CHAPTER 2. ANALYTICAL FRAMEWORK

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2.1 INTRODUCTION

Section 6317(b)(1) of Title 42, United States Code (42 U.S.C.), as directed by 346(b)(1) of the Energy Policy and Conservation Act (EPCA), requires the U.S. Department of Energy (DOE) to set forth energy conservation standards that are technologically feasible and economically justified, and would achieve the maximum improvement in energy efficiency. This chapter describes the general analytical framework that DOE uses in developing such standards and, in particular, standards for small electric motors. The analytical framework is a description of the methodology, analytical tools, and relationships among the various analyses that are part of this rulemaking. For example, the methodology that addresses the statutory requirement for economic justification includes analyses of life-cycle cost (LCC); economic impact on manufacturers and users; national benefits; impacts, if any, on utility companies; and impacts, if any, from lessening competition among manufacturers. DOE will also solicit the views of the Department of Justice (DOJ) on any lessening of competition likely to result from the imposition of a proposed standard.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The columns labeled “Key Inputs” and “Key Outputs” show how the analyses fit into the rulemaking process, and how they relate to each other. Key inputs are the types of data and information that the analyses require. Some key inputs exist in public databases; DOE also collects other inputs from interested parties and persons with special knowledge. Key outputs are analytical results that feed directly into the standards-setting process. Arrows connecting analyses show types of information that feed from one analysis to another.

