Savings (quads)						
	0.04	0.18	0.49	0.70	1.11	4.57
NPV of Consumer Costs and Benefits (2015$ billion)						
3% discount rate	0.1	0.6	1.6	2.2	3.3	(4.9)
7% discount rate	0.1	0.2	0.6	0.7	1.1	(4.7)
Cumulative FFC Emissions Reduction (Total FFC Emission)						
CO_2 (million metric tons)	2.2	10.6	29.2	41.3	65.6	271.3
SO_2 (thousand tons)	1.2	5.8	16.0	22.7	36.0	149.6
NO_X (thousand tons)	4.1	19.5	53.8	76.2	121.0	498.4
Hg (tons)	0.0	0.0	0.1	0.1	0.1	0.6
CH_4 (thousand tons)	9.8	46.7	128.9	182.7	290.1	1192.1
CH_4 (thousand tons CO_2eq) *	275.0	1308.7	3609.9	5116.0	8123.3	33378.7
N_2O (thousand tons)	0.0	0.1	0.3	0.5	0.8	3.1
N_2O (thousand tons CO_2eq) *	6.8	32.2	88.8	125.8	199.8	829.3
Value of Emissions Reduction (Total FFC Emissions)						
CO_2 (2015$ million) **	0.01 to 0.21	0.07 to 0.99	0.19 to 2.73	0.27 to 3.87	0.43 to 6.14	1.84 to 26.02
NO_X − 3% discount rate (2015$ million).	7.0 to 16.0	33.4 to 76.1	92.1 to 210.0	130.5 to 297.5	207.2 to 472.3	891.8 to 2033.4
NO_X − 7% discount rate (2015$ million).	2.6 to 5.8	12.3 to 27.8	34.0 to 76.6	48.1 to 108.5	76.4 to 172.3	343.4 to 774.2

Parentheses indicate negative (−) values.
* CO_2eq is the quantity of CO_2 that would have the same global warming potential (GWP).
** Range of the economic value of CO_2 reductions is based on estimates of the global benefit of reduced CO2 emissions.

TABLE V. 37—SUMMARY OF ANALYTICAL RESULTS FOR COMPRESSORS TSLS: MANUFACTURER AND CONSUMER IMPACTS *

Category	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
Manufacturer Impacts						
Industry NPV (2014$ million) (No-new-standards case INPV = 497.1).	476.8 to 480.4	439.3 to 451.9	345.8 to 385.7	301.8	256.0	105.3
Industry NPV *(% change)*	(4.1) to (3.4)	(11.6) to (9.1)	(30.4) to (22.4)	(39.3)	(48.5)	(78.8)
Consumer Average LCC Savings (2015$)						
RP_FS_L_AC	$9,056	$8,902	$9,443	$7,579	$7,748	$7,817
RP_FS_L_WC	$14,396	$15,011	$16,538	$13,649	$14,397	$15,512
RP_FS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	$5,182
RP_FS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	$5,686
RP_VS_L_AC	$5,073	$6,061	$6,746	$5,732	$6,408	$5,784
RP_VS_L_WC	$12,017	$13,865	$14,922	$11,996	$12,055	$10,082
RP_VS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	$11,104
RP_VS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	$8,748
R1_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	($282)
R3_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	($693)
Consumer Simple PBP (years)						
RP_FS_L_AC	1.3	1.7	2.1	2.3	2.6	3.3
RP_FS_L_WC	2.0	2.4	2.8	3.0	3.2	3.8

TABLE V. 37—SUMMARY OF ANALYTICAL RESULTS FOR COMPRESSORS TSLS: MANUFACTURER AND CONSUMER IMPACTS *—Continued

Category	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
RP_FS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	3.6
RP_FS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	4.0
RP_VS_L_AC	2.1	2.5	3.0	3.3	3.8	4.9
RP_VS_L_WC	2.8	3.4	4.1	4.3	4.9	5.9
RP_VS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	3.0
RP_VS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	2.7
R1_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	9.2
R3_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	12.1
Percent of Consumers that Experience Net Cost						
RP_FS_L_AC	0%	0%	1%	3%	5%	14%
RP_FS_L_WC	0%	1%	3%	5%	7%	15%
RP_FS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	8%
RP_FS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	10%
RP_VS_L_AC	0%	1%	4%	8%	13%	31%
RP_VS_L_WC	1%	3%	8%	14%	21%	40%
RP_VS_LF_AC	n.a.	n.a.	n.a.	n.a.	n.a.	6%
RP_VS_LF_WC	n.a.	n.a.	n.a.	n.a.	n.a.	5%
R1_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	78%
R3_FS_L_XX	n.a.	n.a.	n.a.	n.a.	n.a.	83%

* Parentheses indicate negative (−) values.
The entry "n.a." means not applicable because no standards are being proposed for these equipment classes.

DOE first considered TSL 6, which represents the max-tech efficiency level. TSL 6 would save 4.57 quads of energy, an amount DOE considers significant. Under TSL 6, the NPV of consumer benefit would be −$4.71 billion using a discount rate of 7 percent, and −$4.94 billion using a discount rate of 3 percent.

The cumulative emissions reductions at TSL 6 are 271.3 Mt of CO_2,149.6 thousand tons of SO_2, 498.4 thousand tons of NO_X, 0.552 ton of Hg, 1192.1 thousand tons of CH_4, and 3.13 thousand tons of N_2O. The estimated monetary value of the CO_2 emissions reduction at TSL 6 ranges from $1,837 million to $26,016 million.

At TSL 6, the average LCC impacts are savings that range from $5,784 to $5,512 for rotary lubricated equipment classes, $5,182 to $11,104 for rotary lubricant-free equipment classes, and −$282 to −$693 for reciprocating equipment classes. The simple payback periods range from 3.3 to 5.9 years for rotary lubricated equipment classes, 2.7 to 4.0 years for rotary lubricant-free equipment classes, 9.2 to 12.1 years for reciprocating equipment classes. The fraction of consumers experiencing a net LCC cost ranges from 14 to 40 percent for rotary lubricated equipment classes, 5 to 10 percent for rotary lubricant-free equipment classes, and 78- to 83-percent for reciprocating equipment classes.

At TSL 6, DOE estimates a decrease in INPV of $391.8 million, which represents a loss of 78.8 percent in INPV for manufacturers.

The Secretary tentatively concludes that at TSL 6 for compressors, the benefits of energy savings, emission reductions, and the estimated monetary value of the emissions reductions would be outweighed by the negative NPV of consumer benefits, the economic burden on some consumers, and the significant burden on the industry, including the conversion costs and profit margin impacts that could result in a large reduction in INPV. Consequently, the Secretary has tentatively concluded that TSL 6 is not economically justified.

DOE then considered TSL 5, which would save 1.11 quads of energy, an amount DOE considers significant. Under TSL 5, the NPV of consumer benefit would be $1.07 billion using a discount rate of 7 percent, and $3.28 billion using a discount rate of 3 percent.

The cumulative emissions reductions at TSL 5 are 65.6 Mt of CO_2,36.0 thousand tons of SO_2, 121.0 thousand tons of NO_X, 0.133 ton of Hg, 290.1 thousand tons of CH_4, and 0.75 thousand tons of N_2O. The estimated monetary value of the CO_2 emissions reduction at TSL 5 ranges from $427 million to $6,138 million.

At TSL 5 there is no projected increase in efficiency for rotary lubricant-free and reciprocating equipment classes. At TSL 5 for rotary lubricated equipment classes, the average LCC impact would result in savings that range from $6,408 for RP_VS_L_AC to $14,397 for RP_FS_L_WC. The simple payback period ranges from 2.6 years for RP_FS_L_AC to 4.9 years for RP_VS_L_WC. The fraction of consumers experiencing a net LCC cost ranges from 5-percent for RP_FS_L_AC to 21-percent for RP_VS_L_WC.

At TSL 5, DOE estimates a decrease in INPV of $241.1 million, which represents a loss of 48.5 percent in INPV for manufacturers.

Based on this analysis, DOE tentatively concludes that at TSL 5, the benefits of energy savings, positive NPV of consumer benefits, emission reductions, and the estimated monetary value of the emissions reductions would be outweighed by the economic burden on some consumers, and significant burden on the industry, including the conversion costs and profit margin impacts that could result in a large reduction in INPV. Consequently, DOE has tentatively concluded that TSL 5 is not economically justified.

DOE then considered TSL 4, which would save 0.70 quads of energy, an amount DOE considers significant. Under TSL 4, the NPV of consumer benefit would be $0.75 billion using a discount rate of 7 percent, and $2.21 billion using a discount rate of 3 percent.

The cumulative emissions reductions at TSL 4 are 41.3 Mt of CO_2, 22.7 thousand tons of SO_2, 76.2 thousand tons of NO_X, 0.084 ton of Hg, 182.7 thousand tons of CH_4, and 0.47 thousand tons of N_2O. The estimated monetary value of the CO_2 emissions reduction at TSL 4 ranges from $269 million to $3,866 million.

At TSL 4 there is no projected increase in efficiency for rotary lubricant-free and reciprocating equipment classes. At TSL 4 for rotary lubricated equipment classes, the average LCC impact would result in savings that range from $5,732 for RP_VS_L_AC to $13,649 for RP_FS_L_WC. The simple payback period ranges from 2.3 years for RP_FS_L_AC to 4.3 years for RP_VS_L_WC. The fraction of consumers experiencing a net LCC cost ranges from 3 percent for RP_FS_L_AC to 14-percent for RP_VS_L_WC.

At TSL 4, DOE estimates a decrease in INPV of $195.3 million, which represents a loss of 39.3 percent in INPV for manufacturers.