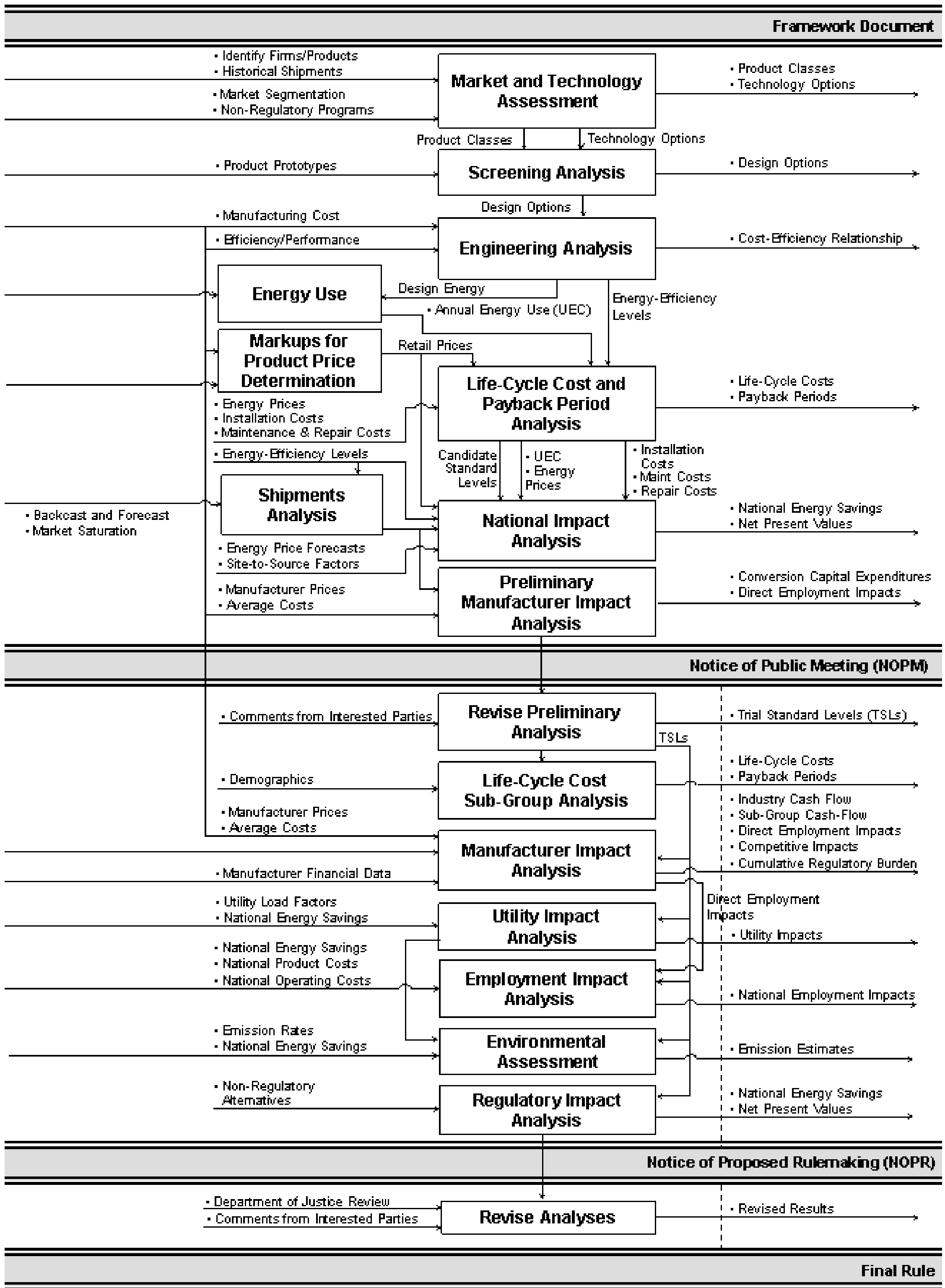

Figure 2.1.1 Flow Diagram of Analyses for the Small Electric Motor Rulemaking Process

The analyses performed prior to the notice of proposed rulemaking (NOPR) stage as part of the preliminary analyses and described in the preliminary technical support document (preliminary TSD) are listed below. These analyses were revised for the NOPR based on new information from comments received, and then revised again for the final rule, and are now included as part of the accompanying notice and are reported in this TSD.

- A market and technology assessment is conducted to characterize the relevant equipment markets and existing technology options, including prototype designs.

- A screening analysis is conducted to review each technology option and determine if it is technologically feasible; is practical to manufacture, install, and service; would adversely affect equipment utility or equipment availability; or would have adverse impacts on health and safety.

- An engineering analysis is conducted to develop the cost-efficiency relationship, which is the increased manufacturer selling prices (material, labor, factory overhead, selling, general and administrative expenses, research and development costs, and profit) of more efficient equipment.

- An equipment price markup analysis is conducted to convert the manufacturer's selling-price estimates from the engineering analysis to customer prices, which are then used in the LCC and payback period (PBP) analyses and the manufacturer impact analysis (MIA).

- An energy use analysis is conducted to determine the annual energy use characteristics of small electric motors.

- LCC and PBP analyses are conducted to calculate, at the customer level, the discounted savings in operating costs (less maintenance and repair costs) throughout the estimated average life of the covered equipment compared to any increase in the installed cost for the equipment likely to result directly from the imposition of the standard.

- A shipments analysis is conducted which forecasts equipment shipments. This analysis is then used to calculate the national impacts of standards on energy consumption and costs, net present value (NPV), and future manufacturer cash flows.

- A national impact analysis is conducted to assess the aggregate impacts at the national level of NPV of total customer LCC and national energy savings (NES).

- A preliminary MIA is conducted to assess the potential impacts of energy conservation standards on manufacturers such as capital conversion expenditures, marketing costs, shipments, and research and development costs.

The additional analyses performed for the NOPR stage include those listed below. In addition, DOE re-analyzes the work done in the preliminary stage based on comments and new information received. These analyses were subsequently revised for the final rule stage and reported in this final rule TSD.

- An LCC sub-group analysis is conducted to evaluate variations in commercial business type characteristics (*e.g.*, energy prices, equipment use patterns, and installation and maintenance costs) that might cause a standard to affect particular customer sub-populations.

- A manufacturer impact analysis is conducted to estimate the financial impact of standards on manufacturers and to calculate impacts on competition, employment, and manufacturing capacity.

- A utility impact analysis is conducted to estimate the effects of proposed standards on electric utilities.

- An employment impact analysis is conducted to assess the aggregate impacts on national employment.

- An environmental assessment is conducted to provide estimates of changes in emissions of pollutants from electricity generation (*i.e.*, carbon dioxide (CO_2), oxides of nitrogen (NO_x), and mercury (Hg).

- A regulatory impact analysis is conducted to present major alternatives to proposed standards that could achieve substantially the same regulatory goal at a lower cost.

2.2 BACKGROUND

DOE conducted a formal effort to consider further improvements to the process used to develop appliance efficiency standards. DOE called on energy efficiency groups, manufacturers, trade associations, state agencies, utilities, and other interested parties to provide input to this effort. As a result of this combined effort, DOE published *Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Customer Products* (the "Process Rule"), 10 CFR 430, Subpart C, Appendix A. The Process Rule outlined the procedural improvements identified by the interested parties, and included a review of the: 1) economic models, 2) analytical tools, 3) methodologies, 4) non-regulatory approaches, and 5) prioritization of future rules.

DOE developed an analytical framework for the small electric motor rulemaking under the Process Rule. DOE documented this analytical framework in the *Energy Conservation Standards Rulemaking Framework Document for Small Electric Motors* and presented the analytical approach to interested parties during a public meeting on September 13, 2007. This document is available at:

http://www1.eere.energy.gov/buildings/appliance_standards/commercial/small_electric_motors.html.

The following sections describe the different analytical components of the rulemaking framework.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant product markets and existing technology options.

2.3.1 Market Assessment

When initiating a standards rulemaking, DOE develops information on the present and past industry structure and market characteristics for the equipment concerned. This activity assesses the industry and equipment both quantitatively and qualitatively, based on publicly available information. DOE addresses the following: (1) manufacturer market share and characteristics, (2) existing regulatory and non-regulatory equipment efficiency improvement initiatives, and (3) trends in product characteristics and retail markets. This information serves as resource material throughout the rulemaking.

For this rulemaking, DOE reviewed existing literature and interviewed manufacturers to get an overall picture of the small electric motor market in the United States. Product catalogs, third-party experts, and small electric motor manufacturers provided the bulk of the information. The appropriate sections of the final rule describe the analysis and resulting information as reported in the TSD.

DOE uses the most reliable and accurate data available at the time of each analysis in its rulemakings. All data is available for public review.

2.3.2 Technology Assessment

DOE typically uses information about existing and past technology options and prototype designs to help determine which technologies manufacturers use to attain higher energy performance levels. In consultation with interested parties, DOE develops a list of technologies for consideration. Initially, these technologies encompass all those it believes are technologically feasible.

For this rulemaking, DOE developed a list of technologically feasible design options after consultation with manufacturers and third-party experts, as described in chapter 3 of the TSD.

2.4 SCREENING ANALYSIS

In the screening analysis, DOE screens out technologies that are not technologically feasible; not practicable to manufacture, install, or service; have an adverse impact on equipment utility or availability; or have adverse impacts on health and safety. In the engineering analysis, DOE further considers design options that remain after the screening process.

As described in chapter 4 of the TSD, DOE grouped technologies into the following categories: (1) technology options not screened out that decrease small electric motor losses and the type of motor losses they reduce and (2) technology options screened out and the type of motor losses they reduce.

2.5 ENGINEERING ANALYSIS

As presented in chapter 5, the engineering analysis establishes the relationship between the manufacturer selling price and efficiency of small electric motors. This relationship serves as the basis for cost/benefit calculations for individual customers, manufacturers, and the Nation. The engineering analysis discusses cost-efficiency curves, product classes analyzed, representative baseline units, the methodology used to develop manufacturing selling prices, and the methodology used to develop the energy consumption model.