Based on this analysis, DOE tentatively concludes that at TSL 4 the benefits of energy savings, positive NPV of consumer benefits, emission reductions, and the estimated monetary value of the emissions reductions would be outweighed by the economic burden on some consumers, and significant burden on the industry, including the conversion costs and profit margin impacts that could result in a large reduction in INPV. Consequently, DOE has tentatively concluded that TSL 4 is not economically justified.

DOE then considered TSL 3, which would save 0.49 quads of energy, an amount DOE considers significant. Under TSL 3, the NPV of consumer benefit would be $0.56 billion using a discount rate of 7 percent, and $1.62 billion using a discount rate of 3 percent.

The cumulative emissions reductions at TSL 3 are 29.2 Mt of CO_2, 16.0 thousand tons of SO_2, 53.8 thousand tons of NO_X, 0.059 ton of Hg, 128.9 thousand tons of CH_4, and 0.34 thousand tons of N_2O. The estimated monetary value of the CO_2 emissions reduction at TSL 3 ranges from $190 million to $2,728 million.

At TSL 3 there is no projected increase in efficiency for rotary lubricant-free and reciprocating equipment classes. At TSL 3 for rotary lubricated equipment classes the average LCC impact would result in savings that range from $6,746 for RP_VS_L_AC to $16,538 for RP_FS_L_WC. The simple payback period ranges from 2.1 years for RP_FS_L_AC to 4.1 years for RP_VS_L_WC. The fraction of consumers experiencing a net LCC cost ranges from 1 percent for RP_FS_L_AC to 8-percent for RP_VS_L_WC.

At TSL 3, the projected change in INPV ranges from a decrease of $111.4 million to a decrease of $151.3 million, which represent decreases of 22.4 percent and 30.4 percent, respectively.

Based on this analysis, DOE tentatively concludes that at TSL 3 for compressors, the benefits of energy savings, positive NPV of consumer benefits, emission reductions, and the estimated monetary value of the emissions reductions would be outweighed by the economic burden on some consumers, and significant burden on the industry, including the conversion costs and profit margin impacts that could result in a large reduction in INPV. Consequently, DOE has tentatively concluded that TSL 3 is not economically justified.

DOE then considered TSL 2, which would save 0.18 quads of energy, an amount DOE considers significant. Under TSL 2, the NPV of consumer benefit would be $0.23 billion using a discount rate of 7 percent, and $0.63 billion using a discount rate of 3 percent.

The cumulative emissions reductions at TSL 2 are 10.6 Mt of CO_2, 5.8 thousand tons of SO_2, 19.5 thousand tons of NO_X, 0.021 ton of Hg, 46.7 thousand tons of CH_4, and 0.12 thousand tons of N_2O. The estimated monetary value of the CO_2 emissions reduction at TSL 2 ranges from $69 million to $989 million.

At TSL 2 there is no projected increase in efficiency for rotary lubricant-free and reciprocating equipment classes. At TSL 2 for rotary lubricated equipment classes, the average LCC impact would result in savings that range from $6,061 for RP_VS_L_AC to $15,011 for RP_FS_L_WC. The simple payback period ranges from 1.7 years for RP_FS_L_AC to 3.4 years for RP_VS_L_WC. The fraction of consumers experiencing a net LCC cost ranges from zero percent for RP_FS_L_AC to 3-percent for RP_VS_L_WC.

At TSL 2, the projected change in INPV ranges from a decrease of $45.2 million to a decrease of $57.8 million, which represent decreases of 9.1 percent and 11.6 percent, respectively.

After considering the analysis and weighing the benefits and burdens, and based upon DOE's understanding of currently available information, DOE has tentatively concluded that at TSL 2 for compressors the benefits of energy savings, positive NPV of consumer benefits, emission reductions, the estimated monetary value of the emissions reductions, and positive average LCC savings would outweigh the negative impacts on some consumers and the potential reduction in INPV for manufacturers. Accordingly, DOE has tentatively concluded that TSL 2 would offer the maximum improvement in efficiency that is technologically feasible and economically justified, and would result in the significant conservation of energy.

Therefore, based on the above considerations, DOE proposes to adopt the energy conservation standards for compressors at TSL 2. The proposed standards, expressed in package isentropic efficiency are shown in Table V.38. Table V.39 through Table V.42 provide mathematical coefficients required to calculate package isentropic efficiency in Table V.38. For ''Fixed-speed compressor'' equipment classes, the relevant Package Isentropic Efficiency is Full-Load Package Isentropic Efficiency; for ''Variable-speed compressor'' equipment classes, the relevant Package Isentropic Efficiency is Part-Load Package Isentropic Efficiency. Both Full- and Part-Load Package Isentropic Efficiency are determined in accordance with the proposed DOE test procedure. These proposed standards, if adopted, would apply to all compressors listed in Table V.38 and manufactured in, or imported into, the United States starting on the proposed compliance date specified in this proposal.

TABLE V.38—PROPOSED ENERGY CONSERVATION STANDARDS FOR COMPRESSORS

Equipment class	Minimum package isentropic efficiency	η_{Regr} (package isentropic efficiency reference curve)	d
Rotary; Lubricated; Air-cooled; Fixed-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln(.472 * V_1)^2 + 0.139 * \ln(.472 * V_1) + 0.271$.	−15
Rotary; Lubricated; Air-cooled; Variable-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.0155 * \ln(.472 * V_1)^2 + 0.216 * \ln(.472 * V_1) + 0.00905$.	−10
Rotary; Lubricated; Water-cooled; Fixed-speed.	$.0235 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln(.472 * V_1)^2 + 0.139 * \ln(.472 * V_1) + 0.271$.	−15
Rotary; Lubricated; Water-cooled; Variable-speed.	$.0235 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.0155 * \ln(.472 * V_1)^2 + 0.216 * \ln(.472 * V_1) + 0.00905$.	−15

TABLE V.38—PROPOSED ENERGY CONSERVATION STANDARDS FOR COMPRESSORS—Continued

Equipment class	Minimum package isentropic efficiency	η_{Regr} (package isentropic efficiency reference curve)	d
Rotary; Lubricant-free; Air-cooled; Fixed-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$A_1 * \ln(.472 * V_1)^2 + B_1 * \ln(.472 * V_1) + C_1$.	−11
Rotary; Lubricant-free; Air-cooled; Variable-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$A_2 * \ln(.472 * V_1)^2 + B_2 * \ln(.472 * V_1) + C_2$.	−13
Rotary; Lubricant-free; Water-cooled; Fixed-speed.	$A_3 * \ln(.472 * V_1)^2 + B_3 * \ln(.472 * V_1) + C_3 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$.	$A_1 * \ln(.472 * V_1)^2 + B_1 * \ln(.472 * V_1) + C_1$.	−11
Rotary; Lubricant-free; Water-cooled; Variable-speed.	$A_4 * \ln(.472 * V_1)^2 + B_4 * \ln(.472 * V_1) + C_4 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$.	$A_2 * \ln(.472 * V_1)^2 + B_2 * \ln(.472 * V_1) + C_2$.	−13

TABLE V.39—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, AIR AND WATER-COOLED, FIXED-SPEED AIR COMPRESSORS

Full-load actual volume flow rate range (acfm)	A_1	B_1	C_1
$0 \leq V_1 \geq 161$	−0.00928	0.139	0.191
$161 < V_1 \leq 2125$	0.00281	0.0344	0.417
$2125 < V_1$	−0.00928	0.139	0.271

TABLE V.40—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, AIR AND WATER-COOLED, VARIABLE-SPEED AIR COMPRESSORS

Full-load actual volume flow rate range (acfm)	A_2	B_2	C_2
$0 < V_1 \leq 102$	−0.0155	0.216	−0.0984
$102 < V_1 \leq 1426$	0.000	0.0958	0.134
$1426 < V_1$	−0.0155	0.216	0.00905

TABLE V.41—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, WATER-COOLED, FIXED-SPEED AIR COMPRESSORS

Full-load actual volume flow rate range (acfm)	A_3	B_3	C_3
$0 < V < 102$	0	0	0
$102 \leq V_1$	−0.00924	0.117	−0.315

TABLE V.42—COEFFICIENTS FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR ROTARY, LUBRICANT-FREE, WATER-COOLED, VARIABLE-SPEED AIR COMPRESSORS

Full-load actual volume flow rate range (acfm)	A_4	B_4	C_4
$0 < V_1 < 74$	0	0	0
$74 \leq V_1$	0.000173	0.00783	−0.0300

DOE requests comments and data that will aid in the refinement of its analysis of the calculated reduction to the industry's net present value at the TSL 3 level (see section V.B.2.a). These impacts are captured in the Manufacturing Impact Analysis, and in particular within the DOE's Government Regulatory Impact Model (see section V.B.2). Comments are also requested on DOE's inputs to the product and capital conversion costs, including the lack of available skilled design engineers (see section V.B.2.c) and product production costs (see section V.B.2.a), as well as DOE's assumptions regarding mark-up scenarios, specifically the assumption regarding the percentage of costs that will be passed on to consumers (see section IV.C.7).

This is identified as Issue 52 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

2. Summary of Annualized Benefits and Costs of the Proposed Standards

The benefits and costs of the proposed standards can also be expressed in terms of annualized values. The annualized net benefit is the sum of: (1) The annualized national economic value (expressed in 2015$) of the benefits from operating equipment that meet the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase costs, and (2) the annualized monetary value of the benefits of CO_2 and NO_X emission reductions.[122]

Table V.43 shows the annualized values for compressors under TSL 2,

[122] To convert the time-series of costs and benefits into annualized values, DOE calculated a present value in 2016, the year used for discounting the NPV of total consumer costs and savings. For the benefits, DOE calculated a present value associated with each year's shipments in the year in which the shipments occur (2020, 2030, *etc.*), and then discounted the present value from each year to 2016. The calculation uses discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions, for which DOE used case-specific discount rates. Using the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in the compliance year that yields the same present value.

expressed in 2015$. The results under the primary estimate are as follows.

Using a 7-percent discount rate for benefits and costs other than CO_2 reduction (for which DOE used a 3-percent discount rate along with the average SCC series that has a value of $40.0/t in 2015), the estimated cost of the standards proposed in this rule is 10.4 million per year in increased equipment costs, while the estimated annual benefits are $36.0 million in reduced equipment operating costs, $19.2 million in CO_2 reductions, and $1.4 million in reduced NO_X emissions. In this case, the net benefit amounts to $46 million per year.

Using a 3-percent discount rate for all benefits and costs and the average SCC series that has a value of $40.0/t in 2015, the estimated cost of the proposed standards is $10.9 million per year in increased equipment costs, while the estimated annual benefits are $48.4 million in reduced operating costs, $19.2 million in CO_2 reductions, and $2.0 million in reduced NO_X emissions. In this case, the net benefit amounts to $59 million per year.

TABLE V.43—ANNUALIZED BENEFITS AND COSTS OF PROPOSED STANDARDS (TSL 2) FOR COMPRESSORS SOLD IN 2022–2051

	Discount rate	Primary estimate*	Low net benefits estimate*	High net benefits estimate*
		million 2015$/year		
Benefits				
Consumer Operating Cost Savings	7%	36.0	29.3	43.7.
	3%	48.4	38.9	60.4.
CO_2 Reduction (using mean SCC at 5% discount rate)**	5%	5.7	4.8	6.9.
CO_2 Reduction (using mean SCC at 3% discount rate)**	3%	19.2	16.0	23.2.
CO_2 Reduction (using mean SCC at 2.5% discount rate)**	2.5%	28.1	23.3	33.9.
CO_2 Reduction (using 95th percentile SCC at 3% discount rate)**.	3%	58.5	48.6	70.6.
NO_X Reduction†	7%	1.4	1.2	3.7.
	3%	2.0	1.6	5.4.
Total Benefits††	7% plus CO_2 range	43 to 96	35 to 79	54 to 118.
	7%	57	46	71.
	3% plus CO_2 range	56 to 109	45 to 89	73 to 136.
	3%	70	57	89.
Costs				
Consumer Incremental Installed Equipment Costs	7%	10.4	8.9	11.8.
	3%	10.9	9.2	12.4.
Net Benefits				
Total††	7% plus CO_2 range	33 to 85	26 to 70	42 to 106.
	7%	46	38	59.
	3% plus CO_2 range	45 to 98	36 to 80	60 to 124.
	3%	59	47	77.

* This table presents the annualized costs and benefits associated with compressors shipped in 2022–2051. These results include benefits to consumers which accrue after 2051 from the equipment purchased in 2022–2051. The Primary, Low Benefits, and High Benefits Estimates utilize projections of energy prices from the *AEO 2015* Reference case, Low Economic Growth case, and High Economic Growth case, respectively. In addition, incremental product costs reflect a constant trend in the Primary Estimate, an increasing trend in the Low Benefits Estimate, and a decreasing trend in the High Benefits Estimate. The methods used to derive projected price trends are explained in section IV.H.1. Note that the Benefits and Costs may not sum to the Net Benefits due to rounding.

** The CO_2 reduction benefits are calculated using 4 different sets of SCC values. The first three use the average SCC calculated using 5%, 3%, and 2.5% discount rates, respectively. The fourth represents the 95th percentile of the SCC distribution calculated using a 3% discount rate. The SCC values are emission year specific. See section IV.L.1 for more details.

† DOE estimated the monetized value of NO_X emissions reductions using benefit per ton estimates from the *Regulatory Impact Analysis for the Clean Power Plan Final Rule,* published in August 2015 by EPA's Office of Air Quality Planning and Standards. (Available at: *http://www.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.*) See section IV.L.2 for further discussion. For DOE's Primary Estimate and Low Net Benefits Estimate, the agency is using a national benefit-per-ton estimate for NO_X emitted from the Electric Generating Unit sector based on an estimate of premature mortality derived from the ACS study (Krewski et al., 2009). For DOE's High Net Benefits Estimate, the benefit-per-ton estimates were based on the Six Cities study (Lepuele et al., 2011), which are nearly two-and-a-half times larger than those from the ACS study.

†† Total Benefits for both the 3% and 7% cases are derived using the series corresponding to the average SCC with a 3-percent discount rate ($40.0/t case). In the rows labeled "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

VI. Certification Requirements

DOE proposes to adopt the reporting requirements in a new section 429.61(b) within subpart B of 10 CFR part 429. This section would also include sampling requirements, which are discussed in the test procedure NOPR. Consistent with other types of covered products and equipment, the proposed section (10 CFR 429.61(b)) would specify that the general certification report requirements contained in 10 CFR 429.12 apply to compressors. The additional requirements proposed in 10 CFR 429.61 would require manufacturers to supply certain additional information to DOE in certification reports for compressors to demonstrate compliance with any energy conservation standards established as a result of this rulemaking.

Specifically, DOE proposes that the following data be included in the certification reports and be made public on DOE's Web site:

- Full-load package isentropic efficiency or part-load package isentropic efficiency, as applicable (dimensionless);
- Full-load actual volume flow rate (in actual cubic feet per minute);
- Compressor motor nominal horsepower (in horsepower);
- Full-load operating pressure (in pounds per square inch, gauge);
- Maximum full-flow operating pressure (in pounds per square inch, gauge); and
- Pressure ratio (dimensionless).

10 CFR 429.12(b) already requires reporting of manufacturer name, model number(s), and equipment class for all covered products and equipment.

With respect to reporting model number(s), a certification report must include a basic model number and the manufacturer's (individual) model number(s). A manufacturer's model number (individual model number) is the identifier used by a manufacturer to uniquely identify what is commonly considered a ''model'' in industry—all units of a particular design. The manufacturer's (individual) model number typically appears on the product nameplate, in product catalogs and in other product advertising literature. In contrast, the basic model number is a number used by the manufacturer to indicate to DOE how the manufacturer has grouped its individual models for the purposes of testing and rating; many manufacturers choose to use a model number that is similar to the individual model numbers in the basic model, but that is not required. The manufacturer's individual model number(s) in each basic model must reference not only the bare compressor, but also any motor and controls with which the compressor is being rated.

VII. Procedural Issues and Regulatory Review

A. Review Under Executive Orders 12866 and 13563

Section 1(b)(1) of Executive Order 12866, ''Regulatory Planning and Review,'' 58 FR 51735 (Oct. 4, 1993), requires each agency to identify the problem that it intends to address, including, where applicable, the failures of private markets or public institutions that warrant new agency action, as well as to assess the significance of that problem. The problems that the proposed standards set forth in this NOPR are intended to address are as follows:

(1) Insufficient information and the high costs of gathering and analyzing relevant information leads some consumers to miss opportunities to make cost-effective investments in energy efficiency.

(2) In some cases, the benefits of more-efficient equipment are not realized due to misaligned incentives between purchasers and users. An example of such a case is when the equipment purchase decision is made by a building contractor or building owner who does not pay the energy costs.

(3) There are external benefits resulting from improved energy efficiency of appliances and equipment that are not captured by the users of such equipment. These benefits include externalities related to public health, environmental protection, and national energy security that are not reflected in energy prices, such as reduced emissions of air pollutants and greenhouse gases that impact human health and global warming. DOE attempts to quantify some of the external benefits through use of social cost of carbon values.

In addition, DOE has determined that this regulatory action is not a ''significant regulatory action'' under section 3(f) of Executive Order 12866. Section 6(a)(3)(A) of the Executive Order states that absent a material change in the development of the planned regulatory action, regulatory action not designated as significant will not be subject to review under the aforementioned section unless, within 10 working days of receipt of DOE's list of planned regulatory actions, the Administrator of OIRA notifies the agency that OIRA has determined that a planned regulation is a significant regulatory action within the meaning of the Executive order.

DOE has also reviewed this regulation pursuant to Executive Order 13563, issued on January 18, 2011. 76 FR 3281 (January 21, 2011). Executive Order 13563 is supplemental to and explicitly reaffirms the principles, structures, and definitions governing regulatory review established in Executive Order 12866. To the extent permitted by law, agencies are required by Executive Order 13563 to: (1) Propose or adopt a regulation only upon a reasoned determination that its benefits justify its costs (recognizing that some benefits and costs are difficult to quantify); (2) tailor regulations to impose the least burden on society, consistent with obtaining regulatory objectives, taking into account, among other things, and to the extent practicable, the costs of cumulative regulations; (3) select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity); (4) to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt; and (5) identify and assess available alternatives to direct regulation, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public.

DOE emphasizes as well that Executive Order 13563 requires agencies to use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible. In its guidance, OIRA has emphasized that such techniques may include identifying changing future compliance costs that might result from technological innovation or anticipated behavioral changes. For the reasons stated in the preamble, DOE believes that this NOPR is consistent with these principles, including the requirement that, to the extent permitted by law, benefits justify costs and that net benefits are maximized.

B. Review Under the Regulatory Flexibility Act

The Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*) requires preparation of an initial regulatory flexibility analysis (IRFA) for any rule that by law must be proposed for public comment, unless the agency certifies that the rule, if promulgated, will not have a significant economic impact on a substantial number of small entities. As required by Executive Order 13272, ''Proper Consideration of Small Entities in Agency Rulemaking,'' 67 FR 53461 (August 16, 2002), DOE published procedures and policies on February 19, 2003, to ensure that the potential impacts of its rules on small entities are properly considered during the rulemaking process. 68 FR 7990. DOE has made its procedures and policies available on the Office of the General Counsel's Web site (*http://energy.gov/gc/office-general-counsel*). DOE has prepared the following IRFA for the equipment that are the subject of this rulemaking.