2.5.1 Modified Design Option Approach

In this rulemaking, DOE conducted the engineering analysis using a modified design-option approach where DOE employed a technical expert with motor design software to develop motor designs at several efficiency levels for each analyzed product class. Based on these simulated designs and manufacturer and component supplier data, DOE calculated manufacturing costs and selling prices associated with each efficiency level. DOE decided on this approach after receiving insufficient response to its request for the manufacturer data needed to execute an efficiency-level approach for the preliminary analyses. The design-option approach allows DOE to make its engineering analysis methodologies, assumptions, and results publicly available, thereby permitting all interested parties the opportunity to review and comment on this information. The design options considered in the engineering analysis include: copper die-cast rotor, reduce skew on stack, increase cross-sectional area of rotor conductor bars, increase end-ring size, change gauge of copper wire in stator, manipulate stator slot size, decrease air gap between rotor and stator to 12.5 thousandths of an inch, improve grades of electrical steel, use thinner steel laminations, anneal steel laminations, add stack height, use high efficiency lamination materials, change capacitors ratings, install better ball bearings and lubricant, and install a more efficient cooling system. Chapter 5 of the TSD contains a detailed description of the product classes analyzed and the analytical models DOE used to conduct the small electric motors engineering analysis and chapter 3 of the TSD contains a detailed description of how all the design options increase motor efficiency.

2.5.2 Manufacturing Cost Model

DOE used a cost model to estimate the core production cost of small electric motors. This cost model was developed using motor teardowns performed by a third-part expert. The approach for the teardowns involved the disassembly of three representative small electric motors on the market today, an analysis of the materials and manufacturing processes, and the development of a spreadsheet model. DOE obtained input from interested parties on the small electric motor manufacturer selling prices estimates and assumptions to confirm their accuracy.

2.6 ENERGY USE CHARACTERIZATION

The energy use and end-use load characterization analysis (chapter 6) produces energy use estimates and end-use load shapes for small electric motors. The energy use estimates enable evaluation of energy savings from the operation of small electric motors equipment at various efficiency levels, while the end-use load characterization allows evaluation of the impact on electricity monthly and peak demand from the operation of motors. The analysis produces a distribution of results for a variety of building types and uses covering a range of climate locations in order to represent the diversity of use, and performance, of small electric motors.

2.7 MARKUPS TO DETERMINE EQUIPMENT PRICE

DOE used manufacturer-to-customer markups to convert the manufacturer selling-price estimates from the engineering analysis to customer prices, which were then used in the LCC, PBP, and manufacturer impact analyses. Because retail prices are required for the baseline performance level and all other performance levels under consideration, DOE obtained these retail prices by applying manufacturer-to-customer markups to the manufacturer selling-price estimates.

Before it can develop markups, DOE must identify distribution channels (i.e., how the equipment is distributed from the manufacturer to the customer). Once it established proper distribution channels for each of the product classes, DOE relied on economic data from the U.S. Census Bureau and input from the industry to determine how much product prices are increased as they pass from the manufacturer to the customer (see chapter 7 of the TSD).

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

New energy conservation standards on equipment usually reduce operating expenses and increase customer prices. DOE analyzed the net effect of new standards on customers by evaluating the net LCC using the cost-efficiency relationship derived in the engineering analysis, as well as the energy costs derived from the energy use characterization analysis. Inputs to the LCC calculation include the installed cost to the customer (customer price plus installation cost), operating expenses (energy expenses and maintenance costs), the lifetime of the motor, and a discount rate. These inputs are described in detail in chapter 8 of the TSD.

The installed cost typically increases and operating cost typically decreases in response to new standards. Thus, there is a specific time in the life of higher-than-baseline efficiency equipment when the net operating-cost benefit (in dollars) from the time of purchase is equal to the incremental first cost of purchasing the more efficient equipment. The length of time required for equipment to reach this cost-equivalence point is known as the payback period.