For manufacturers of compressors, the Small Business Administration (SBA) has set a size threshold, which defines those entities classified as ''small businesses'' for the purposes of the statute. DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of the rule. (65 FR 30840, 30849 (May 15, 2000), as amended at 65 FR 53533, 53544 (Sept. 5, 2000), and codified at 13 CFR part 121.) The size standards are listed by North American Industry Classification System (NAICS) code and industry description and are available at *http://www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf*. Manufacturing of compressors is classified under NAICS 333912, ''Air and Gas Compressor Manufacturing.'' The SBA sets a threshold of 500 employees or fewer for an entity to be considered as a small business for this category.

1. Description on Estimated Number of Small Entities Regulated

a. Methodology for Estimating the Number of Small Entities

To estimate the number of small business manufacturers of equipment within the scope of this rulemaking, DOE conducted a market survey using available public information. DOE's research involved industry trade association membership directories (including CAGI), individual company and online retailer Web sites, and market research tools (*e.g.,* Hoovers reports) to create a list of companies that manufacture equipment covered by this rulemaking. DOE presented its list to manufacturers in MIA interviews and asked industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at DOE public meetings. DOE reviewed publicly-available data and contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer. DOE screened out companies that do not offer equipment within the scope of this rulemaking, do not meet the definition of a ''small business,'' or are foreign-owned and operated.

b. Compressor Industry Structure and Nature of Competition

DOE identified a total of 37 manufacturers of compressor equipment sold in the United States and within the scope of this rulemaking. Seventeen of these manufacturers met the 500-employee threshold defined by the SBA to qualify as a small business, but only 13 were domestic companies. All 13 domestic small businesses manufacture reciprocating air compressors, while only five of the 13 manufacture rotary air compressors.

Within the compressor industry, manufacturers can be classified into two categories; original equipment manufacturers (OEMs) and compressor packagers. OEMs manufacture their own air-ends and assemble them with other components to create complete package compressors. Packagers assemble motors and other accessories with air-ends purchased from other companies, resulting in a complete compressor.

Within the rotary air compressor industry, DOE identified 20 manufacturers; 15 are OEMs and five are packagers of compressors. Of the 20 total manufacturers, seven large OEMs supply approximately 80-percent of shipments and revenues. Of the five domestic small rotary air compressor businesses identified, DOE's research indicates that two are OEMs and three are packagers.

The reciprocating air compressor market has a significantly different structure than the rotary market. The reciprocating market is highly fragmented, consisting of approximately 16 large and 17 small OEMs and packagers. Five of the 16 large businesses are members of CAGI. Eight of the 16 large manufacturers are believed to be packagers. Of the 18 identified small businesses, 13 are domestic. DOE notes that some interviewed manufacturers stated that there are potentially a large number of domestic small reciprocating air compressor manufacturers who assemble compressor packages from nearly complete components. These unidentified small manufacturers are not members of CAGI and typically have a limited marketing presence. DOE was not able to identify these small businesses. Based on this information, it is possible that DOE's list of 13 small domestic players may not include all small U.S. manufacturers in the industry. Of the 13 identified domestic reciprocating air compressor manufacturers, three are believed to be OEMs and 10 are believed to be packagers.

Table VII.1 presents both the total number of domestic small businesses offering equipment in each equipment class grouping as well as the breakdown between domestic small business OEMs and domestic small business packagers.

TABLE VII.1—NUMBER OF DOMESTIC SMALL BUSINESSES MANUFACTURING COMPRESSORS BY EQUIPMENT CLASS GROUPING

Equipment class grouping	Number of domestic small original equipment manufacturers	Number of domestic small packagers	Total number of domestic small businesses
Rotary Air Compressors	2	3	5
Reciprocating Air Compressors	3	10	13
Total	3	10	13

DOE requests comment on the number and names of domestic small manufacturers producing covered equipment. This is identified as Issue 53 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

c. Manufacturer Participation

DOE reached out to all 13 identified domestic small businesses to invite them to take part in manufacturer impact analysis interviews. As mentioned previously, all thirteen domestic small businesses manufacturer reciprocating air compressors, while only five of the thirteen manufacturer rotary air compressors.

As a part of the domestic small business outreach process, DOE attempted to obtain the best contact information possible for each domestic small business. To do so, DOE directly solicited domestic small business contact information from known industry participants. In addition, DOE also researched domestic small business contact information using publically available information. When these methods were successful, DOE initiated contact with domestic small businesses by emailing recommended, specific individuals within an organization. When specific email addresses were not available, DOE contacted manufacturers using general contact information provided on manufacturer Web pages; this includes contact web forms, as well as general sales, support, and information email addresses.

Of the five domestic small manufacturers of rotary compressors, two responded to DOE's contact attempt and were willing to discuss potential standards with DOE. These two manufacturers are the only known domestic small OEMs of rotary compressor. The three that did not respond are believed to be packagers.

Of the thirteen domestic small manufacturers of reciprocating compressors, four responded to DOE's contact attempt and ultimately, three were willing to discuss potential standards with DOE. DOE notes that one of the three is a reciprocating compressor packager, while the other two are OEMs of both reciprocating and rotary compressors. The latter are the same manufacturers discussed in the previous paragraph. DOE notes that no new standards for reciprocating compressors are proposed in this document.

Finally, DOE also discussed information about small businesses and potential impacts on small businesses while interviewing large manufacturers.

2. Description and Estimate of Compliance Requirements

Because DOE proposes to establish standards for only rotary equipment, this section will only focus on the estimated impacts to the five domestic small manufacturers of rotary compressors.

Of the five domestic small rotary compressor manufacturers identified, DOE's research indicates that two are OEMs and three are packagers. Whereas OEMs would be expected to incur significant redesign and capital conversion costs in order to comply with amended standards, packagers would not. Unlike OEMs, packagers would not face significant capital conversion costs, as the processes they use to assemble completed packages from purchased air-ends and components is not expected to change. Packagers are also not expected to face significant product redesign costs, as the burden of engineering and redesigning the air-end and other key components would reside with OEMs. However, as manufacturers OEMs and packagers are both expected to incur new compliance and testing costs, as any new energy conservation standard would require their equipment to be tested and certified to the standard, using a DOE test procedure.

As a result of these efforts, the following discussion of domestic small business impacts considers capital, redesign, and compliance cost impacts facing rotary OEMs, while only considering compliance cost impacts for rotary packagers.

DOE estimates that domestic small rotary compressor OEMs account for approximately 9 percent of models available in the market. As such, DOE estimates that 9 percent of the total industry product and capital conversion costs (excluding compliance costs) are attributed to domestic small rotary compressor OEMs. At TSL 2, the level proposed in this document, 9-percent of total conversion costs (excluding compliance costs) equates to $7.9 to $10.3 million; the remaining $78.3 to $102.0 million is attributed to large OEMs. DOE's conversion cost estimates were derived from total industry conversion costs discussed previously in section IV.J.2.b.i. DOE notes that the ranges shown here relate to the two conversion cost scenarios investigated in section IV.J.2.b.i.

DOE also estimates that, combined, domestic small rotary compressor OEMs and packagers account for approximately 15-percent of models available in the market. As such, DOE estimates that 15-percent of the total industry testing and compliance costs are attributed to domestic small rotary compressor OEMs and packagers. At TSL 2, this equates to $1.9 million for domestic small manufacturers and $10.9 million for large OEMs. DOE notes that these costs represent those involved in testing and ensuring compliance of both lubricated and non-lubricated equipment with the proposed standards. DOE's testing and compliance cost estimates were derived from total industry conversion costs discussed previously in section IV.J.2.b.i.

Finally, DOE estimated revenues for the five domestic small rotary manufacturers. To do so, DOE researched publicly available revenue estimates from Hoovers [123] and scaled those revenues to reflect only the portion of a company's revenues attributable to rotary compressor sales. DOE estimates the aggregate 2014 rotary compressor revenues for the five domestic small manufacturers to be approximately $41.6 million. DOE's GRIM results estimate total industry 2014 revenues (including small businesses) to be $583.8 million. Accordingly, revenues from large rotary manufacturers are estimated to be $542.2 million. As such DOE estimates domestic small rotary manufacturers account for approximately 7.1-percent of industry revenues and large manufacturers account for 92.9-percent. Comparing costs to revenues for each group, DOE estimates total conversion costs, including testing and compliance, at TSL 2 are approximately 23.8-to 29.5-percent of revenues for domestic small manufacturers and 16.4 to 20.8 percent of revenues for large manufacturers. Table VII.2 summarizes domestic small and large business conversion and compliance costs and shows the relative impacts of conversion costs on domestic small manufacturers relative to large manufacturers.

TABLE VII.2—AGGREGATED IMPACTS OF CONVERSION COSTS ON A DOMESTIC SMALL MANUFACTURERS AT THE PROPOSED STANDARD, TSL 2

	Aggregate impact to domestic small rotary manufacturers	Aggregate impact to large, rotary manufacturers
Total Product and Capital Conversion Costs, Excluding Compliance and Testing Costs (Millions).	$7.9 to $10.3	$78.3 to $102.0.
Total Testing and Compliance Costs (Millions)	$1.9	$10.9.
Total Conversion, Testing, and Compliance Costs (Millions)	$9.9 to $12.3	$89.2 to $112.9.
2014 Revenues (Millions)	$41.6	$542.2.
Total Conversion, Testing, and Compliance Cost, as a Percentage of Annual Revenue	23.8% to 29.5%	16.4% to 20.8%.

[123] Hoovers Inc., Company Profiles, Various Companies (Available at: *www.hoovers.com/*).

However, as noted in section V.B.2.a, the GRIM free cash flow results in 2021 indicated that some manufacturers may need to access the capital markets in order to fund conversion costs directly related to the proposed standard. Given that small manufacturers may have greater difficulty securing outside capital [124] and that the necessary conversion costs are not insignificant to the size of a small business, it is possible the domestic small OEMs may be forced to retire a greater portion of product models than large competitors. Also, smaller companies often have a higher cost of borrowing due to higher risk on the part of investors, largely attributed to lower cash flows and lower per unit profitability. In these cases, small manufacturers may observe higher costs of debt than larger manufacturers.

DOE notes that this conversion cost analysis assumes that compressors sold by domestic small manufacturers are of the same efficiency distribution as those sold by large manufacturers. DOE requests comment and data on the relative efficiency of equipment sold by domestic small manufacturers, as compared to equipment sold by large manufacturers. This is identified as Issue 54 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

DOE requests comment and data on the impact of the proposed standard on domestic small business manufacturers. Specifically, DOE requests comment on the magnitude of conversion costs for a domestic small manufacturers and the number or percent of models produced by domestic small manufacturers. DOE also requests data on the cost of capital for domestic small manufacturers to better quantify how domestic small manufacturers might be disadvantaged relative to large competitors. This is identified as Issue 55 in section VIII.E, ''Issues on Which DOE Seeks Comment.''

3. Duplication, Overlap, and Conflict With Other Rules and Regulations

DOE is not aware of any rules or regulations that duplicate, overlap, or conflict with the rule being considered today.

4. Significant Alternatives to the Rule

The discussion above analyzes impacts on small businesses that would result from DOE's proposed rule. In addition to the other TSLs being considered, the NOPR TSD includes an analysis of the following policy alternatives: (1) No change in standards; (2) consumer rebates; (3) consumer tax credits; (4) manufacturer tax credits; and (5) voluntary energy efficiency targets. While these alternatives may mitigate to some varying extent the economic impacts on small entities compared to the proposed standards, DOE does not intend to consider these alternatives further because in several cases, they would not be feasible to implement without authority and funding from Congress, and in all cases, DOE has determined that the energy savings of these alternatives are significantly smaller than those that would be expected to result from adoption of the proposed standard levels (ranging from approximately 11-percent to 66-percent of the energy savings from the proposed standards). Accordingly, DOE is declining to adopt any of these alternatives and is proposing the standards set forth in this rulemaking. (See chapter 17 of the NOPR TSD for further detail on the policy alternatives DOE considered.)

Additional compliance flexibilities may be available through other means. For example, individual manufacturers may petition for a waiver of the applicable test procedure. Further, EPCA provides that a manufacturer whose annual gross revenue from all of its operations does not exceed $8,000,000 may apply for an exemption from all or part of an energy conservation standard for a period not longer than 24 months after the effective date of a final rule establishing the standard. Additionally, Section 504 of the Department of Energy Organization Act, 42 U.S.C. 7194, provides authority for the Secretary to adjust a rule issued under EPCA in order to prevent ''special hardship, inequity, or unfair distribution of burdens'' that may be imposed on that manufacturer as a result of such rule. Manufacturers should refer to 10 CFR part 430, subpart E, and Part 1003 for additional details.

DOE continues to seek input from businesses that would be affected by this rulemaking and will consider comments received in the development of any final rule.

C. Review Under the Paperwork Reduction Act

Manufacturers of compressors must certify to DOE that their equipment complies with any applicable energy conservation standards. In certifying compliance, manufacturers must test their equipment according to the DOE test procedures for compressors, including any amendments adopted for those test procedures. DOE has established regulations for the certification and recordkeeping requirements for covered consumer products and commercial equipment. *See generally* 10 CFR part 429. The collection-of-information requirement for the certification and recordkeeping is subject to review and approval by OMB under the Paperwork Reduction Act (PRA). This requirement has been approved by OMB under OMB control number 1910–1400. Public reporting burden for the certification is estimated to average 30 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to comply with, a collection of information subject to the requirements of the PRA, unless that collection of information displays a currently valid OMB Control Number.

D. Review Under the National Environmental Policy Act of 1969

Pursuant to the National Environmental Policy Act (NEPA) of 1969, DOE has determined that the proposed rule fits within the category of actions included in Categorical Exclusion (CX) B5.1 and otherwise meets the requirements for application of a CX. See 10 CFR part 1021, App. B, B5.1(b); 1021.410(b) and App. B, B(1)–(5). The proposed rule fits within this category of actions because it is a rulemaking that establishes energy conservation standards for consumer products or industrial equipment, and for which none of the exceptions identified in CX B5.1(b) apply. Therefore, DOE has made a CX determination for this rulemaking, and DOE does not need to prepare an Environmental Assessment or Environmental Impact Statement for this proposed rule. DOE's CX determination for this proposed rule is available at *http://energy.gov/nepa/categorical-exclusion-cx-determinations-cx.*

E. Review Under Executive Order 13132

Executive Order 13132, ''Federalism,'' 64 FR 43255 (August 10, 1999), imposes certain requirements on Federal agencies formulating and implementing policies or regulations that preempt State law or that have Federalism implications. The Executive Order requires agencies to examine the constitutional and statutory authority supporting any action that would limit the policymaking discretion of the States and to carefully assess the

[124] Simon, Ruth, and Angus Loten, ''Small-Business Lending Is Slow to Recover,'' *Wall Street Journal,* August 14, 2014. Accessed August 2014, available at *http://online.wsj.com/articles/small-business-lending-is-slow-to-recover-1408329562.*

necessity for such actions. The Executive Order also requires agencies to have an accountable process to ensure meaningful and timely input by State and local officials in the development of regulatory policies that have Federalism implications. On March 14, 2000, DOE published a statement of policy describing the intergovernmental consultation process it will follow in the development of such regulations. 65 FR 13735. DOE has examined this proposed rule and has tentatively determined that it would not have a substantial direct effect on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. EPCA governs and prescribes Federal preemption of State regulations as to energy conservation for the products that are the subject of this proposed rule. States can petition DOE for exemption from such preemption to the extent, and based on criteria, set forth in EPCA. (42 U.S.C. 6297) Therefore, no further action is required by Executive Order 13132.

F. Review Under Executive Order 12988

With respect to the review of existing regulations and the promulgation of new regulations, section 3(a) of Executive Order 12988, ''Civil Justice Reform,'' imposes on Federal agencies the general duty to adhere to the following requirements: (1) Eliminate drafting errors and ambiguity; (2) write regulations to minimize litigation; (3) provide a clear legal standard for affected conduct rather than a general standard; and (4) promote simplification and burden reduction. 61 FR 4729 (February 7, 1996). Regarding the review required by section 3(a), section 3(b) of Executive Order 12988 specifically requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) Clearly specifies the preemptive effect, if any; (2) clearly specifies any effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct while promoting simplification and burden reduction; (4) specifies the retroactive effect, if any; (5) adequately defines key terms; and (6) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. Section 3(c) of Executive Order 12988 requires Executive agencies to review regulations in light of applicable standards in section 3(a) and section 3(b) to determine whether they are met or it is unreasonable to meet one or more of them. DOE has completed the required review and determined that, to the extent permitted by law, this proposed rule meets the relevant standards of Executive Order 12988.

G. Review Under the Unfunded Mandates Reform Act of 1995

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA) requires each Federal agency to assess the effects of Federal regulatory actions on State, local, and Tribal governments and the private sector. Public Law 104–4, sec. 201 (codified at 2 U.S.C. 1531). For a proposed regulatory action likely to result in a rule that may cause the expenditure by State, local, and Tribal governments, in the aggregate, or by the private sector of $100 million or more in any one year (adjusted annually for inflation), section 202 of UMRA requires a Federal agency to publish a written statement that estimates the resulting costs, benefits, and other effects on the national economy. (2 U.S.C. 1532(a), (b)) The UMRA also requires a Federal agency to develop an effective process to permit timely input by elected officers of State, local, and Tribal governments on a proposed ''significant intergovernmental mandate,'' and requires an agency plan for giving notice and opportunity for timely input to potentially affected small governments before establishing any requirements that might significantly or uniquely affect them. On March 18, 1997, DOE published a statement of policy on its process for intergovernmental consultation under UMRA. 62 FR 12820. DOE's policy statement is also available at *http://energy.gov/sites/prod/files/gcprod/documents/umra_97.pdf*.

DOE has concluded that this proposed rule is not expected to require expenditures of $100 million or more on the private sector. As a result, the analytical requirements of UMRA described above are not applicable.

H. Review Under the Treasury and General Government Appropriations Act, 1999

Section 654 of the Treasury and General Government Appropriations Act, 1999 (Pub. L. 105–277) requires Federal agencies to issue a Family Policymaking Assessment for any rule that may affect family well-being. This proposed rule would not have any impact on the autonomy or integrity of the family as an institution. Accordingly, DOE has concluded that it is not necessary to prepare a Family Policymaking Assessment.

I. Review Under Executive Order 12630

Pursuant to Executive Order 12630, ''Governmental Actions and Interference with Constitutionally Protected Property Rights,'' 53 FR 8859 (March 15, 1988), DOE has determined that this proposed rule would not result in any takings that might require compensation under the Fifth Amendment to the U.S. Constitution.