DOE conducted the LCC and PBP analyses using distributions of values to reflect the conditions in the field for motor life, motor retail price, national or regional energy costs, energy consumption, and discount rates. The life-cycle cost sub-group analysis includes an assessment of impacts on customer sub-groups.

For small electric motors, it was necessary to determine several of the input values for the LCC estimation, including retail prices; electricity prices; discount rate; maintenance, service, and installation costs; and motor lifetimes.

DOE developed discount rates by estimating the cost of capital to companies that manufacture small electric motors covered under this rulemaking. DOE commonly uses the cost of capital 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. This corporate finance approach is referred to as the weighted-average cost of capital.

DOE considered expected changes to maintenance, repair, and installation costs for the motors covered in this rulemaking. Typically, small incremental changes in motor efficiency incur no, or only very small, changes in repair and maintenance costs over baseline efficiency products. There is a greater probability that motors with efficiencies that are significantly greater than the baseline will incur increased repair and maintenance costs since such motors are more likely to incorporate technologies that are new to the industry and not widely available. DOE relied on input from manufacturers and other interested parties to develop appropriate repair and maintenance costs.

2.9 SHIPMENTS ANALYSIS

One of the more important components of any estimate of future impacts from energy efficiency standards is small electric motor shipments (Chapter 9). Forecasts of shipments for the base case and each potential standard case are used as an input to the national energy savings (NES) model. DOE developed these shipment forecasts for each of the three covered small motor categories (polyphase, capacitor-start induction-run, and capacitor-start capacitor-run motors). Within each motor category, shipments are comprised of products in a number of horsepower ratings and three rotation speeds (corresponding to 2-pole, 4-pole, and 6-pole motors).

The core of the shipments analysis is an accounting model that the DOE developed to simulate how future purchases are incorporated into an in-service stock of aging motors that are gradually replaced. The model keeps track of the aging and replacement of small electric motor capacity given a projection of future motor sales growth. Small electric motor shipments and a retirement function influence how the motors in service and the supply of motor capacity changes over time. DOE also developed a cross-elasticity model to forecast the effect of standards on the market shares of CSIR and CSCR motors within each combination of motor size and speed; this model is described in chapter 9.

2.10 NATIONAL IMPACT ANALYSIS

The national impact analysis assesses the NPV of total customer LCC and NES. DOE determined both the NPV and NES for the performance levels considered for the product classes analyzed. To make the analysis more accessible and transparent to all interested parties, DOE prepared a NES spreadsheet model in Microsoft Excel to forecast energy savings and the national economic costs and savings resulting from new standards. The NES spreadsheet model does not use probability distributions for inputs or outputs. To assess the impact of input uncertainty on the NES and NPV results, DOE can conduct sensitivity analyses for future analyses by running scenarios on input variables of concern for interested parties. DOE conducted an assessment of the aggregate economic impacts at the national level as described in chapter 10 of the TSD.

2.10.1 National Energy Savings Analysis

The inputs for determining NES are (1) annual energy consumption per unit, (2) shipments, (3) equipment stock, (4) national energy consumption, and (5) site-to-source conversion factors. DOE calculated the national energy consumption by multiplying the number of units, or stock, of small electric motors by the unit energy consumption. Then, DOE calculated national annual energy savings from the difference between national energy consumption in the base case (without new efficiency standards) and in each higher efficiency standard case. The analysis included estimated energy savings by fuel type used for generating electricity. DOE estimated energy consumption and savings based on site energy, and converted the electricity consumption and savings to source energy. Cumulative energy savings are the sum of the annual NES, which DOE determined over specific time periods.

2.10.2 Net Present Value Analysis

The inputs for determining NPV are (1) total annual installed cost, (2) total annual operating cost savings, (3) discount factor, (4) present value of costs, and (5) present value of savings. DOE calculated net savings each year as the difference between total operating-cost savings (including electricity, repair, and maintenance cost savings) and increases in total installed costs (including equipment price and installation cost). DOE calculated savings over the life of the motor, accounting for differences in yearly energy rates. DOE calculated NPV as the difference between the present value of operating cost savings and the present value of increased total installed costs. DOE discounted future costs and savings to the present with a discount factor.