J. Review Under the Treasury and General Government Appropriations Act, 2001

Section 515 of the Treasury and General Government Appropriations Act, 2001 (44 U.S.C. 3516 note) provides for Federal agencies to review most disseminations of information to the public under information quality guidelines established by each agency pursuant to general guidelines issued by OMB. OMB's guidelines were published at 67 FR 8452 (Feb. 22, 2002), and DOE's guidelines were published at 67 FR 62446 (Oct. 7, 2002). DOE has reviewed this NOPR under the OMB and DOE guidelines and has concluded that it is consistent with applicable policies in those guidelines.

K. Review Under Executive Order 13211

Executive Order 13211, ''Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use,'' 66 FR 28355 (May 22, 2001), requires Federal agencies to prepare and submit to OIRA at OMB, a Statement of Energy Effects for any proposed significant energy action. A ''significant energy action'' is defined as any action by an agency that promulgates or is expected to lead to promulgation of a final rule, and that: (1) Is a significant regulatory action under Executive Order 12866, or any successor order; and (2) is likely to have a significant adverse effect on the supply, distribution, or use of energy, or (3) is designated by the Administrator of OIRA as a significant energy action. For any proposed significant energy action, the agency must give a detailed statement of any adverse effects on energy supply, distribution, or use should the proposal be implemented, and of reasonable alternatives to the action and their expected benefits on energy supply, distribution, and use.

DOE has tentatively concluded that this regulatory action, which proposes new energy conservation standards for compressors, is not a significant energy action because the proposed standards are not likely to have a significant adverse effect on the supply, distribution, or use of energy, nor has it been designated as such by the Administrator at OIRA. Accordingly, DOE has not prepared a Statement of Energy Effects on this proposed rule.

L. Review Under the Information Quality Bulletin for Peer Review

On December 16, 2004, OMB, in consultation with the Office of Science and Technology Policy (OSTP), issued its Final Information Quality Bulletin for Peer Review (the Bulletin). 70 FR 2664 (January 14, 2005). The Bulletin establishes that certain scientific information shall be peer reviewed by qualified specialists before it is disseminated by the Federal Government, including influential scientific information related to agency regulatory actions. The purpose of the bulletin is to enhance the quality and credibility of the Government's scientific information. Under the Bulletin, the energy conservation standards rulemaking analyses are ''influential scientific information,'' which the Bulletin defines as ''scientific information the agency reasonably can determine will have, or does have, a clear and substantial impact on important public policies or private sector decisions.'' *Id.* at FR 2667.

In response to OMB's Bulletin, DOE conducted formal in-progress peer reviews of the energy conservation standards development process and analyses and has prepared a Peer Review Report pertaining to the energy conservation standards rulemaking analyses. Generation of this report involved a rigorous, formal, and documented evaluation using objective criteria and qualified and independent reviewers to make a judgment as to the technical/scientific/business merit, the actual or anticipated results, and the productivity and management effectiveness of programs and/or projects. The ''Energy Conservation Standards Rulemaking Peer Review Report'' dated February 2007 has been disseminated and is available at the following Web site: *http://energy.gov/eere/buildings/downloads/energy-conservation-standards-rulemaking-peer-review-report*.

VIII. Public Participation

A. Attendance at the Public Meeting

The time, date, and location of the public meeting are listed in the **DATES** and **ADDRESSES** sections at the beginning of this document. If you plan to attend the public meeting, please notify Ms. Brenda Edwards at (202) 586–2945 or *Brenda.Edwards@ee.doe.gov*.

Please note that foreign nationals visiting DOE Headquarters are subject to advance security screening procedures which require advance notice prior to attendance at the public meeting. If a foreign national wishes to participate in the public meeting, please inform DOE of this fact as soon as possible by contacting Ms. Regina Washington at (202) 586–1214 or by email (*Regina.Washington@ee.doe.gov*) so that the necessary procedures can be completed.

DOE requires visitors to have laptops and other devices, such as tablets, checked upon entry into the Forrestal Building. Any person wishing to bring these devices into the building will be required to obtain a property pass. Visitors should avoid bringing these devices, or allow an extra 45 minutes to check in. Please report to the visitor's desk to have devices checked before proceeding through security.

Due to the REAL ID Act implemented by the Department of Homeland Security (DHS), there have been recent changes regarding identification (ID) requirements for individuals wishing to enter Federal buildings from specific States and U.S. territories. As a result, driver's licenses from several States or territory will not be accepted for building entry, and instead, one of the alternate forms of ID listed below will be required. DHS has determined that regular driver's licenses (and ID cards) from the following jurisdictions are not acceptable for entry into DOE facilities: Alaska, American Samoa, Arizona, Louisiana, Maine, Massachusetts, Minnesota, New York, Oklahoma, and Washington. Acceptable alternate forms of Photo-ID include: U.S. Passport or Passport Card; an Enhanced Driver's License or Enhanced ID-Card issued by the States of Minnesota, New York, or Washington (Enhanced licenses issued by these States are clearly marked Enhanced or Enhanced Driver's License); a military ID or other Federal government-issued Photo-ID card.

In addition, you can attend the public meeting via webinar. Webinar registration information, participant instructions, and information about the capabilities available to webinar participants will be published on DOE's Web site at *https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/87* Participants are responsible for ensuring their systems are compatible with the webinar software.

B. Procedure for Submitting Prepared General Statements for Distribution

Any person who has plans to present a prepared general statement may request that copies of his or her statement be made available at the public meeting. Such persons may submit requests, along with an advance electronic copy of their statement in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format, to the appropriate address shown in the **ADDRESSES** section at the beginning of this document. The request and advance copy of statements must be received at least one week before the public meeting and may be emailed, hand-delivered, or sent by mail. DOE prefers to receive requests and advance copies via email. Please include a telephone number to enable DOE staff to make follow-up contact, if needed.

C. Conduct of the Public Meeting

DOE will designate a DOE official to preside at the public meeting and may also use a professional facilitator to aid discussion. The meeting will not be a judicial or evidentiary-type public hearing, but DOE will conduct it in accordance with section 336 of EPCA. (42 U.S.C. 6306) A court reporter will be present to record the proceedings and prepare a transcript. DOE reserves the right to schedule the order of presentations and to establish the procedures governing the conduct of the public meeting. There shall not be discussion of proprietary information, costs or prices, market share, or other commercial matters regulated by U.S. anti-trust laws. After the public meeting, interested parties may submit further comments on the proceedings, as well as on any aspect of the rulemaking, until the end of the comment period.

The public meeting will be conducted in an informal, conference style. DOE will present summaries of comments received before the public meeting, allow time for prepared general statements by participants, and encourage all interested parties to share their views on issues affecting this rulemaking. Each participant will be allowed to make a general statement (within time limits determined by DOE), before the discussion of specific topics. DOE will allow, as time permits, other participants to comment briefly on any general statements.

At the end of all prepared statements on a topic, DOE will permit participants to clarify their statements briefly and comment on statements made by others. Participants should be prepared to answer questions by DOE and by other participants concerning these issues. DOE representatives may also ask questions of participants concerning other matters relevant to this rulemaking. The official conducting the public meeting will accept additional comments or questions from those attending, as time permits. The presiding official will announce any further procedural rules or modification of the above procedures that may be needed for the proper conduct of the public meeting.

A transcript of the public meeting will be included in the docket, which can be viewed as described in the *Docket* section at the beginning of this document and will be accessible on the DOE Web site. In addition, any person may buy a copy of the transcript from the transcribing reporter.

D. Submission of Comments

DOE will accept comments, data, and information regarding this proposed rule before or after the public meeting, but no later than the date provided in the **DATES** section at the beginning of this proposed rule. Interested parties may submit comments, data, and other information using any of the methods described in the **ADDRESSES** section at the beginning of this document.

Submitting comments via *www.regulations.gov.* The *www.regulations.gov* Web page will require you to provide your name and contact information. Your contact information will be viewable to DOE Building Technologies staff only. Your contact information will not be publicly viewable except for your first and last names, organization name (if any), and submitter representative name (if any). If your comment is not processed properly because of technical difficulties, DOE will use this information to contact you. If DOE cannot read your comment due to technical difficulties and cannot contact you for clarification, DOE may not be able to consider your comment.

However, your contact information will be publicly viewable if you include it in the comment itself or in any documents attached to your comment. Any information that you do not want to be publicly viewable should not be included in your comment, nor in any document attached to your comment. Otherwise, persons viewing comments will see only first and last names, organization names, correspondence containing comments, and any documents submitted with the comments.

Do not submit to *www.regulations.gov* information for which disclosure is restricted by statute, such as trade secrets and commercial or financial information (hereinafter referred to as Confidential Business Information (CBI)). Comments submitted through *www.regulations.gov* cannot be claimed as CBI. Comments received through the Web site will waive any CBI claims for the information submitted. For information on submitting CBI, see the Confidential Business Information section below.

DOE processes submissions made through *www.regulations.gov* before posting. Normally, comments will be posted within a few days of being submitted. However, if large volumes of comments are being processed simultaneously, your comment may not be viewable for up to several weeks. Please keep the comment tracking number that *www.regulations.gov* provides after you have successfully uploaded your comment.

Submitting comments via email, hand delivery/courier, or mail. Comments and documents submitted via email, hand delivery/courier, or mail also will be posted to *www.regulations.gov.* If you do not want your personal contact information to be publicly viewable, do not include it in your comment or any accompanying documents. Instead, provide your contact information in a cover letter. Include your first and last names, email address, telephone number, and optional mailing address. The cover letter will not be publicly viewable as long as it does not include any comments

Include contact information each time you submit comments, data, documents, and other information to DOE. If you submit via mail or hand delivery/courier, please provide all items on a CD, if feasible, in which case it is not necessary to submit printed copies. No telefacsimiles (faxes) will be accepted.

Comments, data, and other information submitted to DOE electronically should be provided in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format. Provide documents that are not secured, that are written in English, and that are free of any defects or viruses. Documents should not contain special characters or any form of encryption and, if possible, they should carry the electronic signature of the author.

Campaign form letters. Please submit campaign form letters by the originating organization in batches of between 50 to 500 form letters per PDF or as one form letter with a list of supporters' names compiled into one or more PDFs. This reduces comment processing and posting time.

Confidential Business Information. Pursuant to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit via email, postal mail, or hand delivery/courier two well-marked copies: One copy of the document marked ''confidential'' including all the information believed to be confidential, and one copy of the document marked ''non-confidential'' with the information believed to be confidential deleted. Submit these documents via email or on a CD, if feasible. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

Factors of interest to DOE when evaluating requests to treat submitted information as confidential include: (1) A description of the items; (2) whether and why such items are customarily treated as confidential within the industry; (3) whether the information is generally known by or available from other sources; (4) whether the information has previously been made available to others without obligation concerning its confidentiality; (5) an explanation of the competitive injury to the submitting person that would result from public disclosure; (6) when such information might lose its confidential character due to the passage of time; and (7) why disclosure of the information would be contrary to the public interest.

It is DOE's policy that all comments may be included in the public docket, without change and as received, including any personal information provided in the comments (except information deemed to be exempt from public disclosure).

E. Issues on Which DOE Seeks Comment

Although DOE welcomes comments on any aspect of this proposal, DOE is particularly interested in receiving comments and views of interested parties concerning the following issues:

1. DOE invites comments on whether DOE should adopt standards for compressors at TSL 3 instead of at TSL 2.

2. DOE seeks comment on its proposal to limit the scope of energy conservation standard proposed in this document to only equipment that is made up of a compression element (bare compressor), driver(s), mechanical equipment to drive the compressor element, and any ancillary equipment (*i.e.,* a ''packaged compressor''), through the use of the defined term, ''air compressors.''

3. DOE seeks comment on its proposal to limit the scope of energy conservation standard proposed in this document to only compressors that are designed to compress air and that have inlets open to the atmosphere or other source of air, through the use of the defined term, ''air compressors.''

4. DOE requests comment on its proposal to consider standards for both single- and three-phase compressor equipment. DOE also requests comment on any market trends that may affect the efficiency of such equipment in the future. DOE requests data that may aid in characterizing the relative cost and performance of equipment of different

motor phase counts, so that DOE can better evaluate whether a substitution incentive is likely to be created.

5. DOE requests comment on the proposal to include only compressors with a compressor motor nominal horsepower of greater than or equal to 1 and less than or equal to 500 within the scope of this energy conservation standard.

6. DOE requests comment on its proposal to establish separate equipment classes for rotary and reciprocating equipment, and on whether and why utility or performance differences exist between the two types of equipment. DOE requests comment on its proposal to establish separate equipment classes for rotary and reciprocating equipment, and on whether and why utility or performance differences exist between the two types of equipment.

7. DOE requests comment on separating equipment classes by lubricant presence, and specifically on whether ISO 8573–1:2010 is suitable for characterizing compressors on that basis. DOE also requests comments on the proposed definitions for lubricated compressor, lubricant-free compressors, and auxiliary substance.

8. DOE requests comment on its proposal to establish separate equipment classes for air- and water-cooled equipment. DOE also requests comments on the proposed definitions for air- and water-cooled compressor.

9. DOE requests comment on the establishment of separate equipment classes, by motor phase count, for reciprocating equipment.

10. DOE also requests comment on the proposal to combine single- and three-phase rotary equipment in each rotary equipment class.

11. DOE also requests comment specifically on IE4 or ''super premium'' electric motors, their suitability for compressors, and on any efforts to incorporate them into newly developed equipment.

12. DOE seeks comment on whether sufficient resources would be available such that criterion 2 of the screening analysis is satisfied.

13. DOE requests comment on the use of 125 and 175 psig as representative pressures to establish absolute MSPs for rotary and reciprocating equipment classes, respectively.

14. DOE requests comment on DOE's proposal to establish efficiency levels that are independent of pressure.

15. DOE also requests comment on DOE's proposal to establish incremental MSPs that are independent of pressure.

16. DOE requests additional data which can be used to refine its current baseline, max-tech, and efficiency level assumptions.

17. DOE requests comment on the use of the EU Lot 31 regression curve for piston standard air compressors to define the regression curve of the R3_FS_L_XX equipment class.

18. DOE requests comment and supporting data on the efficiency levels established for the RP_FS_L_AC, RP_VS_L_AC, and R3_FS_L_XX equipment classes.

19. DOE requests comment on the proposed efficiency levels selected for the RP_VS_LF_AC equipment class regarding their representation of the market, and any data that could improve the analysis.

20. DOE requests comment on the proposed efficiency levels selected for the RP_VS_LF_WC equipment class regarding their representation of the market, and any data that could improve the analysis.

21. DOE requests comment and supporting data on the proposed efficiency levels established for the R1_FS_L_XX equipment class.

22. DOE requests comment on the use of Lot 31 MSP-Flow-Efficiency Relationships to develop MSP-flow-efficiency relationships for the proposed RP_FS_L_AC and RP_VS_L_AC equipment classes.

23. DOE requests comment on the methods used to develop RP_FS_LF_AC (lubricant-free) incremental MSP. Specifically, DOE requests comment on the use of RP_FS_L_AC (lubricated) incremental MSP relationship to develop a lubricant-free incremental MSP relationship.

24. DOE requests comment and supporting data on the MSPs established for the RP_FS_LF_AC equipment class.

25. DOE requests comment on the methods used to develop RP_VS_LF_AC (lubricant-free) incremental MSP. Specifically, DOE requests comment on the use of RP_VS_L_AC (lubricated) incremental MSP relationship to develop a lubricant-free incremental MSP relationship.

26. DOE requests comment and supporting data on the MSPs established for the RP_VS_LF_AC equipment class.

27. DOE requests comment on the use of incremental MSP for air-cooled equipment classes to represent incremental MSP for water-cooled equipment classes.

28. DOE requests comment and supporting data on the MSPs established for the R3_FS_L_XX equipment class.

29. DOE requests comment on the use of incremental MSP for the R3_FS_L_XX equipment classes to represent incremental MSP for the R1_FS_L_XX equipment classes.

30. DOE requests comment on its estimates for manufacturer markups, as well as material, labor, depreciation, and overhead breakdowns.

31. DOE seeks input on its analysis of market channels listed above in Table IV.28, particularly related to whether the channels include all necessary intermediate steps, and the estimated market share of each channel.

32. Table IV.29 shows the distribution of air compressor application for both rotary and reciprocating air compressors. DOE seeks comment on its distribution of air compressors application.

33. DOE requests comment and information on average annual operating hours for the compressor types and applications in the scope of this rulemaking.

34. DOE requests comment and information on typical load profiles for the air compressor types and applications in the scope of this rulemaking.

35. DOE seeks data on the degree that compressors are over- or under-sized for an intended application. Specifically, DOE requests data on the degree that air compressors are operated at duty points other than their intended design point.

36. DOE requests information and data on the degree that a compressor's pressure can be set above or below its design point. Additionally, DOE requests information and data on air compressor efficiency when it is operated above the design point pressure.

37. DOE requests comments on the most appropriate trend to use for real (inflation-adjusted) compressor prices.

38. DOE requests comment on whether any of the efficiency levels considered in this NOPR might lead to an increase in installation costs and, if so, data regarding the magnitude of the increased cost for each relevant efficiency level.

39. DOE seeks comment on these minimum, average, and maximum equipment lifetimes, and whether or not they are appropriate for all equipment classes.

40. DOE seeks comment on the total 2013 shipments by equipment class.

41. DOE seeks comment on its assumption that air compressors with a capacity of no more than 50 ACFM are used in commercial applications, and air compressors greater than 50 ACFM are used in industrial applications.

42. DOE seeks comment on the share of shipments by equipment class, and how these shares may change over time.

43. DOE seeks comment on whether the assumed price elasticities are reasonable for air compressors.

44. DOE seeks comment on its assumption of no change over time in the market share of more efficient equipment in the no-new-standards case.

45. DOE seeks information on any projected change in equipment efficiencies over time, specifically whether or not the market shares of air compressors by efficiency would change after the publication of a new standard.

46. DOE requests comment on its estimates of average industry financial parameters.

47. DOE requests comment on the use of failure rates for rotary compressor equipment as a proxy for reciprocating equipment failure rates.

48. DOE requests feedback on its conversion cost methodology, including quantitative estimates and qualitative descriptions of the capital and product conversion costs manufacturers would incur in order to comply with amended energy conservation standards.

49. DOE requests comments on the total annual direct employment levels in the industry.

50. DOE requests comment on potential bottlenecks in manufacturing capacity or constraints in engineering resources that could result from a new standard.

51. DOE requests comments on the cumulative regulatory burden facing compressor manufacturers. Specifically, DOE seeks input on any equipment-specific Federal regulations with which compliance is required within three years of the proposed compliance date for any final compressor standards, as well as on recommendations on how DOE may be able to align varying regulations to mitigate cumulative burden.

DOE requests comments and data that will aid in the refinement of its analysis of the calculated reduction to the industry's net present value at the TSL 3 level (see section V.B.2.a). These impacts are captured in the Manufacturing Impact Analysis, and in particular within the DOE's Government Regulatory Impact Model (see section V.B.2). Comments are also requested on DOE's inputs to the product and capital conversion costs, including the lack of available skilled design engineers (see section V.B.2.c) and product production costs (see section V.B.2.a), as well as DOE's assumptions regarding mark-up scenarios, specifically the assumption regarding the percentage of costs that will be passed on to consumers (see section IV.C.7).