DOE calculated increases in total installed costs as the product of the difference in the total installed cost between the base case and standards case and the annual shipments in the standards case. Because costs of more efficient equipment bought in the standards case are higher than the costs of equipment bought in the base case, price increases appear as negative values in the NPV.

DOE expressed operating cost savings as decreases in operating costs associated with the lower energy consumption of motors bought in the standards case compared to the base efficiency case. Total operating-cost savings are the product of savings per motor and the number of motors.

2.10.3 Efficiency Scenarios and Trends

Several of the inputs for determining NES (*e.g.*, the annual energy consumption per unit) and NPV (*e.g.*, the total annual installed cost and the total annual operating-cost savings) depend on the efficiency of the equipment. Thus, DOE developed base case and standards case efficiency trends. The efficiency trends specify the annual historical and forecasted shipment-weighted average equipment efficiencies.

DOE based historical shipment-weighted average efficiency trends for small electric motors on limited catalog efficiency data and test results from representative motor lines. DOE found no evidence of trends toward greater efficiency within the class of covered motors, and therefore did not use an efficiency trend in either the base or standards cases.

DOE based its standards case forecasts (*i.e.*, forecasts of efficiency trends after standards take effect) on the use of a roll-up efficiency scenario and parallel growth trend. Under a roll-up scenario, all motors at performance levels below a prospective standard are moved or rolled up to the minimum performance level allowed under the new standard. The distribution of motors at higher efficiency standard levels is unaffected (*i.e.*, the motor remains at its pre-standard performance levels). The roll-up efficiency scenario dictates how DOE determined efficiency distributions in the first year a new standard takes effect, but does not define how motor efficiency will be distributed in the future. Under the parallel growth trend, DOE assumes that the standards case efficiency trend parallels the base case efficiency trend; in the case of small electric motors this means there was no trend toward higher efficiency in the standards case. In other words, the initial jump in shipment-weighted efficiency that occurs when the standard first becomes effective is maintained throughout the forecast.

2.11 LIFE-CYCLE COST SUB-GROUP ANALYSIS

The LCC sub-group analysis evaluates economic impacts on virtually any group of customers. In analyzing the potential impact of new or amended standards on customers, DOE evaluates the impact on identifiable groups of customers (*i.e.*, sub-groups), such as small businesses, that may not be equally affected by a national standard level. In this rulemaking, this analysis examined the economic impacts on different groups of customers by estimating the average change in LCC and by calculating the fraction of customers that would benefit. DOE analyzed the potential effect of standards for small businesses and customers with space-constrained applications, two consumer sub-groups of interest identified by DOE. For small businesses, DOE analyzed the potential impacts of standards by conducting the analysis with different discount rates, as small businesses do not have the same access to capital as larger businesses.

2.12 MANUFACTURER IMPACT ANALYSIS

DOE performed an MIA to estimate the financial impact of higher energy conservation standards on small electric motor manufacturers, and to calculate the impact of such standards on domestic manufacturing employment and plant capacity. The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM) - an industry-cash-flow model customized for this rulemaking. The GRIM inputs are data characterizing the industry cost structure, shipments, and revenues. The key output is the industry net present value (INPV). Different sets of assumptions (scenarios) produce different results. The qualitative part of the MIA addresses factors such as motor characteristics, characteristics of particular firms, and market and equipment trends, and includes an assessment of the impacts of standards on sub-groups of manufacturers.

DOE conducted the MIA in three phases. Phase one consisted of preparing an industry characterization and identifying key issues. Phase two addressed the broader industry where DOE would use the GRIM to perform an industry cash flow analysis. DOE also developed a questionnaire for interviewing small electric motor manufacturers about the potential impacts of new energy conservation standards on their business during phase two. Phase three involved interviewing manufacturers and adjusting the industry cash flow analysis as needed. Phase three also examined any additional impacts on competition, manufacturing capacity, direct employment, and the cumulative burden of other regulations on manufacturers. The complete MIA is outlined in Chapter 12 of the TSD.

2.13 UTILITY IMPACT ANALYSIS

The utility impact analysis estimates the effects of reduced energy consumption due to improved appliance efficiency on the utility industry. This utility analysis compares forecast results for a case comparable to the *AEO2009* Reference Case and forecasts for policy cases incorporating each of the small electric motors trial standard levels.

The utility impact analysis reports the changes in installed capacity and generation by plant type that result for each trial standard level, as well as changes in electricity sales to the residential, commercial and industrial sectors. The estimated impacts of the standard are the difference between the valued forecasted by a variant of EIA's *National Energy Modeling System* (currently termed NEMS-BT, BT referring to the DOE's Building Technologies Program), and the *AEO 2009* Reference Case.

2.14 EMPLOYMENT IMPACT ANALYSIS

The imposition of standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered motors and at affiliated distribution and service companies. DOE evaluates the direct employment impacts in the manufacturer impact analysis. Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect). The combined direct and indirect employment impacts are investigated in the employment impact analysis using the "Impact of Sector Energy Technologies" (ImSET) model. The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis to estimate the employment and income effects of energy-saving technologies on buildings, industry, and transportation. Compared to simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments.

2.15 ENVIRONMENTAL ASSESSMENT

The primary environmental effects of energy conservation standards for the small electric motors covered under this rulemaking will be decreased emissions resulting from reduced electrical energy consumption. The environmental assessment tracks the impact of possible standards on CO_2, NO_x, and Hg. DOE bases these calculations on the NEMS-BT modeling work proposed for the utility impact analysis. This approach has the advantage of examining the marginal impact of higher efficiency standards for the covered motors on the utility generation mix and the subsequent environmental emissions.

CO_2 emissions are tracked in NEMS-BT by a detailed module that produces robust results because of its broad coverage of all sectors and inclusion of interactive effects. NEMS-BT also has an algorithm for estimating Hg and NOx emissions from power generation. Details can be found in chapter 15 of the TSD.

2.16 REGULATORY IMPACT ANALYSIS

In the NOPR stage, DOE prepared a regulatory impact analysis (RIA) pursuant to Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735 (October 4, 1993), which is subject to review under the Executive Order by the Office of Information and Regulatory Affairs at the Office of Management and Budget. The RIA addressed the potential for non-regulatory approaches to supplant or augment energy conservation standards to improve the energy efficiency or reduce the energy consumption of the small electric motors covered under this rulemaking.

Voluntary and other non-regulatory efforts by manufacturers, utilities, and other interested parties can result in substantial improvements to energy efficiency or reductions in energy consumption. DOE considered and quantitatively evaluated a number of non-regulatory approaches in chapter 16 of the TSD. Based on this review, DOE is not confident that any of the alternatives DOE examined would save as much energy as today's final rule, and the financial incentives in particular may engender significant free ridership issues. Also, several of the alternatives would require new enabling legislation, since authority to carry out those alternatives does not exist.

2.17 DEPARTMENT OF JUSTICE REVIEW

Section 325(o)(2)(B)(i)(V) of the Energy Policy and Conservation Act states that before the Secretary of Energy may prescribe a new or amended energy conservation standard, the Secretary shall ask the Attorney General to make a determination of "the impact of any lessening of competition…that is likely to result from the imposition of the standard." (42 U.S.C. 6295) Pursuant to this requirement, DOE will solicit the views of the DOJ on any lessening of competition that is likely to result from the imposition of a proposed standard and will give the views provided full consideration in assessing the economic justification of a proposed standard. DOE may consult with DOJ at earlier stages in the standards development process to seek to obtain preliminary views on competitive impacts.