52. DOE requests comment on the number and names of domestic small manufacturers producing covered equipment.

53. DOE notes that this conversion cost analysis assumes that compressors sold by domestic small manufacturers are of the same efficiency distribution as those sold by large manufacturers. DOE requests comment and data on the relative efficiency of equipment sold by domestic small manufacturers, as compared to equipment sold by large manufacturers.

54. DOE requests comment and data on the impact of the proposed standard on domestic small business manufacturers. Specifically, DOE requests comment on the magnitude of conversion costs for a domestic small manufacturers and the number or percent of models produced by domestic small manufacturers. DOE also requests data on the cost of capital for domestic small manufacturers to better quantify how domestic small manufacturers might be disadvantaged relative to large competitors.

IX. Approval of the Office of the Secretary

The Secretary of Energy has approved publication of this notice of proposed rulemaking.

List of Subjects

10 CFR Part 429

Confidential business information, Energy conservation, Household appliances, Imports, Reporting and recordkeeping requirements.

10 CFR Part 430

Administrative practice and procedure, Confidential business information, Energy conservation, Household appliances, Imports, Incorporation by reference, Intergovernmental relations, Small businesses.

Issued in Washington, DC, on April 29, 2016.

David Friedman,

Principal Deputy Assistant Secretary, Energy Efficiency and Renewable Energy.

For the reasons set forth in the preamble, DOE proposes to amend parts 429 and 430 of chapter II, subchapter D, of title 10 of the Code of Federal Regulations, as set forth below:

PART 429—CERTIFICATION, COMPLIANCE, AND ENFORCEMENT FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT

■ 1. The authority citation for part 429 continues to read as follows:

Authority: 42 U.S.C. 6291–6317.

■ 2. Section 429.12 is amended by revising paragraph (b)(13) to read as follows:

§ 429.12 General requirements applicable to certification reports.

* * * * *

(b) * * *

(13) Product specific information listed in §§ 429.14 through 429.61 of this chapter.

* * * * *

■ 3. Section 429.61 [proposed at 81 FR 27219, (May 5, 2016)] is amended by adding paragraph (b) to read as follows:

§ 429.61 Compressors.

* * * * *

(b) *Certification reports.* (1) The requirements of § 429.12 are applicable to compressors; and

(2) Pursuant to § 429.12(b)(13), a certification report will include the following public product-specific information:

(i) Full- or part-load package isentropic efficiency, as applicable (dimensionless);

(ii) Full-load actual volume flow rate (in actual cubic feet per minute);

(iii) Compressor motor nominal horsepower (in horsepower);

(iv) Full-load operating pressure (in pounds per square inch, gauge);

(v) Maximum full-flow operating pressure (in pounds per square inch, gauge); and

(vi) Pressure ratio (dimensionless).

PART 431—ENERGY CONSERVATION PROGRAM FOR CERTAIN COMMERCIAL AND INDUSTRIAL EQUIPMENT

■ 4. The authority citation for part 431 continues to read as follows:

Authority: 42 U.S.C. 6291–6317.

■ 5. Section 431.342 [proposed at 81 FR 27219 (May 5, 2016)] is amended by adding, in alphabetical order, definitions for the terms ''Air-cooled compressor,'' ''Auxiliary substance,'' ''Lubricant-free compressor,'' ''Lubricated compressor,'' and ''Water-cooled compressor.''

The additions read as follows:

§ 431.342 Definitions concerning compressors.

* * * * *

Air-cooled compressor means a compressor that utilizes air to cool both the compressed air and, if present, any auxiliary substances used to facilitate compression.

* * * * *

Auxiliary substance means any substance deliberately introduced into a compression process to aid in compression of a gas by any of the following: lubricating, sealing mechanical clearances, or absorbing heat.

* * * * *

Lubricant-free compressor means a compressor that does not introduce any auxiliary substance into the compression chamber at any time during operation.

Lubricated compressor means a compressor that introduces an auxiliary substance into the compression chamber during compression.

* * * * *

Water-cooled compressor means a compressor that utilizes chilled water provided by an external system to cool both the compressed air and, if present, any auxiliary substance used to facilitate compression.

■ 6. Section 431.345 is added to read as follows:

§ 431.345 Energy conservation standards and effective dates.

(a) Each compressor that is manufactured starting on [*date five years after date of publication in the* **Federal Register**] and that:

(1) Is an air compressor;

(2) Is a rotary compressor;

(3) Is driven by a brushless electric motor;

(4) Is distributed in commerce with a compressor motor nominal horsepower greater than or equal to 1 and less than or equal to 500 horsepower (hp);

(5) Has a full-load operating pressure greater than or equal to 31 pounds per square inch gauge (psig) and less than or equal to 225 psig;

(6) Is manufactured alone or as a component of another piece of equipment; and

(7) Is in one of the equipment classes listed in the Table 1, must have a full-load package isentropic efficiency or part-load package isentropic efficiency that is not less than the appropriate ''Minimum Package Isentropic Efficiency'' value listed in Table 1.

TABLE 1—ENERGY CONSERVATION STANDARDS FOR CERTAIN COMPRESSORS

Equipment class	Minimum package isentropic efficiency	η_{Regr} (package isentropic efficiency reference curve)	d (percentage loss reduction)
Rotary; Lubricated; Air-cooled; Fixed-speed Compressor.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln(.472 * V_1)^2 + 0.139 * \ln(.472 * V_1) + 0.271$.	−15
Rotary; Lubricated; Air-cooled; Variable-speed Compressor.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.0155 * \ln(.472 * V_1)^2 + 0.216 * \ln(.472 * V_1) + 0.00905$.	−10
Rotary; Lubricated; Water-cooled; Fixed-speed Compressor.	$.0235 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.00928 * \ln(.472 * V_1)^2 + 0.139 * \ln(.472 * V_1) + 0.271$.	−15
Rotary; Lubricated; Watercooled; Variable-speed Compressor.	$.0235 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$-0.0155 * \ln(.472 * V_1)^2 + 0.216 * \ln(.472 * V_1) + 0.00905$.	−15
Rotary; Lubricant-free; Air-cooled; Fixed-speed Compressor.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$A_1 * \ln(.472 * V_1)^2 + B_1 * \ln(.472 * V_1) + C_1$.	−11
Rotary; Lubricant-free; Air-cooled; Variable-speed.	$\eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$	$A_2 * \ln(.472 * V_1)^2 + B_2 * \ln(.472 * V_1) + C_2$.	−13
Rotary; Lubricant-free; Water-cooled; Fixed-speed Compressor.	$A_3 * \ln(.472 * V_1)^2 + B_3 * \ln(.472 * V_1) + C_3 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$.	$A_1 * \ln(.472 * V_1)^2 + B_1 * \ln(.472 * V_1) + C_1$.	−11
Rotary; Lubricant-free; Water-cooled; Variable-speed Compressor.	$A_4 * \ln(.472 * V_1)^2 + B_4 * \ln(.472 * V_1) + C_4 + \eta_{Regr} + (1 - \eta_{Regr}) * (d/100)$.	$A_2 * \ln(.472 * V_1)^2 + B_2 * \ln(.472 * V_1) + C_2$.	−13

Instructions for the use of Table 1:

(1) To determine the standard level a compressor must meet, the correct equipment class must be identified. The descriptions are in the first column (''Equipment Class''); definitions for these descriptions are found in § 431.342.

(2) The second column (''Minimum Package Isentropic Efficiency'') contains the applicable energy conservation standard level, provided in terms of package isentropic efficiency.

(3) For ''Fixed-speed compressor'' equipment classes, the relevant Package Isentropic Efficiency is Full-Load Package Isentropic Efficiency. For ''Variable-speed compressor'' equipment classes, the relevant Package Isentropic Efficiency is Part-Load Package Isentropic Efficiency. Both Full- and Part-Load Package Isentropic Efficiency are determined in accordance with the test procedure in § 431.344.

(4) The second column (''Minimum Package Isentropic Efficiency'') references the third column (''η_{Regr}''), also a function of full-load actual volume flow rate, and the fourth column (''d''). The equations are provided separately to maintain consistency with the language of the preamble and analysis.

(5) The second and third columns contain the term V_1, which denotes compressor full-load actual volume flow rate, given in terms of actual cubic feet per minute (''acfm'') in inlet air conditions and determined in accordance with the test procedure in § 431.344.

(6) The second and third columns contain the mathematical coefficients A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4, C_1, C_2, C_3, and C_4. Refer to Tables 1A, 1B, 1C, and 1D for the values of these coefficients.

TABLE 1A—CERTAIN COEFFICIENTS

Full-load actual volume flow rate range (acfm)	A_1	B_1	C_1
$0 < V_1 \leq 161$	−0.00928	0.139	0.191
$161 < V_1 \leq 2125$	0.00281	0.0344	0.417
$2125 < V_1$	−0.00928	0.139	0.271

TABLE 1B—CERTAIN COEFFICIENTS

Full-load actual volume flow rate range (acfm)	A_2	B_2	C_2
$0 < V_1 \leq 102$	−0.0155	0.216	−0.0984
$102 < V_1 \leq 1426$	0.000	0.0958	0.134
$1426 < V_1$	−0.0155	0.216	0.00905

TABLE 1C—CERTAIN COEFFICIENTS

Full-load actual volume flow rate range (acfm)	A_3	B_3	C_3
$0 < V_1 < 102$	0	0	0
$102 \leq V_1$	−0.00924	0.117	−0.315

TABLE 1D—CERTAIN COEFFICIENTS

Full-load actual volume flow rate range (acfm)	A_4	B_4	C_4
$0 < V_1 < 74$	0	0	0
$74 \leq V_1$	0.000173	0.00783	−0.0300

(b) [Reserved]

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